Management-Dependent Soil Variability and Surface Hydraulic Properties of Southeastern U.S. Coastal Plain Plinthic Kandiudults

by

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Abstract

Soil surveys are the foundation for natural resource planning and management and have been developed to illustrate and characterize the spatial variability of our soil resource; however, decade-scale temporal variability in near-surface properties largely induced by management may be more critical from an interpretation standpoint. With the initial survey of the soil resource nearly complete, future goals of the National Cooperative Soil Survey will concentrate on improving soil interpretations within the context of anthropogenic soil change. An improved understanding of variability of near-surface soil properties can greatly improve soil survey applications, land use management, and policy development. Soil hydraulic properties are of particular importance due to their role in ecosystem function and wide application within soil interpretations.

The National Cooperative Soil Survey defines a management-dependent property as a type of dynamic soil property which changes on a human time-scale due to anthropogenic disturbances. Interest in soil change and C sequestration has led to increased emphasis on characterization and inventory of these properties. Decades of research has shown that management can have vast effects on near-surface soil properties, but to what extent these effects have occurred on southeastern Coastal Plain soils is unclear. The Wiregrass region has a broad range of natural and agroecosystems ranging from native longleaf pine (*Pinus palustris*) forests to conventional monoculture row crop land. The upper 50 cm in most upland soils of the region are coarse textured with relatively high permeability and low water holding capacity. Because short-term droughts during the growing season often limit ecosystem productivity, near-surface hydraulic properties are of utmost importance.

For a prime farmland, benchmark soil map unit in the Wiregrass region of the Alabama Coastal Plain, objectives of this study were to: 1) assess the degree of management-dependent versus use-invariant soil property variability, 2) evaluate the impacts of long-term land use systems on near-surface soil properties, 3) evaluate soil C pools and sequestration potentials, and 4) develop improved relationships between management-dependent soil properties and near-surface soil hydraulic properties, including development of pedotransfer functions. Near-surface (0-50 cm) soil physical, chemical, and hydraulic properties within Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) consociations were measured under long-term (>10 years) conventional and conservation row cropping, pasture, pine plantation, and old-growth Longleaf pine forest. Pedon description and characterization were conducted at each site to quantify use-invariant variability.

Variability in the investigated management-dependent properties was greater than observed variability of use-invariant soil properties. Significant anthropogenic influences were observed on near-surface soil properties as a function of long-term land use systems (best expressed in chemical and C properties). Based on C contents, stratification of C and N pools, surface exchange capacities, and aggregate stability, longleaf and pasture systems had superior soil quality. Differences in C sequestration were observed across natural and agroecosystems, with pastures having the highest (57 Mg C ha^{-1}) and conventional row crop (38 Mg ha^{-1}) the lowest C contents (0-50 cm). Relationships among near-surface hydraulic properties and management-dependent soil properties allowed development of regression based algorithms that adequately described near-surface hydraulic property variability using both use-invariant and management-dependent soil properties. Because many of these properties are correlated, it is likely that a subset of properties to be measured can be developed to characterize management-dependent variability. Considering the importance of management-dependent properties to ecosystem function and map unit interpretations, creating management schemes and soil interpretations based on land use may be better suited than heavy reliance on use-invariant properties.

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I. Literature Review

Introduction

Soil hydraulic properties (e.g., drainage class, available water holding capacity, saturated hydraulic conductivity, and infiltration rates) are of great importance to soil interpretations. When short-term droughts occur, the southeastern U.S. experiences a decrease in agricultural productivity and pressure on water supplies facilitating the need for improved water resource management. Soil properties at landscape scales dictate re-distribution, retention, and filtration of rain water, a vital component of the hydrologic cycle. Estimates of hydraulic properties are included in published soil surveys, and are utilized in many agriculture, forestry, engineering, and land-planning applications.

Soil surveys are the foundation for natural resource planning and management and have been developed to illustrate and characterize spatial variability of our soil resources (Trangmar et al., 1985; Duffera et al., 2007); however, decade-scale temporal variability in near-surface properties largely induced by management is critical for many interpretations. In addition to the need for improved information on soil hydraulic properties, an improved understanding of spatial and temporal variability of near-surface soil properties can greatly improve soil survey applications, land use management, and policy development (Tugel et al., 2008).

The *'once-over'* soil survey in the U.S. is nearly complete, and there are growing concerns of global climate change; interest in the mitigation of atmospheric

CO_2 using the soil resource has grown (Six et al., 2002; Lal, 2004a; Halpern et al., 2010; Mishra et al., 2010). Atmospheric CO_2 concentration continues to rise 1.96 ppm yr^{-1} (2005-2009 average) to our current level of 386.27 ppm (Tans, 2010). To reduce the amount of CO_2 in the atmosphere, *soil carbon (C) sequestration*, or the assimilation of C from the atmosphere to the soil via plant photosynthesis (Lal, 2004b), may be a practical option. Soil organic carbon (SOC) pool measurements in terrestrial ecosystems can improve knowledge of the global C cycle and the capacity of the soil resource to serve as a C sink (Mishra et al., 2010).

Soil Quality, or the capacity of a soil to function (Karlen et al. 1997), is a product of not only inherent soil properties developed by factors of soil formation (Jenny, 1941), but also dynamic soil properties. Dynamic soil properties, or those that change on the human time scale (termed anthropocene), are a product of both natural processes and human management/land use impacts. Dynamic soil properties encompass physical, biological, chemical and hydraulic aspects of the soil. Dynamic soil properties that change due to management are termed use- or management-dependent properties. For several decades, researchers have found near-surface soil properties such as SOC, particulate organic matter, aggregate stability, water dispersible clay, and soil infiltration rates in the same map unit are largely management-dependent. Not only are these near-surface, management-dependent soil properties used as soil quality indicators (Karlen et al. 1997), they are also used to develop accurate interpretations.

Due to the time consuming and costly procedures associated with measuring soil hydraulic properties, they are often estimated from other physical soil properties. This is accomplished through the development of Pedotransfer Functions (PTFs), which are algorithms that describe soil-water relationships based on basic soil properties (Bouma and van Lanen, 1987). Although PTFs have mixed success predicting hydraulic parameters, Wendroth et al. (2006) state that PTFs can successfully estimate transport behaviors in large regions with different soils.

Soils of the southeastern Alabama Coastal Plain region are intensively utilized for row crops, grazing, and forestry while urbanization places strain on soil and water resources of the region. In addition, the study of C pools and associated soil sequestration is paramount. Therefore, documentation of soil change as affected by land use can increase our understanding of the sustainability of soil resources of this region. The assessment of soil change impacts on soil hydraulic properties is especially critical due to increasing demands on water resources.

Southern Coastal Plain

The Southern Coastal Plain (SCP) is the largest Major Land Resource Area (MLRA) in the United States, and extends from Virginia to Texas. The landscapes of this MLRA vary from nearly level, to gently rolling hills and valleys, to areas with steep uplands. The parent materials in this region are composed of unconsolidated fluvio-marine sediments deposited from the Cretaceous to Quaternary time period. The SCP is bordered by the “fall line” on the northern and western boundaries, which delineates the inland extent of the unconsolidated Coastal Plain sediments (NRCS, 2006).

The fall line is an erosional scarp formed from a past shoreline in the Mesozoic time period. Jurassic and Cretaceous Era rivers and streams draining the Appalachian Mountains deposited a thick wedge of silt, sands, and gravels as deltaic deposits in the coastal waters of the Atlantic Ocean. With time, this wedge was overlain by Cretaceous sands and carbonates. Eventually, in many areas, Quaternary materials consisting of unconsolidated clay, silt, sand, and gravels were deposited over older strata. The subsequent erosion and deposition of the unconsolidated Quaternary materials largely gives rise to the current landscape of the region (NRCS, 2006).

Average annual precipitation of the SCP is between 100 and 150 cm, with inland areas along the Gulf receiving more than 150 cm. Minimum precipitation occurs in autumn, while maximum precipitation falls in late winter and spring. Average air temperature is between 13 and 20°C, and a freeze-free period of 250 to 350 days exists in the region (NRCS, 2006).

Soils of the SCP are mostly Ultisols, Entisols, and Inceptisols, with Hapludults, Kandiudults, Kanhapludults, and Paleudults dominating upland soils (Causarano et al., 2008). These soils predominately have a thermic soil temperature regime and an udic soil moisture regime. Soils typically possess kaolinitic or siliceous mineralogy with loamy sand to sandy loam textured surface horizons (NRCS, 2006). Upland soils typically have varying expression and thickness of eluvial horizons, and are dominated by subsurface horizons with relatively more clay. Subsurface horizons are often kandic and/or argillic diagnostic horizons with kaolinitic or mixed mineralogies (Soil Survey Staff, 2008).

Land use varies across the region, but timber production, cash crops and forage production are of importance throughout the SCP. Common crops include corn (*Zea sp.*), cotton (*Gossypium hirsutum*), peanuts (*Arachis hypogaea*), soybeans (*Glycine max*), wheat (*Triticum aestivum*), vegetable crops, hay and pasture. Pastures are grazed mainly by beef cattle (*Bos Taurus*) (NRCS, 2006). Forested areas are usually covered by longleaf pine (*Pinus palustris*), loblolly pine (*Pinus taeda*), sweetgum (*Liquidambar styraciflua*), southern red oak (*Quercus falcate*), and hickory (*Carya sp.*) (Soil Survey Staff, 2008).

Dougherty Plain

Ecoregions possess similar ecosystems, environmental factors and resources. Homogenous components include soils, vegetation, climate, geology, hydrology, and physiography (Woods et al., 1996). Ecoregions provide a spatially based framework for research, assessment, and monitoring of ecological entities (Griffith et al., 2001). “By recognizing the spatial differences in the capacities and potentials of ecosystems, ecoregions stratify the environment by its probable response to disturbance” (Griffith et al., 2004), including human stresses (Woods et al., 1996). Depending on the scale of assessment, ecoregions are classified in a hierarchical manner using a Roman numeral system; I corresponding to the coarsest level, increasing to IV (highest resolution) (Woods et al., 1996).

The Dougherty Plain, located in Alabama, Florida and Georgia, is one of fourteen level IV ecoregions found within the Southeastern Plains level III ecoregion (Griffith et al., 2001). The 1,583,260 hectares that compose the Dougherty Plain consist of lightly dissected, irregular plains that slope in a south to southwest direction (Brook, 1985; Griffith et al., 2008). Elevation of the region ranges from 24 to 149 m above sea level, with local relief ranging from 24 to 61 m (Griffith et al., 2001). Native vegetation was predominantly a longleaf pine/wiregrass (*Aristida stricta*) system (Griffith et al., 2008), of which < 5% remains in remnants today (Boyer and White, 1990). Because of its native vegetation type, the Dougherty Plain is commonly referred to as the Wiregrass region.

The Dougherty Plain is a covered karst landscape (a region where carbonate bedrock is covered by thick residual soil) with shallow sinkholes (Brook, 1985). “The surficial geology consists of residuum that is white to moderate-reddish-orange locally mottled sandy clay and residual clay with scattered layers of gravelly medium to coarse sand, fossiliferous chert and limestone boulders and limonitic sand masses” (Szabo et al., 1988). The residuum was derived from the dissolution of the parent material (limestone) in the undifferentiated Jackson Group (Eocene aged) and Oligocene Series (Oligocene aged), with slumping of the above Pliocene and Miocene sediments (Szabo et al., 1988).

Typical soils of the Wiregrass region include the Orangeburg, Lucy, Faceville and Dothan series. The Dothan series (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) concept is a soil with a thick solum (>150cm), depth to horizons with ≥ 5% plinthite ranging from 60 to 150 cm, ironstone pebbles up to 5% in the A and upper part of B horizons, quartzite pebbles up to 5% throughout the profile, and moderately to very strongly acid throughout (with the exception of limed surface horizons). Dothan soils are well drained soils formed in thick beds of unconsolidated, medium to fine textured fluvio-marine sediments, found on side slopes and ridge tops of uplands with 0 to 12 % slopes. The soil consists of an ochric epipedon with kandic and argillic subsurface diagnostic horizons (Soil Survey Staff, 2008). The Dothan series is a benchmark soil of the southeastern U.S. Coastal Plain, and map units dominated by Dothan soils that are level to gently sloping are considered prime farmland in the region.

Cash crop and forage production are dominant throughout the Wiregrass region of Alabama. Soybeans, cotton, corn, peanuts, sorghum (*Sorghum japonicum*), pecan (*Carya illinoinensis*) and wheat are the major crops grown (Griffith et al., 2008). Pastures are grazed mainly by beef cattle (NRCS, 2006). Dothan soils have mostly been cleared and used for production of corn, cotton, peanuts, vegetable crops, hay and pasture. Forested areas are usually covered by longleaf pine, loblolly pine, sweetgum, southern red oak, and hickory (Soil Survey Staff, 2008).

Soil Survey

Soil Survey is a paradigm-based science in which the soil-landscape model is utilized. The validity of this model is so substantial that a soil scientist can accurately survey the soil resource while only observing a very small portion of the soil (Hudson, 1992). A soil survey "describes the characteristics of the soils in a given area, classifies the soils according to a standard system of classification, plots the boundaries of the soils on a map, and makes predictions about the behavior of soils" (Soil Survey Division Staff, 1993). Soil surveys are the foundation for natural resource management, and facilitate land use planning as well as evaluate and predict land use impacts. Soil surveys, which are developed at different scales, partition soil variability across landscapes. The foundation of soil survey is the inventory of static soil properties to provide data for input-based models and establish soil suitabilities and limitations (Tugel et al., 2005) to form recommendations regarding potential uses (Karlen et al., 2003b).

Soil surveys use *map units* as the basis of distinguishing different soil areas. The soil map presents different soil map units that are characteristic of soil as a natural body, and provide the basis for estimating suitabilities and limitations under various management practices for different soils (Buol et al., 2003). Soil maps illustrate properties of natural bodies of soils in a landscape and correlate these properties to an appropriate taxonomic class, which is then used to name the map unit (Soil Survey Staff, 2003).

Map units are a collection of similar areas defined and named in terms of their soil components; they differ from all other in a survey area, and are uniquely identified on a soil map (Soil Survey Division Staff, 1993). Each individual area is referred to as a delineation or polygon. Although size and properties used to distinguish certain delineations is a product of the scale and objective of the soil survey, taxonomic classes provide basic sets of soil properties used for establishing these delineations. There are four kinds of map units: consociations, complexes, associations, and undifferentiated groups (Soil Survey Division Staff, 1993).

In a consociation map unit, delineated areas are dominated by one soil taxa and similar soils. This map unit will primarily consist of the soil for which the map unit is named (at minimum 50%), with at least 75% of the map unit consisting of soils that are similar and would not have significant differences in interpretations. A consociation will have less than 15% dissimilar inclusions (Buol et al., 2003). Complexes and associations are composed of two or more dissimilar components that occur in regularly repeated patterns and are sufficiently different in morphology or behavior that they cannot be considered a consociation. The differentiating criterion for these two mapping units (complexes and associations) is based on an arbitrary scaling rule: if the major components can be separated at a scale of 1:24,000, the mapping unit is referred to as an association (Soil Survey Division Staff, 1993). Undifferentiated groups consist of two or more taxa that are not consistently associated geographically. Second order level soil surveys (scales of 1:12,000 to 1:30,000), which are used for general agriculture and urban planning, usually consist of consociation and complex mapping units (Soil Survey Division Staff, 1993).

Soil Variability

Soils are inherently variable which presents management challenges (Duffera et al., 2007). Variability of soil properties is often described by classical statistical methods, which assume variation is distributed randomly within a mapping unit, yet soil properties exhibit spatial correlation (Cambardella et al., 1994). In general, soil samples collected close to one another will be more similar than samples collected at farther distances. Soils are considered to possess two types of variability: spatial (intrinsic) and temporal (extrinsic) (Cambardella et al., 1994) and both must be taken into consideration when designing sampling protocols (Moebius et al., 2007).

Soil spatial variability is a continuum of scales and is dependent on the property of interest, area or volume observed, and method of determination (Wilding, 1985). Spatial heterogeneity of soil properties is a product of factors and processes acting at different spatial and temporal scales (Duffera et al., 2007). The driving forces inducing spatial variability include the state soil forming factors climate, parent material, relief, and biology interacting within the context of time (Jenny, 1941). The temporal aspect of spatial variability, in the broadest sense, may be considered the unit of time from which soil formation began up to the anthropocene (i.e., the scale at which human impacts are not apparent). The basic soil model as outlined by Jenny (1941) implies that geographic or spatial variability of soils is inherent (Arnold, 1983). van Es et al. (1999) conclude inherent variation to be the greatest source of soil variability.

“Soils do not occur randomly and thus have a degree of predictability” (Hartung et al., 1991); soil properties will tend to be similar if formed under similar conditions (e.g., parent material, topography, and biology). For instance, patterns of climate, vegetation, and parent material may be used to survey soils in a large (regional) area, while local patterns of topography and relief (termed terrain attributes) and parent material with relation to time may be used to make conclusions about soils at the field-scale (Soil Survey Division Staff, 1993). For this reason, soil classification and survey have been successful at characterizing spatial variability at scales which surveys are produced (Trangmar et al., 1985).

The coefficient of variation (CV) of soil properties (standard deviation/mean expressed on percentage basis) is often utilized to describe soil variability within taxonomic-based units. The CV is dimensionless and allows values of different parameters to be compared. In a review of the literature, Warrick and Nielson (1980) divided soil property variability into relative CV classes for properties sampled at both large (within map unit) and small (landscape) spatial scales. Generally, the CV increases with less resolution (Wilding and Drees, 1983). While addressing expected variability of soil properties within a natural landscape unit (map unit), Wilding and Drees (1983) divided CV values into three classes of variability: least variable (CVs < 15%), moderately variable (CVs 15 – 35%), and most variable (CVs >35%).

Duffera et al. (2007) investigated variability of select soil properties from three Ultisols (Typic Paleudults, Aquic Paleudults, and Aeric Paleaquults) in the North Carolina Coastal Plain. Bulk density had the least variation (CV=8%), which is consistent with other research (Warrick and Nielson, 1980). Studies have shown properties with moderate variability (CVs=15-35%) include particle size (Warrick and Nielson, 1980; Wilding and Drees 1983; Duffera et al., 2007), soil water content (Warrick and Nielson, 1980; Duffera et al., 2007), cation exchange capacity (CEC), base saturation, and soil structure (Wilding and Drees, 1983). Properties that exhibit the most variability (CVs > 35%) within a single map unit include hydraulic conductivity, solum thickness, depth to mottling, and fine clay (< 0.2 μm) and organic matter contents (Wilding and Drees, 1983). Although van Es et al. (1999) concluded that inherent soil properties are the dominant source of soil variability, they were careful to indicate that the magnitude of management-induced variability is not well known.

Temporal variation results from both natural and anthropogenic processes (van Es et al., 1999; Tugel et al., 2005). Natural processes include climactic (seasonal/daily climate fluctuations; varying weathering intensities), geologic (tectonic activity; erosion), and biologic (biota transitions). Anthropogenic processes include human-induced changes in land use (e.g., converting native forest to crop land) or management practices (e.g., conventional versus conservation tillage, liming/fertilization, irrigation, or trafficking). Regardless of the specific mechanism inducing temporal change, it is recognized that most soil properties, particularly near-surface soil properties, undergo varying degrees of change depending on the time-scale of observation (Cassel, 1983).

Intrinsic soil properties often dictate the range of management-induced variability (Norfleet et al., 2003); however, many aspects of soil previously thought to be static are in fact relatively dynamic at decade scales (Richter, 2007). Although relationships among soil properties as a function of temporal processes are lacking, the concept of *soil change* has been developed to characterize and quantify effects of time-dependent processes on soil properties.

Soil Change

Soil surveys include limited information on the dynamic nature of soils and do not adequately address soil change (Tugel et al., 2005). Soil change is temporal variation in soil properties at a specific location and is driven by natural factors, human use and management, and their combined effects (Tugel et al., 2005). Soil change is assessed through the study of temporal dynamics using space-for-time substitutions, repeated soil surveys, computer modeling, or long-term soil experiments (Richter et al., 2007). Dynamic soil properties are components of soil change directly related to decadal to centurial human and natural impacts (Tugel et al., 2005) and used to assess soil quality.

Soil Quality

Soil quality has a definition that is dynamic in itself. The concept of soil quality has evolved in response to increased global emphasis on sustainable land use (Karlen et al., 2003a). Some have defined soil quality as: “the ability of soil to support crop growth which includes factors such as degree of tilth, aggregation, organic matter content, soil depth, water holding capacity, infiltration rate, pH changes, nutrient capacity and so forth” (Power and Myers, 1989), “the capacity of a soil to function within the ecosystem boundaries and interact positively with the environment external to that ecosystem” (Larson and Pierce, 1991), and simply “fitness for use” (Pierce and Larson, 1993). Consensus on a definition of soil quality is lacking, but a widely accepted definition has been provided:

“The capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation”

(Karlen et al., 1997).

Assessment of soil quality requires considerations of classification and land use (Andrews et al., 2004). Karlen et al. (1997) stated that soil quality could be recognized in two distinct ways; first, as an inherent characteristic of a soil (inherent soil quality), and second, as the condition of the soil in relation to management (dynamic soil quality). The first method reflects the full potential of a soil to perform a specific function. The latter method assumes that a soil has excellent soil quality if it is performing at or near its potential for its particular land use or management, and vice versa.

Soil quality assessment is performed by measurement of biological, chemical, and physical properties and their interactions (Warkentin and Fletcher, 1977) through indicator selection and evaluation (Karlen et al., 2003a). Soil quality indicators are defined as those soil properties and processes that have the greatest relationship with soil function (Andrews et al., 2004) and can be classified as either inherent or dynamic (Wienhold et al., 2004). Inherent indicators are determined by the soil forming factors of climate, parent material, topography and biology acting over significant time periods. Dynamic soil indicators describe the soil condition due to recent land use or management decisions. Wienhold et al. (2004) further define recent land use and management practices as those at a decade time scale.

Due to interactions among soil properties, complications in defining soil quality indicators arise. Doran and Parkin (1996) suggest development of a list of measurable soil properties that define major processes in soils which reflect field conditions. The authors state that soil quality indicators should encompass ecosystem function, integrate soil properties and processes, be applicable to field conditions, be sensitive to management, and be part of existing soil databases. Karlen et al. (1997) provided examples of dynamic soil quality indicators (i.e., physical, chemical, and biological properties). Physical dynamic soil quality indicators include bulk density, water stable aggregates, and soil strength. Chemical dynamic indicators consist of exchange capacity, pH, SOC and related pools, and nutrients, while biological dynamic indicators are often comprised of microbial biomass and respiration, nematode communities, and fatty-acid profiles.

Regardless of the property or process being evaluated, it must influence the function for which the assessment is being made, be measurable against a definable standard, and be sensitive enough to detect differences in time and space at the point scale (Karlen et al., 1997). The purpose of soil quality assessment is to determine if management systems are functioning at acceptable levels of performance, and to provide opportunities to evaluate and re-design sustainable soil and land management systems (Doran and Parkin, 1994). Soil quality assessment and indicator selection is dependent on land use and management goals of the area (Andrews et al., 2004), therefore, assessment of soil quality must use management-dependent soil property data (Norfleet et al., 2003).

Management Dependent Properties

“In the Anthropocene age, pedologists are increasingly focused on the science and management of human-affected soils” (Richter, 2007). Most dynamic soil properties are located in the near-surface and are greatly influenced by land use. Use- or management-dependent properties comprise the anthropogenic portion of dynamic soil properties (Tugel et al., 2008). Large differences in dynamic soil properties and subsequent interpretations indicate the need for collection of use- or management-dependent soil property data (Norfleet et al., 2003). Measurements of management-dependent properties are essential in the study of soil degradation, productivity, restoration and maintenance (Norfleet et al., 2003).

Soil Organic Carbon and Nitrogen Pools

Soil organic matter (SOM) consists of living organisms, slightly altered plant and animal organic residues, and well-decomposed organic residues that vary in their stability and susceptibility to further decomposition (Sikora and Stott, 1996). Soil organic matter is a source and sink for plant nutrients, and is important in both natural and managed ecosystems (Cambardella and Elliott, 1992). Soil organic matter acts as a binding agent for soil particles, holds nutrients and water, supports biological activity (Zobeck et al., 2008) and can be redistributed among fractions through disturbances such as tillage (Cambardella and Elliott, 1992) and prescribed burning (Wells, 1971).

Soil organic carbon constitutes approximately 58% of SOM by weight (Sikora and Stott, 1996). The global soil C pool of 2500 gigatons (Gt) includes about 1550 Gt of SOC which is 3 and 4.5 times the size of the atmospheric and biotic pools, respectively (Lal, 2004a). Changes in SOC stocks with management, climate, or land use change are difficult to measure due to spatial and temporal variability in soils (Six et al., 2002), however SOC is a “keystone soil quality indicator, being inextricably linked to other physical, chemical, and biological soil quality indicators” (Reeves, 1997). Worldwide, SOC has positive effects on physical (Du et al., 2009; So et al., 2009; Guo et al., 2010), chemical (Motta et al., 2002; Rice et al., 2007; Lopez-Fando and Pardo, 2009), biological (Kara et al., 2008; Mina et al., 2008; Adeli et al., 2009), and hydraulic (Rawls et al., 2003; Truman et al., 2005; Wesseling et al., 2009) soil properties.

Research indicates that SOC is affected by management in southeastern U.S. soils. In a review by Causarano et al. (2008), surface (0-5 cm) SOC values of Piedmont and Coastal Plain Ultisols were significantly different among agronomic management systems (conventional, conservation and pasture systems). These researchers found that pastures contained 1.9 and 3.1 times greater SOC than conservation and conventional systems, respectively. Truman et al. (2005) found that surface SOC content (0-3 cm) was 53% higher for conservation (0.86 g kg^{-1}) versus conventional systems (0.56 g kg^{-1}) in a central Alabama Coastal Plain Plinthic Paleudult-Typic Hapludult complex. For Typic Paleudults on 0-2% slopes, Fesha (2004) found surface SOC values (0-5 cm) for hayland to be 91, 94, and 157% higher than planted pine, no-tillage, and conventional tillage systems, respectively. On Typic Kanhapludults, Franzluebbers et al. (2000) found SOC (0-20 cm) to be significantly greater for forestland (130 years old) compared to a conservation system (24 years old), hayland (40 years old), and grazingland (50 years old).

Soil organic matter can be fractionated by particle size. The SOM fraction between 0.05 and 2.00 mm is considered particulate organic matter (POM). Particulate organic matter excludes organic matter associated with silt and clay (<0.05 mm), and is important in the formation of macroaggregates (Causarano et al., 2008). Studies have shown that POM is affected by management and land use (Cambardella and Elliott, 1992; Cambardella et al., 1994; Fesha, 2004; Causarano et al., 2008), and is a key soil quality indicator. Surface (0-5 cm) POM was significantly higher for forested systems relative to conventional row crop systems for Kandiudults of the Georgia Coastal Plain (Levi et al., 2010). While investigating long-term (>20 years) management systems on Piedmont Kanhapludults in Georgia, Franzluebbers and Stuedemann (2002) found surface (0-5 cm) POM values to be 2.5 times greater for pastureland compared to conservation systems. Furthermore, the authors found that POM concentrations (0-20 cm) were significantly different ($P < 0.001$) between pastureland (3.0 g kg^{-1}) and cropland (1.7 g kg^{-1}).

In soils dominated by variable charge (e.g., highly weathered Ultisols with low activity clays), C pools have a major effect on chemical and physical properties (Moody et al., 1997). Loginow et al. (1987) developed a method of SOC characterization using potassium permanganate as a mild oxidizing agent to simulate microbial decomposition of SOM. Tirol-Padre and Ladha (2004) termed this permanganate-oxidizable carbon (POC). Although these authors felt that POC was not a reliable quantifier of the labile or active fraction of C, much of the literature indicates otherwise (Loginow et al. 1987; Blair et al., 1995; Weil et al., 2003; Dell, 2009). Concurrent with the overwhelming agreement that POC is well correlated with the labile fraction of POM, POC is commonly referred to as active carbon (AC), with some advocating it as a sensitive indicator of soil quality (Weil et al., 2003).

Nitrogen (N) is the most intensively managed plant nutrient (Schlemmer et al., 2005) and concentrations are usually very low in natural ecosystems (Marschner, 1995). Nearly 90% of terrestrial N is bound in SOM (Scharenbroch and Lloyd, 2004). Soil mineralization and immobilization largely determine the plant-available N pool. Net mineralization is generally expected with relatively low carbon-to-nitrogen ratios (C:N), and N immobilization occurs when the C:N ratio exceeds 20:1 (Scharenbroch and Lloyd, 2004). Lister et al. (2000) found Dothan soils (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) with managed slash pine (*Pinus elliottii*) to have a soil surface (0-10 cm) C:N of 30:1. In a longleaf pine forest in southwest Georgia, Craft and Chiang (2002) found a soil surface (0-5 cm) C:N of 36:1 for Tifton soils (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults). Levi (2007) found that Coastal Plain row crop land had a soil surface (0-5 cm) C:N of 16:1, and that this value was significantly lower than forested lands on similar soils.

Chemical Soil Properties

Soil fertility is of practical importance, easily measured, affected by management, and is often a basis for soil quality assessment (Motta et al, 2002). Soil fertility is assessed through the examination of C pools, pH, cation exchange capacity, base saturation, aluminum saturation, and nutrient content. Land use and management practices have significant effects on soil fertility and soil chemical properties (Fesha, 2004; Bravo et al., 2007; Levi, 2007).

Soil pH is a critical chemical soil quality parameter (Smith and Doran, 1996) and is often the foundation of soil fertility testing. Balkcom et al. (2005) found that the pH of two Paleudults was affected by tillage in the Alabama Coastal Plain. In an assessment of three soils in the Coastal Plain, Li et al. (2002) found that pH was most affected by liming. Motta et al. (2002) found contradictory results for their study of Coastal Plain Ultisols in southwestern Alabama. In their study, management affected pH of Lucedale soils (Fine-loamy, siliceous, subactive, thermic Rhodic Paleudults), but did not affect Benndale soils (Coarse-loamy, siliceous, semiactive, thermic Typic Paleudults).

Alternatively, Karlen et al. (1989) found eight years of various tillage systems did not have a significant effect on pH in Norfolk soils (Fine-loamy, siliceous, thermic Typic Paleudults).

Cation exchange capacity (CEC) is a measure of the amount of negative charges in the soil (Rhoades, 1982). The CEC is widely used for soil characterization and represents a soil's ability to retain and supply cations to the soil solution (Liu et al., 2001). Base saturation is the ratio of exchangeable bases to the CEC (SSSA, 1996). Aluminum (Al) saturation is the amount of potassium chloride (KCl) extractable Al divided by the sum of extractable bases and KCl-extractable Al (Soil Survey Staff, 2010). These parameters give a relative assessment of nutrient saturation and aluminum toxicity. Li et al. (2002) found that the distribution of base saturation was linked to management practices and that CEC and Al saturation exhibited spatial patterns that corresponded to soil map units. Bravo et al. (2007) and Levi et al. (2010) found that pH and base saturation were affected by management and land use, but that CEC was not.

Extractable nutrient quantities change with land use and management. Significant differences in near-surface extractable nutrient concentrations have been found among a variety of agroecosystems in Alabama and Georgia Ultisols (Fesha, 2004; Levi et al., 2010), and between conventional and conservation agronomic systems (Franzluebbers and Hons, 1996; Motta et al., 2002; Balkcom et al., 2005). However, land use and/or management does not always affect nutrient concentrations. For example, Karlen et al. (1989) found no significant differences in nutrient concentrations between two tillage systems in the Coastal Plain.

Physical Soil Properties

Bulk density is inversely related to soil porosity and is an indicator of the capacity of both soil air and water transport (Spargo et al., 2008). Exceedingly high bulk densities increase penetration resistance, limit root growth, and reduce aeration (Pabin et al., 1998). Water content, organic matter, trafficking, depth of winter freezing, shrink/swell capacity and soil fauna/root action affect bulk density and may obscure direct management effects (Logsdon and Cambardella, 2000). Bulk density values (2.5-17.5 cm) were significantly higher in trafficked areas compared to untrafficked on a Goldsboro fine sandy loam (Fine-loamy, siliceous, subactive, thermic Aquic Paleudults) in the North Carolina Coastal Plain (Wagger and Denton, 1989). Hubbard et al. (1994) found surface (2.5-10.0 cm) bulk densities of Rhodic Kandiudults were highly affected by tillage systems. Similarly, Truman et al. (2005) found bulk density values (0-15 cm) of some Alabama Coastal Plain Ultisols were 4% higher for soils under conservation tillage (1.51 g cm^{-3}) versus conventional tillage (1.45 g cm^{-3}). Fesha (2004) found surface (0-5 cm) bulk density of hayland was 6, 5, and 11% higher than conventional tillage, no-tillage, and woodland systems, respectively.

Water dispersible clay (WDC; particles <0.002 mm) affects soil physical and chemical properties and is sometimes included in data sets evaluating soil quality and management effects on near-surface soil properties (Shaw et al., 2003). Water dispersible clay quantities are affected by SOM, CEC, and pH, and soils high in WDC are susceptible to surface sealing and crusting (Shaw et al., 2002). Azevedo and Schulze (2007) postulate disaggregation to be the main mechanism of WDC production, and Shaw et al. (2003) found that WDC is related to percent water stable aggregates in some

Alabama Ultisols. Management systems that affect SOM (tillage/residue management) can directly influence WDC quantities (Truman et al., 2001; Shaw et al., 2002). However, contrary to the findings of some (Rhoton et al. 2002; Shaw et al., 2003), both Levi et al. (2010) and Fesha (2004) found that WDC values were not affected by agroecosystem in the Coastal Plain.

Aggregate stability is the ability of soil peds to withstand disruption by water and uphold soil structure and pore arrangement (Moebius et al., 2007). The stability of aggregates is essential for understanding soil response to management (Blanco-Canqui et al., 2005) and soil quality (Moebius et al., 2007). Aggregate stability is commonly assessed through aggregate mean-weight diameter (MWD), geometric mean diameter (GMD), and proportion of water-stable aggregates (WSAs) (Salako and Hauser, 2001). Percent WSAs are related to porosity and infiltration, correlated with SOC content (Shaw et al., 2003), and are considered a sensitive indicator of soil change (Moebius et al., 2007).

Green et al. (2005) found aggregate stability (0-5 cm) was a function of tillage system (no-till vs. chisel till) for three Ultisols in the Coastal Plain. Salako and Hauser (2001) established that aggregate stability differed between soil type, land use and soil management. Truman et al. (2005) found that aggregate stability in the surfaces (0-3 cm) of Ultisols in the Alabama Coastal Plain increased between a conservation system (58% WSA) compared to a conventional system (37% WSA). Significant differences in aggregate stability (0-20 cm) in the southeastern United States were found by Blanco-Canqui et al. (2005) as a product of differing long-term (>10 years) land uses (perennial grass, row crop, cool season grass pasture, and forest systems). Contrary to these findings, Azevedo and Schulze (2007) found that land use affects the size, but not stability, of aggregates.

A common deterrent to root growth in southeastern Coastal Plain soils is high soil strength or penetrometer resistance (Busscher et al., 2000). The strength of a soil is it's ability to resist rupture or deformation. Soil strength is most commonly measured by a soil cone penetrometer (Gorucu et al., 2006). The penetrometer reports soil strength indices (Hemmat et al., 2009) which allow comparison of mechanical impedance or relative hardness of soils (Duffera et al., 2007). Cone index (CI) values are calculated by dividing the force required to insert the penetrometer cone by the cone base area. In the southeastern Coastal Plain, high soil strength is especially pronounced in E horizons (Busscher et al., 2000) or at the eluvial–argillic horizon interface (Simoes et al., 2009). Variables known to affect soil strength include bulk density, texture, soil moisture (Duffera et al., 2007), and pore size distribution (Vepraskas, 1984).

Vepraskas (1984) found that CI values of North Carolina Coastal Plain Ultisols were related to the soils effective stress, a temporally dependent property. Duffera et al. (2007) found that CI values for three different southeastern Coastal Plain Ultisols were moderately spatially dependent, and that the variation was accounted for by soil map unit. However Cassel (1983) and Busscher et al. (2000) found that CI variation was a product of tillage management for a Norfolk sandy loam (Fine-loamy, kaolinitic, thermic Typic Kandiudults) and a Goldsboro loamy sand (Fine-loamy, siliceous, subactive, thermic Aquic Paleudults). Soil strength was higher in trafficked interrows compared to untrafficked interrows for some Ultisols in Alabama (Raper et al., 2000). Simoes et al., (2009) found higher CI values (0-50 cm) for a no-till relative to an in-row sub-soiled system on a Dothan sandy loam (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults). Cone index values are also dependent on soil water content. Busscher et al. (1997) found that field variation of soil water content can mask treatment differences, facilitating the need for soil moisture correction of values along with cautious measurement and interpretation.

Hydraulic Soil Properties

Soil saturated hydraulic conductivity (K_{sat}) is a critical hydraulic property (Rawls et al., 1998) that should be measured in the field to minimize disturbance and maintain its functional connection with the surrounding soil (Bouma, 1982). Hydraulic conductivity controls water infiltration, surface runoff, leaching of pesticides, and migration of pollutants, and is highly dependent on soil texture, structure (Bagarello and Sgroi, 2004), and macroporosity (McKeague et al., 1982).

A large number of determinations are needed to assess the magnitude of K_{sat} variation (Logsdon and Jaynes, 1996). Logsdon and Jaynes (1996) emphasized the intrinsic local-scale variability of K_{sat}, stating that it could only be correlated over 1-m in many situations. van Es et al. (1999) found that the extrinsic variability (induced by management) of K_{sat} was more significant than the spatial variability. This is consistent with the findings of Prieksat et al. (1994), whom showed that K_{sat} exhibited temporal variability due to land use, tillage, and dynamics of plant roots.

McKeague et al. (1982) concluded that soil management and land use have major effects on soil structure, porosity, and density, which subsequently affect K_{sat}. Hubbard et al. (1994) found mean surface (2.5-10 cm) K_{sat} for Rhodic Kandiudults varied for different tillage treatments. Fuentes et al. (2004) state that tillage has contrasting effects on K_{sat}; tillage increases macropores, thereby increasing K_{sat}, but also disrupts pore continuity, which decreases K_{sat}. For soils in Iowa, Logsdon and Jaynes (1996) found that surface sealing due to bare surfaces influenced pore arrangement, ultimately affecting K_{sat}. Zeleke and Si (2005) stated that scale should be taken into account when looking at K_{sat}, but found that SOC and bulk density affected K_{sat} regardless of scale. The SOC mostly affected K_{sat} through increased aggregation and microbial activity, while bulk density effects were related to porosity.

Water permeating the soil surface is referred to as infiltration, and is dependent on inherent soil properties, land use and management. Lin et al. (1999a) found that texture had more of an effect on micropore versus macropore flow, downplaying the importance of texture as opposed to structure on infiltration. van Es et al. (1999) found that tillage induced high variability in infiltration. Soils undergoing tillage have temporally variable pore arrangements due to disturbance and settling of soil particles (Logsdon and Jaynes, 1996), which ultimately affects infiltration. Ankeny et al. (1990) found lower infiltration rates in trafficked versus untrafficked interrows.

Vegetation affects infiltration by creating preferential flow paths along root channels that reduce the tortuosity of water flow (Prieksat et al., 1994). Studies have shown that both living and dead roots create preferential flow paths, which often increases infiltration (Gish and Jury, 1981and 1983; Meek et al., 1990). Prieksat et al. (1994) found living roots may increase macroporosity through the formation of desiccation cracks as the plant uptakes soil water, thus affecting infiltration. Antecedent soil moisture also affects infiltration. Soils that are drier have more available pores and higher matric potentials, facilitating greater infiltration (Lin et al., 1999a).

Soil water retention is a hydraulic property that governs soil function and has a vast effect on soil management (Rawls et al., 2003). Soil water retention is dependent on soil physical properties such as texture, structure and bulk density (Babalola, 1978; Rawls et al., 1991; Minasny et al., 1999). Measured retention data are often used in theoretical models to estimate hydraulic properties (e.g., unsaturated hydraulic conductivity) and develop Water Retention Curves (WRCs) that characterize the energy status of soil water (Simunek, 2008).

Several functions are utilized to empirically describe WRCs, most notably the equations developed by Brooks and Corey (1964) and van Genuchten (1980). The Brooks and Corey equation produces relatively accurate estimates for soils with narrow pore-size distributions (i.e., coarse soils or sieved and packed cores); however, the van Genuchten equation has been suggested to more accurately describe retention values, especially those close to saturation (van Genuchten et al., 1991). van Genuchten (1980) established an equation describing soil-water content as a function of pressure head in the form

$$\Theta(h) = \Theta_r + \frac{(\Theta_s - \Theta_r)}{[1 + (\alpha h)^n]^m}$$

where $\Theta(h)$ is the measured volumetric water content at pressure h, and Θ_s and Θ_r are the saturated and residual water contents, respectively. Parameters α, n, and m are empirical constants affecting the shape of the retention curve (van Genuchten et al., 1991); van Genuchten (1980) suggests that $m = 1 - 1/n$ based on Mualem (1976). The constant α is related to the inverse of the air-entry pressure where n is related to the pore-size distribution (Schaap et al., 2001).

Since SOM affects soil structure and related properties, Rawls et al. (2003) found that water retention was affected by differences in SOM content. Soil porosity also affects water retention. Hubbard et al. (1994) found that water retention in surface horizons (2.5–10.1 cm) of Coastal Plain Kandiudults was a product of soil porosity affected by tillage. Another Coastal Plain study found significant differences in water content occurred between two Ultisols as a function of conservation versus conventional management (Truman et al., 2005). The authors concluded the conservation system had higher water contents due to higher infiltration. Fesha (2004) found soil water retention was significantly affected by agroecosystem in some Coastal Plain Ultisols. This researcher found that hayland and no-tillage managements had higher water contents than both conventional tillage and woodland sites.

Available water holding capacity (AWHC) quantifies the soil's ability to store and provide water that is available to plant roots. The AWHC is defined as the difference between water content at field capacity (water content at 0.1 bar) and permanent wilting point (water content at 15.0 bar) (Reynolds et al., 2009). Higher SOM content results in increased AWHC. Wesseling et al. (2009) found that a 10% increase in SOM increased a coarse soil's AWHC 434%, which agreed with the findings of McCoy et al. (2007). Bosch et al. (2005) indicated that conservation tillage increased AWHC relative to conventional tillage in Coastal Plain Kandiudults. The AWHC was higher for old-growth longleaf pine sites compared to managed agroecosystems for some Coastal Plain Ultisols (Levi, 2007). van Genuchten (1980) emphasized the importance of soil water parameters and their usefulness in the prediction of other soil properties, namely through the development of Pedotransfer Functions.

Pedotransfer Functions

Much progress has been made in the direct measurement of hydraulic properties, yet these methods are time consuming and costly. Although temporal and spatial variability of hydraulic characteristics can have significant effects on model results, Wösten et al. (2001) stated that valid predictions rather than direct measurements are satisfactory for many applications. Statistical regression equations expressing relationships between soil properties, usually those that are easily measured (e.g., texture or bulk density), to those that are not (e.g., hydraulic conductivity), have been termed pedotransfer functions (PTFs) (Bouma, 1989).

Wösten et al. (1995) subdivided PTFs into two divisions based on input data of the model; these divisions were termed class and continuous. Class PTFs are relatively easier and inexpensive to develop using categorical data, such as predicting hydraulic conductivity based on the USDA soil textural class (Nemes and Rawls, 2004). Conversely, continuous PTFs predict values based on measured data (e.g., estimating hydraulic conductivity from percentages of clay, silt and organic matter), resulting in improved accuracy but higher cost (Wösten et al., 1995).

Wendroth et al. (2006) declared that PTFs insufficiently describe spatial patterns of soil hydraulic functions. Due to the inherent variability of hydraulic properties, Tietje and Hennings (1996) believe that the prediction of hydraulic properties using PTFs, especially saturated hydraulic conductivity, is inaccurate. Sobieraj et al. (2001) had little success using PTFs to estimate saturated hydraulic conductivity of Typic Hapludults, which they attributed to the inability to characterize and account for soil macroporosity. Shaw et al. (2000) successfully developed continuous PTFs relating particle size to saturated hydraulic conductivity and transport properties for some southeastern sandy Kandiudults.

Hydraulic parameters estimated using soil morphological properties such as pedality, macroporosity, and root density have agreed well with measured values for some southern soils (Lin et al., 1999b). Lin et al. (1999b) also found that class PTFs using morphological features resulted in predictions comparable to continuous PTFs constructed from measured physical properties. In contrast, Lilly (2000) was not able to derive strong relationships between hydraulic conductivity and soil structure (based on ped size) utilizing class PTFs.

Others have used PTFs to estimate water retention parameters (Minasny et al., 1999; Schaap et al., 2001; Timlin et al., 2004). Scheinost et al. (1997) developed a PTF that substantially improved prediction of WRCs, but concluded that there was still a considerable deviation between measured and predicted water contents. This finding was in agreement with Tietje and Tapkenhinrichs (1993) when reviewing PTFs developed using soil texture. Fesha (2004) found that field capacity and permanent wilting point were not predicted well using PTFs for some Alabama Ultisols. However, Rawls et al. (2001) found above average accuracy of water retention estimates compared to literature using the Map Unit User File (MUUF) PTF for southern U.S. soils. Because PTFs predict properties from available basic soil data, they are advantageous due to their relative inexpensiveness and ease of derivation/use; however for application at a specific point, use of a PTF may be inadequate and direct measurement may be the only option (Wösten et al., 2001).

Rationale

Soil Survey is a paradigm based science in which the soil-landscape model is utilized. This paradigm is rooted in the state factor of formation equation (i.e., soils are a function of climate, parent material, relief, and organisms acting over time) which was outlined by Dokuchaeiv and experimentally validated by Jenny (1941). Soil Survey implements this model to characterize the spatial distribution of soils through development of the soil-landscape model (Duffera et al., 2007). The soil-landscape model allows one to discern natural soil bodies, termed soil-landscape units. These units contain similar soils due to similar soil formation factors (Hudson, 1992). In Soil Survey, the soil-landscape is used to group soils into polygons, which are then aggregated into map units. Map units are defined and named in terms of their soil components, which are correlated to taxonomic units (Soil Survey Division Staff, 1993).

Soil survey has emphasized the spatial depiction of soils (utilizing inherent, use-invariant properties) for inventory purposes (Trangmar et al., 1985), but soils are greatly affected by temporal processes as illustrated by the state factor equation above. Similar to spatial variability, temporal variability exhibits many scales. Recently, considerable efforts have been placed on evaluating human impacts on soils occurring during the anthropocene. It is well documented that soils, particularly in the near-surface, have been largely affected by land use and management over the last couple centuries (Brye and West, 2005; Halfmann, 2005; Zhou et al., 2008; Kibunja et al., 2010). However, to what degree these management effects have occurred in southeastern U.S. Coastal Plain soils is uncertain.

Soil change (temporal variation in soil properties at a specific location) results from both natural and anthropogenic processes (Tugel et al., 2005), whereas dynamic soil properties are components of soil change directly related to decadal to centurial human and natural impacts (Tugel et al., 2008). The National Cooperative Soil Survey (NCSS) defines a management or use-dependent property as a type of dynamic soil property which changes on a human time-scale due to anthropogenic disturbances (Soil Survey Staff, 2010a). With the near completion of the initial survey of the U.S., the NCSS is concentrating on improving characterization of use-dependent soil properties and interpretations based on these near-surface properties. The characterization of temporal processes and associated effects, especially those anthropogenically induced, could potentially have vast implications on the future of Soil Survey and the paradigm on which it is based. In addition, management-dependent properties (components of soil change) are often used to assess soil quality.

Soil quality, generally defined as the capacity of a soil to function (Karlen et al., 1997), requires considerations of classification and land use (Andrews et al., 2004). The purpose of soil quality assessment is to determine if management systems are functioning at acceptable levels of performance, and to provide opportunities to evaluate and revise sustainable soil and land management systems (Doran and Parkin, 1994). Dynamic soil quality is based on assessment of management-dependent properties, with SOC and related pools often being the most critical measures in southeastern U.S. soils. Soil C is functionally related to nearly all physical, chemical and hydraulic properties, substantiating it’s necessity as a soil quality metric. Southeastern U.S. Coastal Plain soils are depleted in SOC and have poor dynamic soil quality (e.g., nutrient poor with high bulk densities) due to past intensive monoculture farming practices. Concurrently, humans are a major factor in global C cycles and climate change (Dale et al., 2000). To reduce the amount of CO_2 in the atmosphere, increasing SOC via C sequestration has merit. The measurement of SOC pools and related properties across different agroecosystems can improve knowledge of terrestrial C stocks and the capacity of the soil resource to serve as a C sink (Mishra et al., 2010) as well as address dynamic soil quality in relation to differing anthropogenic stresses (land use).

Soil Survey interpretations convey the suitabilities/limitations of soil-landscape units (Buol et al., 2003). It should be noted that the "application of [survey] interpretations for a specific area of land has an inherent limitation related to the variability in the composition of delineations within a map unit" (Soil Survey Division Staff, 1993). Interpretations are largely based on databases developed from static, use-invariant properties of soils with minimal consideration of management effects. Interpretations were purposefully developed in this manner due to the inability to holistically characterize temporal, use-variant properties and associated variability. Thus, an improved understanding of the magnitude of variability of use-dependent soil properties can greatly improve soil survey applications and land use management (Tugel et al., 2008).

Soil hydraulic properties (e.g., saturated hydraulic conductivity and infiltration rates) are of great importance to soil interpretations, ecosystem function, and the hydrologic cycle, but characterization is problematic as they are highly variable. Hydraulic based interpretations are utilized in many agricultural, forestry, engineering, and land-planning applications. Management practices have vast effects on soil chemical and physical properties, in turn affecting soil hydraulic properties. Southeastern U.S. Coastal Plain soils often have high infiltration rates but low water holding capacity due to sandy epipedons with low SOC contents. Resulting short-term water deficits often limit ecosystem productivity in this region. Management practices (tillage, trafficking, grazing, and prescribed burning) can further deplete SOC, alter pore connectivity, increase bulk density and affect water infiltration, movement, and storage. These adverse effects on soil hydrology can further reduce both soil and water quality. Therefore, documentation of the variability of near-surface soil hydraulic properties can improve interpretations and perhaps lead to improved management strategies in this region.

The Wiregrass region of Alabama has a broad spectrum of agro- and natural ecosystems ranging from native longleaf pine forests to pasture lands. Much of the agricultural land is considered prime farmland (soils that have physical and chemical properties conducive for crop production), and many of the prime farmland soils in the Wiregrass region are found throughout the entire southeastern Coastal Plain region. Considering the extent and utilization of these soils for row crops, grazing, and forestry, documentation of soil change as affected by land use can increase our knowledge on sustainability of our soil and water resources. Furthermore, by addressing a complete range of agroecosystems (with associated range of anthropogenic influences) for the same map unit (same inherent/spatial variability) we can better quantify temporal, anthropogenic induced variability.

Therefore the objectives of this research are to 1) assess the degree of management-dependent versus use-invariant property variability within a benchmark soil map unit of the Wiregrass region of Alabama, and 2) develop improved relationships between dynamic soil properties and near-surface soil hydraulic properties.

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II. Management-dependant variability of southeastern U.S. Coastal Plain Plinthic Kandiudults

Abstract

Soil Survey has emphasized the spatial depiction of soils (utilizing inherent, use-invariant properties) for inventory purposes, and surveys contain limited information on the dynamic nature of the soil resource. The National Cooperative Soil Survey defines a management-dependent property as a type of dynamic soil property which changes on a human time-scale due to anthropogenic disturbances (i.e., indicative of anthropogenic soil change). Interest in soil change and carbon (C) sequestration has led to increased emphasis on the characterization and inventory of these properties. For a prime farmland, benchmark soil map unit in the Wiregrass region of the Alabama Coastal Plain, the objectives of this study were to: 1) assess the degree of management-dependent versus use-invariant soil property variability, 2) evaluate long-term management impacts on near-surface soil properties, and 3) evaluate soil C pools and sequestration potentials. Near-surface (0-50 cm) soil physical, chemical, and hydraulic properties within Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) consociations were measured under long-term (>10 years) conventional and conservation row cropping, pasture, pine plantation, and old-growth Longleaf pine (*Pinus palustris*) forest. Pedon description and characterization were conducted at each site to quantify use-invariant variability. Control section (use-invariant) sand content and CEC (expressed on a clay basis) exhibited low variability (CV≤15%), while control section clay and silt content and depth to argillic horizon, ≥5% plinthite, and iron depletions with chroma ≤ 3 demonstrated moderate variability (15%<CV≤35%).

Management-dependent properties tended to express moderate (C pools, CEC (soil basis), AWHC) or high (CV>35%; WDC, N pools, and K_{sat}) variability. Significant anthropogenic influences were observed on near-surface soil properties as a function of long-term management. Based on C contents, stratification of C and nitrogen (N) pools, surface exchange capacities, and aggregate stability, longleaf and pasture systems had superior soil quality. Pastures sequestered 57 Mg C ha^{-1}, which was 12, 14, 16, and 50% more relative to the conservation (51 Mg ha^{-1}), planted pine (50 Mg ha^{-1}), longleaf (49 Mg ha^{-1}), and conventional (38 Mg ha^{-1}) systems, respectively. The C sequestration potential for these soils lies intermediate to more temperate and tropical regions of the world. Our results indicate that the magnitude of variability of management-dependent properties slightly exceeds variability found inherently within this representative soil map unit. Because many of these properties are correlated, it is likely that a subset of properties to be measured can be developed to help characterize management-dependent variability. Considering the importance of management-dependent properties to ecosystem function and map unit interpretations, creating management schemes and soil interpretations based on land use may be better suited than the heavy reliance on use-invariant properties.

Abstract Abbreviations: AWHC = available water holding capacity, C = carbon, CEC = cation exchange capacity, CV = coefficient of variation, K_{sat} = saturated hydraulic conductivity, N = nitrogen, WDC = water dispersible clay.

Introduction

Soil Survey is a paradigm based science centered on the state factor of formation equation [i.e., soils are a function of climate, parent material, relief, and organisms acting over time (Jenny, 1941)]. Historically, Soil Survey has emphasized the spatial depiction of soils (utilizing inherent, use-invariant properties) for inventory purposes (Trangmar et al., 1985), but soils are greatly affected by temporal processes (time is a state factor in soil formation). Soils possess two types of variability: spatial (intrinsic) and temporal (extrinsic) (Cambardella et al., 1994), with their expression exhibiting scale-dependency (Parkin, 1993). This basic soil model implies that the spatial variability of soils is mostly inherent (Arnold, 1983). Concurrently, temporal soil variation results from both natural (e.g., climate fluctuations) and anthropogenic (e.g., land use) processes (Tugel et al., 2005). Although soil surveys have been used to characterize soil variability (Trangmar et al., 1985; Duffera et al., 2007), they include limited information on the dynamic nature of soils.

Insufficient characterization of soil properties as a function of temporal processes has stimulated research on *soil change*. Soil change is defined as “the temporal variation in soil properties at a specific location” and is driven by natural factors, human use and management, and/or their combined effects (Tugel et al., 2005). Rate-dependence of soil change can be directly observed through long-term experiments, space-for-time substitutions, and repeated soil surveys. Studies of this nature indicate that many properties that were previously thought to be relatively static are actually relatively dynamic at the decade to centurial time-scale (Richter, 2007). Anthropogenic soil change is considerably modifying our natural resources at landscapes scales, ultimately affecting global C and water cycles. By assessing impacts of varying land use or changes in management practices on the soil resource, anthropogenic soil change can be addressed (Knops and Tilman, 2000; Guo and Gifford, 2002).

In an attempt to quantify soil change through the assessment of extrinsic (temporal) variability, dynamic soil properties are investigated. Dynamic soil properties are those which change on human time scales due to both natural and anthropogenic effects. Furthermore, use- or management-dependent properties comprise the anthropogenic portion of dynamic soil properties (Tugel et al., 2008) and are essential in the study of soil degradation, productivity, restoration and maintenance (Norfleet et al., 2003). Measurements of management-dependent properties are used to assess dynamic soil quality. Soil quality is loosely defined as the capacity of a soil to function in relation to a specific use (Karlen et al., 1997). Soil quality is assessed through measurement of biological, chemical, and physical properties and their interactions (Warkentin and Fletcher, 1977). Soil quality indicators are defined as soil properties which exhibit the greatest relationship with soil function (Andrews et al., 2004), and therefore represent the extrinsic variability of soils.

Several near-surface (0-50 cm) chemical and physical management-dependent soil properties (e.g., SOC pools, aggregate stability, or bulk density) are indicative of soil quality and representative of soil change. With growing concerns of increased atmospheric CO_2 and global climate change, interest in mitigation of atmospheric CO_2 through soil C sequestration has grown (Lal, 2004). Soil organic carbon pool assessments can improve knowledge of the global C cycle and the capacities of the soil resource to serve as a C sink (Mishra et al., 2010). Research has indicated that land use changes modify soil C content. For instance, conversion of forested lands to agricultural uses has depleted the soil C stock by 20 to 40% worldwide (Worsham et al., 2010). Furthermore, differences in management practices can have vast effects on C dynamics (Halpern et al., 2010).

Similarly, it is well documented that soils, particularly in the near surface, have been largely affected by land use and management (Brye and West, 2005; Halfmann, 2005; Zhou et al., 2008; Kibunja et al., 2010). However, to what degree these management effects have occurred in southeastern U.S. Coastal Plain soils is uncertain. This region contains a broad spectrum of natural and agroecosystems, spanning from native longleaf pine (*Pinus palustris*)/wiregrass (*Aristida stricta*) forests (of which less than 5% remains; Boyer and White, 1990) to monoculture conventional row crop systems. Associated with this range of land uses is a range of anthropogenic influences and impacts that variably affect the soil resource.

The Wiregrass region of Alabama contains a range of land use and management on prime farmland containing soils that are representative of the southeastern U.S Coastal Plain. Assessment of soil C pools and related properties across different land uses can improve knowledge of terrestrial C stocks and the capacity of the soil to serve as a C sink. Documentation of soil change as affected by land use can increase our understanding of sustainability of soil resources of this region as well as the entire southeastern Coastal Plain. By characterizing both the intrinsic and extrinsic nature of soils, soil interpretation and management can be improved.

Therefore, the objectives of this study are to: 1) assess the degree of management-dependent versus use-invariant soil property variability within a prime farmland, benchmark soil map unit of the Wiregrass Region of Alabama, 2) evaluate impacts of long-term land use/management on near-surface soil properties, and 3) evaluate soil C pools and sequestration in the region.

Materials and Methods

An on-farm survey was performed on a representative map unit (benchmark soil) found within varying land uses (common for the southeastern U.S. Coastal Plain) in the Wiregrass Region of the Alabama Coastal Plain. Samples were taken at random from three repetitions (one for conservation row crop system) of map unit/land use combinations. Land use and or management (discussed in detail below) included conservation and conventional row crop systems, native (old-growth) longleaf pine/wiregrass forests, managed pine plantations, and pastures. Only one site could be found that had been under consistent conservation tillage for ≥ 10 years. Therefore, there were 13 research sites (Figure 1-1) evaluating five natural and agroecosystem land use/managements.

Site Selection:

A Geographic Information System (GIS) approach was used for preliminary site reconnaissance. A combination of Alabama Gap Analysis Project (AL GAP) data (Kleiner et al., 2007), historical land use data (Price et al., 2006), National Resource Conservation Service (NRCS) Soil Survey Geographic (SSURGO) order 2 inventories, land owner interviews, and digital ortho-quadrangle photography was used to select sites of interest. Criteria for site selection included: 1) a Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) map unit, 2) ‘A’ slopes (0 – 2%), and 3) long-term (≥10 years) land use/management. On-site examination of the land use as well as soil map unit verification (described below) followed preliminary reconnaissance. Land use data (≈ 40 years old) utilizing the Enhanced Historical Land-Use and Land-Cover Data Sets of the U.S. Geological Survey (Price et al., 2006) documented historical land use (Table 18 in Appendix).

Land use/managements:

The land use and/or management treatments in this study included a range of natural- and agroecosystems (as described below) that have been in place ≥ 10 years. Ideally, it would be best if all sites had achieved "steady-state" conditions with regard to management-dependent soil properties and land use/management. However, logistically it is difficult to impossible to establish sites that meet all criteria due to the dynamic land management of this region, and 10 years of relatively consistent management is considered long-term for this region. Multiple managements can occur within each representative land use in this region (e.g., both conservation and conventional row crop systems). For the purpose of this study, the Land Use/Management/Ecosystem will be abbreviated as LM, and will consist of:

Conservation row crop– system consisted of an irrigated, strip tilled peanut (*Arachis hypogaea*), cotton (*Gossypium hirsutum*), corn (*Zea* spp.) rotation that had been in place since 1999. A KMC strip till rig with coulters and rolling baskets was utilized. Prior to 2004, the cover crop was planted with a grain drill after disking one or two times. In 2004, cover crops were no-till drilled with no prior disking. Since 1996, the plot was grazed by brood cows and calves during the winter.

Conventional row crop– systems consisted of non-irrigated peanut and cotton rotations. The soil was chisel plowed and disked prior to planting of both crops. In some years, winter cover crops were sown after fall harvest and disking, and included either rye (*Secale cereale*), wheat (*Triticum* spp.), or oat (*Avena sativa*). Systems had been in place for > 11 years.

Longleaf pine/wiregrass forest – sites consisted of varying age (old-growth) longleaf pine forests located in the Conecuh National Forest. Understory vegetation consisted of mixed native bunch grass (dominated by wiregrass) and successional species depending on fire management. Fire, whether prescribed or natural, is important to the maintenance of these ecosystems. Ground cover had been minimally disturbed since stand establishment suggesting these sites had never been cultivated. The Longleaf database for the site indicates that at a minimum, these stands have been present for 69 years.

Pasture – sites predominately consisted of Bahiagrass (*Paspalum notatum)* stands grazed by beef cattle year round. All pastures had been in place for > 20 years.

Planted pine plantation– sites consisted of first or second rotation planted slash (*Pinus elliottii*) or loblolly (*Pinus taeda*) pine trees managed for pole and/or saw timber. The understory was periodically burned with the majority of soil disturbance occurring during site preparation. Based on interviews and conservative estimates of tree age, all sites had been in place for > 15 years.

Pedon characterization:

Soils were described, sampled, and characterized at each site to verify sites were representative of Dothan map units. Soils were obtained from horizons of representative *type* pedons for laboratory analysis to verify map unit placement (Soil Survey Staff, 2010). Samples were air-dried, ground, separated into coarse- (>2 mm) and fine- (≤2 mm) earth fractions, and analyzed for: percent coarse fragments (%>2 mm); particle size distribution using the <2-mm pipette method following SOM removal of surface horizons (upper two) using a 30% H_2O_2 solution and dispersion with a $(NaPO_3)_6$ and Na_2CO_3 solution; cation exchange capacity (CEC) and base saturation (Ca, Mg, K, and Na) by the NH_4OAc (pH 7) method using an autoextractor and analyzed with atomic adsorption spectroscopy (AAS); extractable aluminum (Al) using 1.0 *M* KCl with an autoextractor (12 hour extraction) and measured with inductively coupled plasma (ICP) spectrometry; and effective cation exchange capacity (ECEC) was calculated by summing the NH_4OAc bases and KCl Al (Soil Survey Investigation Staff, 2004).

Thermogravimetric analysis (TGA) was performed to determine the clay (<0.002 mm) mineralogy of the upper control section utilizing a TGA Q50 Thermogravimetric Analyzer (TA Instruments—Waters LLC, New Castle, DE, USA). Kaolinite and gibbsite were quantified using the theoretical water content of both minerals (14 and 34.2%, respectively). Dithionite-citrate-bicarbonate (DCB) extractable iron and aluminum were determined as per Jackson (2005). Iron percentages were reported on an iron oxide basis. Pedons were classified according to Soil Taxonomy (Soil Survey Staff, 2010). The Appendix contains pedon field descriptions and tables 19-31 contain laboratory characterization data.

Field Procedures:

Sampling

Thirteen sites (Figure 1-1) were sampled for chemical and physical analyses. All sampling was performed within an approximate 100 m^2 area centered on each site's characterized pedon location. At row crop sites, where distinguishable, samples were taken from untrafficked interrows. Organic ‘O’ horizons were sampled in forested (longleaf pine/wiregrass and planted pine) sites (two 0.25 m^2 quadrats) and transported in cloth sample bags. Organic horizons were removed prior to mineral soil sampling.

Composite soil samples (10 samples taken with an 8-cm bucket auger or 5-cm cylindrical core) were taken at four depth increments (0-5, 5-15, 15-30, and 30-50 cm) and transported in cloth sample bags. Approximately 400 g of each composite sample (0-5, 5-15, 15-30, and 30-50 cm) were placed in sealed plastic bags and transported in cold storage for active carbon analysis. Active carbon samples were not taken from the three longleaf pine/wiregrass forest sites due to different sampling seasons.

Bulk density was sampled utilizing the core method outlined by Blake and Hartge (1986). Three bulk density samples were obtained within each site location using: 1) a truck-mounted Giddings Hydraulic Probe (Giddings Machine Company, Inc., Fort Collins, CO, USA) or 2) a slide hammer with cylindrical sleeves (one planted pine site due to vehicle inaccessibility) at 0-5, 5-15, 15-30, and 30-50 cm depths and transported in sealed plastic bags. The same diameter core was sampled with both methods of extraction. Three samples at each site were taken with a shovel (to reduce sampling disturbance) at two depths (0-5 and 5-15 cm) and placed in cloth sample bags for determination of water stable aggregates (WSA).

Excluding longleaf pine/wiregrass sites, two replications of undisturbed soil cores (8.5 cm diameter, 6 cm height) were taken at two depths (0-6 cm and 15-21 cm) to determine soil water contents at field capacity and wilting point (10 kPa and 1.5 MPa, respectively). Cores were wrapped in cheese cloth, placed in sealed plastic bags, and transported in cold storage. Samples for moisture determination were also taken from 0-50 cm and transported in sealed plastic bags.

In-situ Measurements

Soil strength (0-50 cm) measurements were taken using a CP40II recording cone penetrometer (ICT International Pty Ltd, Armidale, New South Wales, 2350, Australia). Cone index values consist of a composite of 20 insertions with measurements recorded at 1 cm increments. Three replications of saturated hydraulic conductivity (K_{sat}) were taken at three depths (15, 30, and 50 cm to bottom of bore hole) within each site using a compact constant head permeameter (Amoozegar, 1989; Ammoozemeter; Ksat, Inc., Raleigh, NC). Tap water (EC = 227 μS cm^{-1} for longleaf pine/wiregrass forest sites 1 and 3; EC = 176 μS cm^{-1} all other sites) was used for K_{sat} determination. Replicates were averaged to obtain representative site-depth values.

Laboratory Procedures:

Soil Carbon

Organic ‘O’ horizons were air-dried, weighed, and ground to pass a 1-mm sieve. Two grab samples from each quadrat were analyzed for C and N by dry combustion (LECO CN-2000). Average values from these two quadrats were calculated to acquire a site value.

Active carbon samples (0-5, 5-15, 15-30 and 30-50 cm) were removed from cold storage the day following sampling and moist soils were passed through a 2-mm sieve. Active carbon was determined using a 0.02 M $KMnO_4$ (with the addition of 0.1 M $CaCl_2$) solution and analyzed colorimetrically following the protocol by Weil et al. (2003).

Total soil organic carbon (TOC) and total soil organic nitrogen (TON) were determined on composite samples (0-5, 5-15, 15-30 and 30-50 cm) by dry combustion (LECO CN-2000). Ground (mortar and pestle) samples were replicated (sub-samples) and values averaged to acquire a representative site-depth value. Carbon to nitrogen ratios (C:N) were calculated using C and N concentrations.

Particulate organic matter C and N (>53 μm) (POMC and POMN) were determined using composite samples (0-5, 5-15, 15-30 and 30-50 cm) by the soil dispersion and wet sieving method outlined by Cambardella and Elliot (1992). Ground (mortar and pestle) sub-samples were analyzed for C and N by dry combustion; values were averaged to acquire a representative site-depth value. Mineral-associated C and N (<53 μm) (MC and MN) were determined by difference (e.g., TOC – POMC).

Chemical

Composite soil samples (0-5, 5-15, 15-30 and 30-50 cm) were air-dried, ground and passed through a 2-mm sieve prior to chemical analyses. The methods for CEC, ECEC, base saturation (%) and extractable Al measured on these samples were described previously. Mehlich 1 extractable nutrients (P, Fe, Mn, Zn, Cu, and B) were extracted via the double acid method outlined by Mehlich (1953). Soil pH was measured in 1:1 (w/v) soil to water and 1:2 (w/v) soil to 0.01 *M* $CaCl_2$ solutions (Soil Survey Investigation Staff, 2004).

Physical

Composite soil samples (0-5, 5-15, 15-30, and 30-50 cm) were air-dried and ground to pass a 2-mm sieve prior to determination of the particle size distribution (PSD) and water dispersible clay (WDC). Determination of the PSD using the <2-mm pipette method followed soil organic matter removal using a 30% H_2O_2 solution and dispersion with a $(NaPO_3)_6$ and Na_2CO_3 solution (Soil Survey Investigation Staff, 2004). A modification of the <2-mm pipette method (no organic matter removal or dispersion) was utilized to determine WDC. The clay dispersion ratio (CDR) was calculated as per Igwe (2005). Water stable aggregates were determined according to methods of Kemper and Rosenau (1986) with the use of a humidifier apparatus. Three replications were averaged to acquire a representative site-depth value. Bulk density samples were dried at 105°C prior to weighing and calculations were made according to the method outlined by Blake and Hartge (1986). Replications were averaged to obtain each representative site-depth value.

Undisturbed soil cores were saturated with a 0.01 M $CaCl_2$ solution prior to water retention measurements. Gravimetric water content at field capacity ($\Theta_{g\ 10\ kPa}$) was determined using Tempe cells (model 1405; Soil Moisture Equipment Corporation, Santa Barbara, CA, USA) and wilting point ($\Theta_{g\ 1.5\ MPa}$) was determined using pressure plates (Klute, 1986). Available water holding capacity (AWHC) was determined by difference (i.e., $\Theta_{g\ 10\ kPa} - \Theta_{g\ 1.5\ MPa}$).

Statistical Analysis:

When depth was a factor (i.e., multiple depths), the experimental design consisted of an augmented split plot design with the whole plot in randomized complete blocks; management was the whole-plot factor while depth was the sub-plot factor. The blocking factor consisted of relative classes based on surface (0-50 cm) soil texture. Analysis of variance consisted of mixed models methodology using SAS$^®$ PROC GLIMMIX (SAS Institute Inc., 2003) where management, depth and their two-way interaction were fixed effects and block, block by depth and block by management two-way interactions were random effects. The conservation row crop system was not replicated (n=1), therefore the pooled variance for the remaining crop systems was used to calculate a standard error. The residual covariance was modeled due to correlated error structure caused by lack of randomization among depth; the best fitting model was selected using Akaike's information corrected criterion (AICC) (Bolker et al., 2008; Guertal et al., 2009; SAS Institute Inc., 2010). Land use/managements were compared within depths using the SLICEDIFF option of the LSMEANS statement.

When depth was not a factor (i.e., 0-50 cm or similar comparisons), the experimental design consisted of a randomized complete block design. Again, the blocking factor consisted of relative classes based on surface (0-50 cm) soil texture. Analysis of variance consisted of mixed models methodology using SAS® PROC MIXED (SAS Institute Inc., 2003) where management was the sole fixed effect, and block and the two-way interaction were the random effects. Land use/managements were compared using the PDIFF option of the LSMEANS statement.

Pearson linear correlation coefficients were calculated for select properties using SAS® PROC CORR (SAS Institute Inc., 2003). All significant results were based on a confidence level of 0.05.

Results and Discussion

Soils

All upland sites contained very deep, well-drained soils formed in unconsolidated fluvio-marine sediments. Soils contained ochric epipedons and argillic and kandic subsurface diagnostic horizons. Surface textures ranged from loamy sand to sandy loam and control section particle size families were fine-loamy (>15% fine sand or coarser with 18-35% clay) for all thirteen sampled pedons (Table 1). All profiles contained ≥5% nodular plinthite within 150 cm, placing the soils in Plinthic subgroups. Clay mineralogy was dominated (>50%) by kaolinite and gibbsite (Table 1). Twelve of the thirteen characterized pedons classified as Ultisols, with one pasture site as an Alfisol (Table 1). Elevated base saturation (>35%) in the lower solum of pedon S2009AL-067-3 (Table 28 in the Appendix) was anthropogenically induced (cultural Alfisol) as two pedons sampled on an adjacent fence row (where amendment applications were less and corresponding base saturation was lower) were both Ultisols. Thus, sampled pedons fit within the Dothan series criteria.

Use-invariant Properties

For the purposes of this discussion, *use-invariant* properties are properties that are less subject to change and thought to be relatively more stable. For these analyses, measurements within the control section (upper portion of the argillic/kandic horizon) and deeper (to 180 cm) are emphasized as the control section represents the illuvial portion of the solum, mostly residing below the depth of tillage, and is of taxonomic significance. In addition, measurements of properties less prone to change at decade scales (e.g., texture, mineralogy, morphology) are emphasized. For the thirteen pedons investigated, control section texture, CEC/ECEC (on a clay basis), and mineralogy are shown in Table 2. Reporting CEC and ECEC on a clay basis (i.e., ratio of CEC or ECEC to total clay) represents an index for clay activity, allowing inferences on mineralogy (Soil Survey Investigation Staff, 1995).

Within control sections, percent sand, silt, and clay ranged from 54-72% (mean 63%), 10-17% (mean 12%), and 18-34% (mean 24%), respectively. Cation exchange capacity had a mean of 14 $\mathrm{cmol_c\ kg^{-1}}$ with upper and lower bounds of 17 and 11$\mathrm{cmol_c\ kg^{-1}}$, respectively. Effective cation exchange capacity ranged from 6-12 $\mathrm{cmol_c\ kg^{-1}}$, with a mean value of 9 $\mathrm{cmol_c\ kg^{-1}}$. Kandic horizons were identified due to low CEC and ECEC/clay ratios ($\leq$16 and 12 $\mathrm{cmol_c\ kg^{-1}}$, respectively), indicating highly weathered soils with clays having low activity.

Mineralogical analysis was conducted on the clay fraction of the upper control section. All soils were dominated by kaolinite (ranging from 37-54%, mean 47%) and gibbsite (ranging from 6-26%, mean 15%). Kaolinite has low surface area and exchange capacities, is a product of acid weathering, and found extensively in warm, moist climates (Dixon, 1989). Gibbsite is considered an end member of chemical weathering, and common within highly weathered soils (Hsu, 1989). Free iron oxides ranged from 2.4 to 5.4%, with a mean value of 4.1%. Pedogenic iron oxides (goethite and hematite) tend to concentrate in the clay fraction of these soils (Shaw, 2001).

Select morphological properties are also reported (Field Descriptions 1-13 in the Appendix and summarized in Table 2). The depth from the soil surface to the argillic/kandic horizon (control section) ranged from 20-40 cm, with a mean of 28 cm. Argillic and kandic horizons are primarily distinguished by a clay increase relative to the overlying solum via clay illuviation (indicated by clay films or coatings). These horizons are indicative of stable landscapes and tend to have higher nutrient/water holding capacity and lower hydraulic conductivities relative to overlying eluvial horizons. The depth to occurrence of $\geq$5% plinthite ranged from 26-84 cm (mean 54 cm) from the soil surface. Soil redoximorphic features (iron accumulations and depletions) largely indicate the depth to the seasonal high water table. Iron depletions with a Munsell chroma ≤3 had a mean depth occurrence at 125 cm (range of 85-168 cm).

Management-dependent Soil Properties

Near-surface soil properties were investigated for effects of afore mentioned natural and agroecosystems. For ease of discussion, LMs will be referred to as longleaf, planted pine, pasture, conservation row crop, and conventional row crop. As described in the methods, the conservation row crop system consisted of one replication due to difficulty in finding replications of consistent conservation management in the Wiregrass region. The conservation site was included in the statistical analyses using the pooled variance as described in the methods. Data for the conservation row crop system, however, only provide a point of reference, and as such, minimal discussion of the conservation row crop system data will be included.

These LMs were selected because they are common to the region and encompass a continuum of soil disturbance. The native longleaf land use was considered to have the least disturbed soils, while the conventional row crop system had the most intensively disturbed upper solum. Pine plantations were considered third in disturbance (after row crop systems) due to intensive site preparation. Therefore, intensity of soil disturbance by LM was conventional > conservation > planted pine > pasture > longleaf.

For applicable parameters, both total contents (on a mass per area basis) and concentrations were investigated. Concentrations allow for the comparison of values across studies, whereas contents allow inferences into total sequestration. The soil surface is most indicative of soil change (relative to lower depths) due to natural (e.g., climate) and anthropogenic (e.g., land use) influences. Therefore, many of the management-dependent measurements concentrate within surface and associated eluvial horizons.

Total Soil Organic Carbon and Nitrogen

Total SOC and N contents exhibited a number of LM effects at the soil surface. Total C content was lowest for conventional row crop sites and highest for pasture sites. The addition of organic horizons TOC and TON to the mineral soil (0-50 cm) of forested sites (longleaf and planted pine) resulted in no significant changes. The TOC of the conventional row crop sites (38 Mg ha^{-1}) was lower than the pastures (57 Mg ha^{-1}) (Figure1-2). Causarano et al. (2008) also reported TOC (0-20 cm) was highest for pasture and lowest for conventional row crop systems for some southeastern Ultisols. Greater amounts of C were found at pasture sites relative to conventional sites due to greater C inputs (greater root densities of pastures) and lack of annual soil disturbances (tillage) and C exports (crop biomass).

The TON content was highest for pastures (4938 kg ha^{-1}), which were significantly higher than longleaf (2641 kg ha^{-1}) and conventional row crop (2555 kg ha^{-1}) sites (Figure 1-2). Similarly, Halpern et al. (2010) found TON contents (0-20 cm) decreased with intensity of management for some sandy loam textured soils in Canada. More recalcitrant organic matter (more lignin) in the pasture and forested sites (Binkley and Giardina, 1998), and the inclusion of legume (peanut) residues in the conservation rotation, likely resulted in higher TON contents in these systems.

Although there was not a significant LM effect on TOC or TON concentrations, values tended to decrease with intensity of management (Table 3). Longleaf surface (0-5 cm) TOC concentration was 4, 69, 116, and 279% higher than pasture, planted pine, conservation, and conventional row crop systems, respectively. Fesha (2004) found surface (0-5 cm) TOC to behave similarly with respect to LM (pasture > planted pine > conservation system > conventional system) for some Alabama Ultisols.

Pasture sites had the highest surface (0-5 cm) TON concentration, which was 2.9, 3.0, 3.7, and 5.4 times greater than conservation, longleaf, planted pine, and conventional row crop sites, respectively (Table 3). Similarly, Worsham et al. (2010) found surface (0-7.5 cm) TON for some southeastern Kandiudults was higher for grazed pasture systems relative to planted pine plantations. Likewise, Fesha et al. (2002) found TON (0-20 cm) was highest for pastureland, lowest for conventional row crop systems, and intermediate for planted pine plantations on some Alabama Ultisols.

Our TOC concentrations were comparable to those found by Sainju et al. (2007) for some Plinthic Kandiudults (0-5 and 5-15 cm) under conservation management in the Georgia Coastal Plain, by Watts et al. (2010) for the surface (0-20cm) of some Alabama Ultisols under conventional row crop management, by Fesha et al. (2002) for pasture surfaces (0-20 cm) of Alabama Ultisols, and for Ultisols under longleaf (0-30 cm) (Levi et al., 2010) and planted pine (0-10 cm) (Echeverria et al., 2004) forests in the Coastal Plain.

Particulate and Mineral Organic Carbon and Nitrogen

The concentration of POMC was significantly affected by LM and depth (Table 3), with most differences occurring at the soil surface (0-5 cm). The surface POMC concentration of longleaf sites was significantly higher than all other systems (6.4 times the conventional row crop management). Denef et al. (2007) also found that POMC decreased for row crop systems (0- 20 cm) relative to native vegetation on highly weathered soils. Concentrations of POMC for conservation and conventional row crop managements did not differ, however pasture sites were significantly higher than both. Causarano et al. (2008) reported similar results for the surface (0-5 cm) on a suite of Ultisols across the Southeast. These researchers found that POMC of conventional < conservation << pasture systems. Similar to TON, POMN concentration was highest for pasture sites with the longleaf, conservation, planted pine, and conventional being 3.2, 4.5, 5.1, and 7.5 times lower, respectively (Table 3).

Conventional row crop management POMC content (20 Mg ha^{-1}) (0-50 cm) was significantly lower than pasture (32 Mg ha^{-1}) and forested (longleaf = 28 Mg ha^{-1}; planted pine = 28 Mg ha^{-1}) land uses, but not the conservation system (27 Mg ha^{-1}) (Figure 1-3). Similarly, Franzluebbers and Stuedemann (2008a) reported POMC content (0-30 cm) in Ultisols did not differ between conservation and conventional row crop systems. Another study in the southeastern Coastal Plain found POMC was less for disturbed sites relative to forested sites (Maloney et al., 2007). Pasture POMN content (2696 kg ha^{-1}) (0-50 cm) was higher than all other LMs (Figure 1-3), while no other differences among LMs were found (conservation, conventional, longleaf, and planted pine = 1278, 1359, 1575, and 1755 kg ha^{-1}, respectively). Cambardella and Elliott (2002) also reported POMN contents (0-20 cm) were highest for grassland ecosystems in Nebraska.

The concentrations of MC and MN of forested and conventional systems were lower than those reported by Levi et al. (2010) for other Coastal Plain Kandiudults. There were significant LM by depth interactions for both MC (P=0.0018) and MN (P=0.0009) (Table 3). Surface (0-5 cm) MC concentration of pasture sites was higher than all sites, conventional row crop sites were lower than all others, while no differences were observed among forested and conservation row crop sites. Similarly, Stewart et al. (2008) found MC (0-5 cm) were highest for grassland and lowest for conventional row crop systems. In our study, surface (0-5 cm) MN for pastures was higher than all other systems. Likewise, Levi (2007) reported no differences in MN (0-5 cm) among longleaf, planted pine, and row crop systems in the Georgia Coastal Plain.

Active Carbon

We found AC content (0-50 cm) was affected by LM; pasture (2379 kg ha^{-1}) had significantly higher AC than conventional row crop management (1393 kg ha^{-1}) (Figure 1-4). DuPont et al. (2010) found AC (0-40 cm) was lower for row crop systems relative to perennial grassland in Kansas. Surface (0-5 cm) AC concentrations tended to decrease with management intensity. Conventional AC was 22, 26, and 142 % lower than planted pine, conservation, and pasture sites, respectively (Table 3). Similar to our findings, Stine and Weil (2002) reported AC (0-7.5 cm) differed between conservation and conventional row crop systems. The differences in AC between systems is likely due to the amount and type of C inputs to the system, differences in microbial communities, and differences in soil disturbance affecting rates of organic matter oxidation.

Carbon to Nitrogen Ratios

Soil C:N ratios were similar to previous studies with similar land uses and soils [conservation row crop systems, Sainju et al. (2007); longleaf forests Craft and Chiang, (2002); planted pine, Will et al. (2006); and conventional row crop systems (Levi, 2007)]. A two-way interaction between LM and depth (P<.0001) for whole soil C:Ns was observed (Table 4), and ratios tended to narrow with increasing intensity of management. Forested sites (0-50 cm) had the same C:N ratio, and were significantly higher than conservation row crop, conventional row crop, and pasture sites. Forests tend to have wider C:N ratios due to greater lignin quantities in litter additions (Post and Mann, 1990). A probable explanation of pasture sites having more narrow C:N relative to row crop systems is the recycling of nutrients (cattle manure) and relative lack of biomass exports.

Stratification Ratios of Carbon and Nitrogen Pools

Soil disturbance can alter depth distribution of soil properties. The degree of C pool stratification with depth is an indicator of soil quality (Franzluebbers, 2002) and allows for comparisons across ecosystems (Sá and Lal, 2009). Stratification ratios (SRs) (0-5:30-50 cm) were calculated for TOC and TON, POMC and POMN, MC and MN, and AC (Figure 1-5).

The stratification of TOC decreased with intensity of management (i.e., as soil disturbance decreased, TOC was greater in the surface relative to the subsurface). Longleaf sites were more stratified than all other LMs. Conventional row crop SRs were lower than longleaf and pasture sites, but not lower than conservation row crop or planted pine. Pasture sites were the most stratified (7.4) with respect to TON, followed by conservation row crop (5.8), longleaf (2.9), planted pine (2.7), and conventional row crop (2.0) sites (Figure 1-5). Levi et al. (2010) also found longleaf TON SRs (0-5:15-30 cm) were higher than both planted pine and row crop systems for similar Coastal Plain soils. Franzluebbers and Stuedemann (2008a) found that Typic Kanhapludults in Georgia under conventional systems had TOC SRs (0-3:6-12 cm values) significantly lower than conservation systems. Gál et al. (2007) found both TOC and TON SRs (0-5:30-50 cm) were lower for conventional systems relative to conservation systems in Indiana.

Similar to previous research (Franzluebbers, 2002; Álvaro-Fuentes et al., 2008), POM fractions had much higher SRs relative to other fractions. Stratification of POMC exhibited the same differences among sites as TOC, while the pasture POMN SR was significantly higher than all other sites (Figure 1-5). Levi (2007) also reported there was no difference in POMN SRs (0-5:15-30 cm) between longleaf and row crop systems. Sá and Lal (2009) found that the POMC SR (0-5:20-40 cm) for row crop systems was lower than an adjacent native field.

The AC SR for the conservation row crop system (7.8) was higher than all other sampled sites (conventional (4.5), planted pine (4.0), and pasture (3.3)) (Figure 1-5). This could be explained by greater additions of less lignified C to the surface and lack of incorporation or loss through prescribed fire. The results observed across C pool SRs (decrease with increased disturbance) was expected in these soils (sandy surfaces and clayey subsurfaces) and climate (warm, humid), because increased soil disturbance affects surface microbial activity.

Cation Exchange Capacity

There was no significant LM main effect on CEC. As expected, CEC was affected by depth in these soils (Table 5); as depth increased, CEC generally decreased likely due to a decrease in organic matter. Due to the importance of surface depths for ecosystem function, CEC at the 0-5 cm depth was further investigated (Figure 1-6). Surface CEC of conventional row crop sites (3.05 cmol$_c$ kg soil^{-1}) was lower than pasture (7.11 cmol$_c$ kg soil^{-1}) and longleaf (6.67cmol$_c$ kg soil^{-1}) land uses. The conservation row crop surface (0-5 cm) CEC was 1.6 times that of the conventional management.

Similar to CEC, ECEC was affected by depth but not land use or management. Pasture sites had the highest surface (0-5 cm) ECEC, and was 1.1, 1.6, 2.1, and 2.3 times greater than conservation row crop, conventional row crop, longleaf, and planted pine LMs, respectively (Table 5 and Figure 1-6). Similarly, McGrath et al. (2001) found ECEC (0-20 cm) to be highest for pastures, intermediate for conventional row crop systems, and lowest for tree plantations on some Ultisols. In our study, forested sites were lower than both pasture and conservation row crop systems.

Surface ECEC values of both row crop managements in this study were higher than their associated CEC. Because ECEC essentially measures CEC at field pH, southeastern highly weathered, acidic soils (dominated by variable charge) typically have higher CEC relative to ECEC. Surface (0-5 cm) pHs ≥ 6.0, base saturations of 100%, and the fact that lime and gypsum amendments are common in these agronomic settings likely caused the observed ECEC>CEC.

Exchangeable Bases

Calcium content (0-50 cm) was lowest for longleaf soils and highest for row crop systems (Figure 1-7). High Ca quantities in the surface of the row crop systems (3.84 cmol_c kg soil^{-1} and 2.76 cmol_c kg soil^{-1} for conservation and conventional row crop systems, respectively) are likely a product of amendments (e.g., lime and gypsum). Longleaf Ca (220 kg ha^{-1}) was significantly lower than all other systems. Row crop systems (conservation = 3254 kg ha^{-1} and conventional = 3174 kg ha^{-1}) were also significantly higher than the planted pine land use (1660 kg ha^{-1}). Balkcom et al. (2005) also reported that Ca was not significantly different between conservation and conventional row crop systems in an Alabama Paleudult.

Concentrations of Mg exhibited no significant differences, however, pastures had 1.8, 2.4, 3.8, and 7.3 times higher surface (0-5 cm) concentrations than conservation, conventional, planted pine, and longleaf LMs, respectively (Table 5). Total Mg quantities (0-50 cm) were lowest for longleaf sites (50 kg ha^{-1}) relative to pasture (472 kg ha^{-1}) and row crop sites (conservation = 556 kg ha^{-1} and conventional = 532 kg ha^{-1}) (Figure 1-7). Comparably, Levi (2007) found Mg contents (0-30 cm) were lowest for longleaf, intermediate for planted pine, and highest for row crop systems, with no difference between planted pine and row crop systems for Coastal Plain Ultisols in Georgia.

Potassium contents (0-50 cm) of forested sites (longleaf = 64 kg ha^{-1} and planted pine = 163 kg ha^{-1}) were lower than that of pastures (1111 kg ha^{-1}) (Figure 1-7). Fesha (2004) reported planted pine K was significantly lower than pastures, but no significant differences were observed among conservation row crop, conventional row crop, and pasture sites (0-20 cm) in Alabama Ultisols. Conversely, Franzluebbers and Hons (1996) found conservation systems had significantly higher K contents (0-30 cm) than conventional systems.

Aluminum saturation (AS) percentage is calculated by the KCl extractable Al divided by ECEC, and is an indicator of Al toxicity (Table 5). Aluminum toxicity may occur in kaolinitic soils with pH's up to 5.5 (Soil Survey Investigation Staff, 1995). Longleaf sites had extremely high AS values ranging from 59% at the surface (0-5 cm), to 83% at 15-30 cm, while planted pine sites ranged from 11% (15-30 cm) to 21% at 30-50 cm. The acidic conditions for the forested sites are likely preventing Al to precipitate from solution, and remain in exchangeable form.

Mehlich I Extractable Nutrients

Significant differences in phosphorus (P) concentrations did not exist among LMs; however, P concentrations of forested sites were much lower than other LMs (Table 6). Pasture surface (0-5 cm) P concentrations were 1.4, 2.5, 11, and 50 times larger than conservation row crop, conventional row crop, planted pine, and longleaf sites, respectively. The same trend was observed with P contents at 0-50 cm (Figure 1-8). Forest site P quantities (longleaf = 5 kg ha^{-1} and planted pine = 29 kg ha^{-1}) were significantly lower than pasture sites (342 kg ha^{-1}).

Extractable iron (Fe) was affected by depth (P=.0020) and LM (P=.0417) (Table 6). Average Fe concentration of longleaf was 2.7, 2.8, 3.8, and 3.9 times higher than the pasture, conservation row crop, planted pine, and conventional row crop sites, respectively. Similarly, Li et al. (2010) found that for the surface (0-7.5 cm) of Typic Kanhapludults, there were greater masses and concentrations of Fe in pine forests relative to cultivated systems. The contents (0-50 cm, kg ha^{-1}) of boron (B), copper (Cu), manganese (Mn), and zinc (Zn) all had significant LM differences (Figure 1-7). As examples, similar land use differences have been reported: 1) Franzluebbers and Hons (1996) found conventional row crop Cu contents (0-30 cm) to be lower than conservation systems, 2) Levi (2007) reported Mn concentrations to be lower in longleaf relative to row crop systems, and 3) Fesha (2004) found B concentrations to be lower in pasture systems relative to row crop systems.

Bulk Density

Bulk density (ρ_b) was affected by LM (P<.0001) and depth (P<.0001) (Table 7). Conservation row crop and longleaf LMs had the highest and lowest average (0-50 cm)

ρ_b values (1.62 and 1.34 Mg m^{-3}, respectively). Conventional row crop had the second highest ρ_b values (1.60 Mg m^{-3}) followed by pasture (1.51 Mg m^{-3}) and planted pine (1.48 Mg m^{-3}) LMs. Lisboa et al. (2009) found similar pasture ρ_b values (0-20 cm) for Kandiudults in Brazil, which were higher than adjacent native forestland. All ρ_b values increased with depth from 0-30 cm, but conventional row crop, pasture, and planted pine LM began to decline at the deepest depth sampled (Table 7).

Siri-Prieto et al. (2007) observed similar ρ_b values on similar soils for both conservation and conventional row crop managements. Literature indicates that surface ρ_b tends to increase with the implementation of conservation tillage (Radcliffe et al., 1988; Hubbard et al., 1994; Wander and Bollero, 1999; Truman et al., 2005). In this study, values averaged across 0-50 cm indicate that ρ_b increases with intensity of management. Higher ρ_b values are likely a product of animal and equipment trafficking, and decreases in soil organic matter.

Water Dispersible Clay

Water dispersible clay tended to increase with depth and intensity of management. Water dispersible clay ranged from 1.6% (conservation 0-5 cm) to 10.6% (conventional 15-30 cm) (Table 7). Averages (0-50 cm) ranged from 3.2% (longleaf) to 7.9% (conventional row crop). Igwe (2005) observed similar values and trends for three land uses (pasture, cultivated row crop, and forest) for 0-20 cm of some Ultisols. The author reported that cultivated land (6% WDC) had similar values as pastureland (6%), but was higher than forested land (4%).

There were no significant differences among LMs with respect to CDRs, however, pastures had an average (0-50 cm) CDR 6, 15, 30, and 43% higher than longleaf, planted pine, conventional, and conservation LMs, respectively (Table 7). Our CDRs were similar to those reported by Igwe (2005) for pastured and cultivated LMs, but dissimilar with longleaf site ratios reported by Levi (2007). Opara (2009) found that the CDR was highly correlated (-0.803) with organic matter for Kandiudults under five LMs. Differences in LM affecting soil C likely resulted in the observed differences in WDC and CDRs in this study.

Water Stable Aggregates

Water stable aggregates were affected by LM (*P*=.0095) and depth (*P*<.0001). Aggregate stability increased with depth for all sites. At the surface (0-5 cm), WSA in conventional row crops systems were significantly lower than all other LMs (Table 7), while pastures (0-5 cm) had significantly higher WSAs than all other LMs (except conservation row crop). Conventional row crop system values at both depths were similar to those reported by Levi et al. (2010), however, data for forested sites in this study were lower than theirs.

Soil Strength

There was a general trend of soil strength to increase to the 20-cm depth (30 cm for conservation row crops), and decrease thereafter (Figure 1-9). The conservation site had the highest soil strength (averaged over 0-50 cm, 4259 kPa), which was 1.3, 1.8, 1.9, and 2.1 times higher than the maximum values of pasture (3194 kPa), planted pine (2398 kPa), conventional (2238 kPa), and longleaf (2043 kPa) sites, respectively. We observed significant differences among LMs up to 30 cm. At 10 cm, soil strength was significantly higher within pastures relative to all other LMs. At 20 cm, pastures were only significantly higher than longleaf sites. The conservation site was significantly higher than all other LMs at 30 cm. No significant differences were found from 30 to 50 cm.

Research on Dothan soils has indicated higher soil strength for conservation systems relative to conventional systems, particularly at the surface (Siri-Prieto et al., 2007; Simoes et al., 2009). The longleaf sites had the lowest soil strength from 0-20 cm, while conventional row crop management was the lowest from 20-50 cm. Levi et al. (2010) found row crop land had lower soil strength from 0-10 cm relative to longleaf and planted pine sites, but longleaf was lowest from 10-50 cm. The high soil strength from 0-20 cm for the pasture land use is likely attributed to compaction induced by grazing cattle. The zone of high soil strength centered at 30 cm in the conservation row crop management may be a residual plow pan or a product of pore filling at the argillic/topsoil interface (Simoes et al., 2009).

Management-Dependent versus Use-invariant Soil Properties

The characterization of soil variability can enhance land and natural resource management through improvement of soil inventories and subsequent interpretations and evaluations. In an effort to characterize the variability of the selected benchmark, prime farmland soil map unit, both use-invariant and management-dependent soil properties were investigated (discussed in detail above). Use-invariant (11 total) and management-dependent (27 total) soil properties were placed into groups based on the nature of the property (Table 8). Use-invariant properties were categorized into three groups (physical, mineralogical, and morphological), while management-dependent properties were classed into five groups (physical, chemical, nutrient, hydraulic, and conductivity).

The CV for individual properties was calculated. Thirteen sites (n=13) were used to calculate CVs with the exception of gravimetric water content, AWHC, and AC (these properties not measured in longleaf sites, therefore n=10). Statistics (range, mean, and median) were calculated on CVs within a group to allow for comparisons (Table 8). Figures 1-10 through 1-14 are graphical representations of selected properties averaged by depth across all sites.

Use-invariant Variability

The physical use-invariant group consisted of sand, silt, and clay contents. This group expressed the least variability of both use-invariant and management-dependent groups, with a mean CV of 14% (Table 8). The CV values of this group were lower than those reported by Hillel (1980), and more similar to the range prescribed by Wilding and Drees (1983) for some soil map units. With depth (0-180 cm), variability (as indicated by standard error bars) increased for sand and clay content, but remained relatively constant for silt (Figure 1-10).

The use-invariant properties CEC and ECEC (expressed on a clay basis), and percent gibbsite, kaolinite and iron oxides were grouped together in the mineralogical use-invariant group. This group had the third lowest mean CV (22%) of all groups (Table 8). Percent gibbsite (CV = 38%) was the most variable parameter within the group, while percent kaolinite exhibited little variability (CV = 11%). Variability of both CEC and ECEC (clay basis) decreased with depth (0-180 cm), obtaining relatively static levels at 60 cm (Figure 1-10). The fact that CEC and ECEC (clay basis) remained relatively static with depth, although clay content variability increased, may be attributed to the low activity mineralogy (i.e., kaolinite) of these soils.

Morphological properties were the most variable of the use-invariant groups, and included depth to the argillic/kandic horizon, ≥5% plinthite, and redox depletions of chroma ≤3. This group had a mean CV of 24%, with the lowest and highest values being 21% (chroma ≤3) and 27% (argillic/kandic). This group of properties was the fifth most variable of the eight investigated (Table 8).

Management-dependent Variability

The physical management-dependent group (SS, ρ_b, WDC, CDR, and WSA at 0-5 and 5-15 cm) was the least variable of the management-dependent groups, and second least variable overall (Table 8). The group had a mean CV of 20%, with a low of 7% (ρ_b and WSA at 5-15 cm) and a high of 43% (WDC). Soil strength, ρ_b, and WSA (0-50 cm) tended to decrease in variability with depth, while WDC and CDR appeared to vary more with depth (0-50 cm) (Figure 1-11). Increased variability of WDC and CDR with depth is possibly a product of varying expressions of eluvial horizons among sites (Tables 18-30 and Field Descriptions 1-13 in Appendix).

Chemical management-dependent properties included TOC, TON, POMC, POMN, AC, and CEC and ECEC (Table 8). The group had a mean CV of 41%. The least variable property of the group was CEC (CV = 25%) while POMN exhibited the highest variability (CV = 64%). The C pools were less variable than N pools (Table 8). The three C pools investigated (TOC, POMC, and AC) decreased in variability with depth (0-50 cm), and became relatively static just below the soil surface (5-15 cm) (Figure 1-12). The N pools (TON and POMN) exhibited greater variability at the surface and became relatively static at 15-30 cm (Figure 1-12). Both CEC and ECEC (expressed on a soil basis) decreased in variability with depth (Figure 1-13). Because the majority of C and N inputs occur at the soil surface, coupled with the influence C has on exchange capacities (discussed above), reduced variability with soil depth is not unexpected.

Mehlich 1 extractable P and Fe and NH_4AOc extractable Ca, Mg, and K contents (0-50 cm) were grouped into the nutrient management-dependent property group (Table 8). This group had the widest range of CVs (Fe CV = 63% to P CV =189%), with a mean of 109%. Mehlich 1 P was the most variable parameter investigated in this study. Similarly, Wilding and Drees (1983) reported that exchangeable nutrients tended to have CVs > 35%. The nutrients P, Fe, Ca, and Mg tended to decrease in variability with depth, while K increased in variability from 0-50 cm (Figure 1-14).

Three properties (Θ_g at 10kPa and 1.5MPa and AWHC) at two depths (0-6 and 6-21 cm) were grouped together to form the hydraulic management-dependent property group (Table 8). The AWHC at 15 - 21 cm was the least variable parameter (CV = 17%), while $\Theta_{g\ 1.5MPa}$ (0-6 cm) expressed the most variability (CV = 74%) in this group, which had an overall mean CV of 37%. All parameters tended to express less variability with depth.

The conductivity management-dependent group had the second largest range of CVs. The K_{sat} at 50 cm was the least variable (CV = 71%), while the K_{sat} at 15 cm (CV = 124%) and 30 cm (CV = 164%) were the most, and the second most variable parameter of all investigated soil properties. Hillel (1980) reported three studies that found CVs of K_{sat} to be >100%, which agreed with our data.

Taking all property groupings into consideration, management-dependent variability is greater than the inherent property variability within this soil map unit for these land use systems. The majority of the management-dependent properties became less variable with depth (to 50 cm). Because most of the investigated management-dependent properties differed with respect to LM, it is likely that LM is the driving factor inducing this variation.

Soil Property Relationships

Relationships among near-surface soil properties were investigated using Pearson linear correlation coefficients. Because of their relative importance to soil quality and ecosystem function, our discussion will concentrate on C pools and their relationship with other properties.

For all depths, TOC (g kg^{-1}) was correlated to CEC (0.89) and ECEC (0.61) (Table 9). Exchange capacities are positively correlated to C pools because of SOM's role in charge development (Sikora and Stott, 1996). Because these surface soils contain relatively small amounts of low activity clay, the majority of exchange sites are within soil organic matter. Under this assumption, the exchange capacities relative to TOC were calculated: every addition of 1.0 g of TOC increased CEC and ECEC 0.48 and 0.36 $cmol_c$ [4.8 and 3.6 meq (+)], respectively. The Soil Survey Staff (1995) report a similar relationship for CEC [1g TOC ≈ 3-4 meq (+)]. The strong influence of C on the soil exchange capacity has major implications with respect to soil nutrient dynamics.

Significant correlations among TOC and WDC (-0.33), ρ_b (-0.69), clay (-0.40) and SS (-0.33) were also observed (Table 9).The POMC pool had similar correlations with respect to CEC (0.84), ECEC (0.50), WDC (-0.33), ρ_b (-0.75), clay (-0.36) and SS (-0.40). The AC pool was also correlated to the physical properties WDC (-0.40) and ρ_b (-0.62). Negative relationships of C pools with WDC, ρ_b, and SS indicate that as the amount of C increases in the soil, compaction (indicated by ρ_b and SS) and erodibility (indicated by WDC) decrease. Compaction and erosion have large effects on soil infiltration, water storage, microbial activity and mechanical impedance, all extremely critical soil functions of the region.

Soil C Sequestration

The TOC of the conventional row crop sites (38 Mg ha^{-1}) was only significantly lower than the pastures (57 Mg ha^{-1}) (Figure1-2). Similarly, Causarano et al. (2008) reported TOC (0-20 cm) was highest for pasture and lowest for conventional row crop systems for some southeastern Ultisols. Greater amounts of C were sequestered by pasture sites relative to conventional sites due to greater C inputs (greater root densities of pastures) and lack of annual soil disturbances (tillage) and C exports (crop biomass).

Franzluebbers and Stuedemann (2008c) reported that pasture systems in the southeastern U.S. Piedmont contained 60 Mg C ha^{-1} (0-60 cm), comparable to our 57 Mg C ha^{-1} (0-50 cm) in the Coastal Plain. Reeder and Schuman (2002) reported higher values (90 Mg C ha^{-1}) for grasslands from 0-60 cm in the Great Plains region of the United States. Greater amounts of C (48.5 Mg ha^{-1}) were found for some Mollisols (0-15 cm) under mixed warm and cool season grass management in South Dakota (Riedell et al., 2010). For some Typic Paleudults in Indonesia, Yonekura et al. (2010) reported that grasslands sequestered 48.8 Mg C ha^{-1} from 0-50 cm.

Chen et al. (2010) estimated forests in Canada had a C stock of 190.4 Mg C ha^{-1} and Follett et al. (2009) found soils under native forests in the Midwest contained 180 Mg C ha^{-1} (0-60 cm), which were much greater than the C stocks of soils under native vegetation investigated here (longleaf forest; 49 Mg C ha^{-1}). Maia et al. (2010) reported native forests to have a C content of 54.9 Mg C ha^{-1} for Brazilian Oxisols (0-30 cm).

Large differences in C sequestration of these native forests are likely a function of differing species and/or climates. Yonekura et al. (2010) reported primary forests on Typic Paleudults (0-50 cm) in Indonesia contained 39.1 Mg C ha^{-1}. Our planted pine C content (50 Mg C ha^{-1}) was the same to that estimated by Johnsen et al. (2001) (50 Mg C ha^{-1}) for southeastern soils under loblolly pine plantations managed for 20 year rotations.

Follett et al. (2009) reported higher C contents (0-60 cm) for row crop systems (conservation = 72 Mg C ha^{-1} and conventional = 75 Mg C ha^{-1}) of Midwestern soils relative to our values of 51 and 38 Mg C ha^{-1} for conservation and conventional row crop systems, respectively. Unger (2009) reported similar values to ours for a shallower depth (0-30 cm) of cropland systems (37 Mg C ha^{-1}) in the Great Plains. Maia et al. (2010) reported that cropland under Oxisols sequestered 46 Mg C ha^{-1} from 0-30 cm in Brazil. Chaplot et al. (2010) reported C content (0-30 cm) ranged from 50 to 190 Mg C ha^{-1} for soils under continuous cultivation in Laos. The authors attributed the high C storage to high clay contents in the investigated soils.

Differences in surface soil textures (clayey versus sandy), climates (warm, wet versus cool, dry), and plant species (dominant tree species and grasses) are likely the dominant factors causing the observed differences in C sequestration with our values and those worldwide for similar LMs.

Conclusions

When viewed in aggregate, the variability of investigated management-dependent properties was greater than the variability of use-invariant soil properties for this soil map unit. Soil texture expressed little variability; mineralogy and morphology (use-invariant) and physical management-dependent properties were moderately variable; and chemical, nutrient, and hydraulic management-dependent properties and saturated hydraulic conductivity were highly variable. Although texture had the lowest coefficient of variations, both sand and clay contents increased in variability with depth (to 180 cm). Soil carbon pools, exchange capacities, and bulk densities tended to reach relatively static expressions below surface horizons. Similarly, with the exception of saturated hydraulic conductivity, soil hydraulic properties were less variable with depth.

Significant anthropogenic influences were observed on near-surface soil properties. Amounts and ratios of carbon and nitrogen tended to decrease with increased soil disturbance. More intense management tended to homogenize carbon and nitrogen concentrations (0-50 cm) as reflected by stratification ratios. Differences in surface (0-5cm) exchange capacities were observed with respect to land use/management. Nutrient quantities and bulk densities tended to increase with intensity of management. Significant differences in aggregate stability were observed across land use, and tended to decrease with decreases in carbon content. Soil carbon exhibited strong relations with surface soil exchange properties, compaction (indicated by bulk density and soil strength), and erodibility (indicated by water dispersible clay). Because soil quality assessment is based on desired function, row crop systems had acceptable soil quality with respect to nutrient contents and base saturation. However, based on carbon contents, stratification of carbon and nitrogen pools, surface exchange capacities, and aggregate stability, longleaf and pasture systems had superior soil quality.

Differences in soil carbon sequestration were observed among these systems. The carbon content (0-50 cm) of the conventional row crop sites (38 Mg ha^{-1}) was significantly lower than the pastures (57 Mg ha^{-1}). The carbon sequestered by the other systems was 51 Mg C ha^{-1} for the conservation row crop system, 50 Mg C ha^{-1} for the managed pine plantation, and 49 Mg C ha^{-1} for the native longleaf pine forest. The overall C sequestration potential for these soils lies intermediate to more temperate and tropical regions of the world.

The National Cooperative Soil Survey is emphasizing the characterization of management-dependent properties in the survey program. Our results indicate that the magnitude of variability of these properties slightly exceeds variability found inherently within this representative soil map unit. Because many of these properties are correlated, it is likely that a subset of properties to be measured can be developed to help characterize management-dependent variability. Considering the importance of management-dependent properties to ecosystem function and map unit interpretations, assessment and inventory of these properties for addition to existing soil databases is logical. Furthermore, developing soil interpretations within context of prior land use may be more suitable than complete reliance on use-invariant properties.

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Table 1. Pedon and site identification, long-term land use/management (LM), classification and coordinates of investigated soils in the Wiregrass region of the Alabama Coastal Plain.

Pedon ID	Site ID	LM†	Taxonomic Classification‡	Latitude	Longitude
S2009AL-067-2	CRC	Conservation	Fine-loamy, kaolinitic, thermic Plinthic Kandiudult	31°22'44.2"N	85°18'47.8"W
S2009AL-061-4	RC1	Conventional	Fine-loamy, kaolinitic, thermic Plinthic Kandiudult	31°4'25.9"N	85°39'32.6"W
S2009AL-067-4	RC2	Conventional	Fine-loamy, kaolinitic, thermic Plinthic Kandiudult	31°25'54.6"N	85°21'28.9"W
S2009AL-067-5	RC3	Conventional	Fine-loamy, kaolinitic, thermic Plinthic Kandiudult	31°24'26.7"N	85°20'30.4"W
S2010AL-039-1	LL1	Longleaf	Fine-loamy, kaolinitic, thermic Plinthic Kandiudult	31°6'6"N	86°33'41"W
S2010AL-039-2	LL2	Longleaf	Fine-loamy, kaolinitic, thermic Plinthic Kandiudult	31°9'59"N	86°35'5"W
S2010AL-039-4	LL3	Longleaf	Fine-loamy, kaolinitic, thermic Plinthic Kandiudult	31°6'60"N	86°33'22"W
S2009AL-061-3	P1	Pasture	Fine-loamy, kaolinitic, thermic Plinthic Kandiudult	31°7'21.6"N	85°40'9.2"W
S2009AL-061-1	P2	Pasture	Fine-loamy, kaolinitic, thermic Plinthic Kandiudult	31°4'18.6"N	85°40'45.8"W
S2009AL-067-3	P3	Pasture	Fine-loamy, kaolinitic, thermic Plinthic Kandiudalf§	31°21'1.7"N	85°19'17.1"W
S2009AL-067-1	PP1	Planted Pine	Fine-loamy, kaolinitic, thermic Plinthic Kandiudult	31°19'4.6"N	85°24'32"W
S2009AL-069-1	PP2	Planted Pine	Fine-loamy, kaolinitic, thermic Plinthic Kandiudult	31°8'49.5"N	85°12'41.7"W
S2009AL-061-2	PP3	Planted Pine	Fine-loamy, kaolinitic, thermic Plinthic Kandiudult	31°4'18.6"N	85°41'22.4"W

† Conservation = conservation row crop system; Conventional = conventional row crop system; Longleaf = longleaf pine/wiregrass forest; Pasture = grazed pasture system; Planted pine = managed pine plantation.

‡ As per Soil Taxonomy (Soil Survey Staff, 2010).

§ Verified cultural Alfisol.

Table 2. Selected use-invariant soil properties for Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils within five long-term land use/managements (LM) of the Wiregrass region of the Alabama Coastal Plain.

Pedon	Site ID	Control Section (upper 50 cm of argillic/kandic horizon)									Depth to		
		Sand†	Silt	Clay	Gibbsite	Kaolinite	Fe_2O_3	Al	CEC	ECEC	A/K	Plinthite	C≤ 3
		%							$cmol_c$ kg clay^{-1}		cm		
S2009AL-067-2	CRC	67	11	22	11	46	3	0.7	16	10	31	72	150
S2009AL-061-4	RC1	64	11	26	13	50	5	1.0	12	8	24	52	118
S2009AL-067-4	RC2	54	12	34	15	50	5	1.0	13	7	24	48	112
S2009AL-067-5	RC3	66	12	22	18	39	3	0.6	15	12	20	54	85
S2010AL-039-1	LL1	67	15	19	26	37	5	1.1	16	6	26	50	163
S2010AL-039-2	LL2	60	17	21	10	49	3	0.6	11	10	44	84	168
S2010AL-039-4	LL3	65	15	20	17	40	3	0.8	13	7	35	56	128
S2009AL-061-3	P1	64	10	25	18	46	5	1.0	11	7	26	26	96
S2009AL-061-1	P2	64	10	26	20	47	5	1.1	13	8	20	58	152
S2009AL-067-3	P3	63	13	23	19	47	4	0.9	14	11	37	61	100
S2009AL-067-1	PP1	63	12	25	6	54	5	1.0	11	8	24	59	101
S2009AL-069-1	PP2	72	10	18	8	54	2	0.5	17	11	26	33	130
S2009AL-061-2	PP3	61	11	28	11	50	4	0.9	14	8	28	52	128

† Sand, Silt, and Clay = average particle size separates (0.05-2.0, 0.002-0.05, <0.002 mm, respectively) of control section; Gibbsite and Kaolinite = clay fraction (<0.002 mm) gibbsite and kaolinite quantities in upper control section (first 'Bt' horizon); Fe_2O_3 = dithionite-citrate-bicarbonate extractable iron oxide quantities in upper control section (first 'Bt' horizon); Al = dithionite-citrate-bicarbonate extractable aluminum in upper control section (first 'Bt' horizon); CEC and ECEC = average cation exchange capacity and effective cation exchange capacity (NH4OAc, pH 7) per kg clay of control section; A/K = depth from soil surface to argillic/kandic diagnostic subsurface horizon; Plinthite = depth from soil surface to occurrence of ≥ 5% nodular plinthite; C ≤ 3 = depth from soil surface to occurrence of iron depletions with chroma ≤ 3.

Table 3. Carbon and nitrogen pool concentrations averaged by depth for three repetitions (one conservation row crop system) of Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils within five long-term land use/managements (LM) of the Wiregrass region of the Alabama Coastal Plain.

LM†	Depth	TOC‡	TON	POMC	POMN	MC	MN	AC
	cm	------------------	------------------	--------g kg soil^{-1}--------	------------------	------------------	------------------	mg kg soil^{-1}
Conservation	0 - 5	12.05 cb§	0.89 b	6.36 de	0.46 b	36.24 bc	2.73 b	584 a
	5 - 15	10.08 A	0.57 A	5.93 A	0.23 A	28.48 AB	2.09 AB	315 A
	15 - 30	6.73	0.40	2.74	0.11	22.51	1.53	220
	30 - 50	3.20	0.15	2.07	0.10	7.14	0.67	75
Conventional	0 - 5	6.87 c	0.49 b	3.70 e	0.28 b	22.54 c	1.47 b	305 b
	5 - 15	6.76 A	0.37 A	3.61 A	0.16 A	22.04 B	1.37 B	273 A
	15 - 30	5.00	0.30	2.30	0.14	14.46	0.88	192
	30 - 50	2.95	0.26	1.75	0.17	5.17	0.43	71
Longleaf	0 - 5	26.05 a	0.88 b	23.63 a	0.66 b	35.48 b	1.74 b	-
	5 - 15	10.27 A	0.47 A	6.67 A	0.23 A	23.38 AB	1.31 B	-
	15 - 30	4.07	0.30	2.10	0.16	10.21	0.74	-
	30 - 50	2.67	0.32	1.52	0.22	5.44	0.55	-
Pasture	0 - 5	25.09 a	2.63 a	18.58 b	2.09 a	55.87 a	5.27 a	739 a
	5 - 15	10.19 A	0.86 A	4.96 A	0.40 A	33.00 A	2.86 A	412 A
	15 - 30	5.84	0.44	2.67	0.20	17.04	1.44	261
	30 - 50	4.12	0.33	2.29	0.12	8.10	0.89	223
Planted pine	0 - 5	15.37 b	0.71 b	10.48 c	0.41 b	40.88 b	2.23 b	604 a
	5 - 15	9.23 A	0.61 A	5.07 A	0.41 A	29.00 AB	1.54 B	341 A
	15 - 30	5.71	0.31	3.18	0.15	15.22	0.89	204
	30 - 50	3.63	0.31	2.28	0.17	6.93	0.67	161
ANOVA		------------------	------------------	------------------	P > F	------------------	------------------	------------------
Land use/management (LM)		0.0747	0.2289	0.0204	0.3009	0.1118	0.0549	0.0843
Depth (D)		0.0018	0.0191	0.0025	0.0502	0.0004	0.0008	<.0001
LM*D		0.0003	0.0229	0.0001	0.0377	0.0018	0.0009	0.0019

† Conservation = conservation row crop system; Conventional = conventional row crop system; Longleaf = longleaf pine/wiregrass forest; Pasture = grazed pasture system; Planted pine = managed pine plantation.

‡ TOC and TON = total soil organic carbon and nitrogen; POMC and POMN = particulate organic matter (>53 µm) associated carbon and nitrogen; MC and MN = mineral (<53 µm) associated carbon and nitrogen; AC = active carbon.

§ Simple effect comparisons of LM LS-means by 0-5 cm (lowercase) and 5-15 cm (uppercase) depths; numbers with the same letter are not significantly different at the 0.05 confidence level.

Table 4. Carbon to nitrogen ratios (C:N) averaged by depth for three repetitions (one conservation row crop system) of Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils within five long-term land use/managements (LM) of the Wiregrass region of the Alabama Coastal Plain.

LM†	Depth	$C:N_{total}$‡	$C:N_{part}$	$C:N_{min}$
	cm			
Conservation	0 - 5	14	14	13
	5 - 15	18	26	14
	15 - 30	17	25	15
	30 - 50	21	21	11
Conventional	0 - 5	15	14	16
	5 - 15	19	27	16
	15 - 30	18	38	16
	30 - 50	13	24	12
Longleaf	0 - 5	29	35	21
	5 - 15	22	30	18
	15 - 30	14	16	14
	30 - 50	8	7	10
Pasture	0 - 5	11	10	11
	5 - 15	14	20	12
	15 - 30	14	15	12
	30 - 50	14	21	9
Planted pine	0 - 5	22	26	18
	5 - 15	17	19	18
	15 - 30	20	29	17
	30 - 50	14	20	10
ANOVA				
Land use/management (LM)		0.4305	0.8959	0.0089
Depth (D)		0.2198	0.6493	0.0002
LM*D		0.0001	0.1737	0.0002

† Conservation = conservation row crop system; Conventional = conventional row crop system; Longleaf = longleaf pine/wiregrass forest; Pasture = grazed pasture system; Planted pine = managed pine plantation.

‡ $C:N_{total}$ = whole soil carbon to nitrogen ratio; $C:N_{part}$ = particulate (>53 μm) fraction carbon to nitrogen ratio; $C:N_{min}$ = mineral (<53 μm) fraction carbon to nitrogen ratio.

Table 5. Select soil chemical properties averaged by depth for three repetitions (one conservation row crop system) of Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils within five long-term land use/managements (LM) in the Wiregrass region of the Alabama Coastal Plain.

LM†	Depth	CEC‡	ECEC	Ca	Mg	K	Al	AS	BS	pH
	cm	cmol$_c$ kg soil^{-1}						%		
Conservation	0 - 5	4.82	5.37	3.84	0.69	0.44	0.00	0b§	100	6.0
	5 - 15	3.50	3.22	2.30	0.59	0.23	0.00	0B	92	5.9
	15 - 30	3.40	3.18	2.23	0.62	0.17	0.00	0	94	5.9
	30 - 50	2.24	2.21	1.36	0.50	0.16	0.00	0	99	5.9
Conventional	0 - 5	3.05	3.63	2.76	0.52	0.28	0.00	0b	100	6.6
	5 - 15	2.84	2.82	2.25	0.35	0.16	0.00	0B	95	6.3
	15 - 30	3.08	2.63	1.98	0.47	0.11	0.01	0	88	6.1
	30 - 50	3.14	2.59	1.63	0.72	0.12	0.04	2	86	6.0
Longleaf	0 - 5	6.67	2.77	0.86	0.17	0.07	1.62	58a	18	4.4
	5 - 15	3.60	1.46	0.15	0.05	0.03	1.19	82A	7	4.8
	15 - 30	1.89	0.95	0.09	0.03	0.02	0.79	83	8	4.9
	30 - 50	2.13	1.22	0.11	0.07	0.02	0.99	81	12	4.9
Pasture	0 - 5	7.11	5.92	3.96	1.24	0.39	0.09	2b	73	5.4
	5 - 15	3.94	3.40	2.10	0.71	0.29	0.12	4B	76	5.5
	15 - 30	2.98	2.40	1.44	0.37	0.30	0.09	4	77	5.4
	30 - 50	2.95	2.58	1.34	0.41	0.49	0.14	5	76	5.4
Planted pine	0 - 5	4.37	2.62	1.63	0.33	0.07	0.33	13a	53	5.1
	5 - 15	2.90	1.92	1.14	0.24	0.06	0.31	16A	57	5.3
	15 - 30	2.53	1.84	1.09	0.31	0.05	0.21	11	62	5.3
	30 - 50	3.04	1.98	1.02	0.39	0.06	0.41	21	50	5.0
ANOVA		$P > F$								
Land use/management (LM)		0.7622	0.4371	0.0783	0.5079	0.2132	0.0002	<.0001	0.0003	0.0002
Depth (D)		0.0004	0.0021	0.0042	0.2700	0.0082	0.2773	0.0182	0.5957	0.7018
LM*D		0.1716	0.7893	0.8164	0.2945	0.1316	0.1682	0.0156	0.5051	0.0583

† Conservation = conservation row crop system; Conventional = conventional row crop system; Longleaf = longleaf pine/wiregrass forest; Pasture = grazed pasture system; Planted pine = managed pine plantation.

‡ CEC = cation exchange capacity, NH_4OAc, pH 7; ECEC = effective cation exchange capacity; Ca, Mg, and K = NH_4OAc extractable calcium, magnesium, and potassium; Al = KCl extractable aluminum; AS = aluminum saturation; BS = base saturation, NH_4OAc, pH 7; pH = pH in 1:1 soil:water (w/v).

§ Simple effect comparisons of LM LS-means by 0-5 cm (lowercase) and 5-15 cm (uppercase) depths; numbers with the same letter are not significantly different at the 0.05 confidence level.

Table 6. Mehlich I extractable nutrient concentrations averaged by depth for three repetitions (one conservation row crop system) of Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils within five long-term land use/managements (LM) in the Wiregrass region of the Alabama Coastal Plain.

LM†	Depth	P‡	B	Cu	Fe	Mn	Zn
	cm	---mg kg^{-1}--					
Conservation	0 - 5	69	2 ab§	2	22 b	25	2
	5 - 15	50	1 AB	5	26 B	14	2
	15 - 30	40	1	4	30	11	2
	30 - 50	15	1	5	14	10	1
Conventional	0 - 5	39	2 a	2	17 b	15	2
	5 - 15	33	2 A	2	16 B	11	2
	15 - 30	20	2	3	19	10	1
	30 - 50	2	2	3	13	6	0
Longleaf	0 - 5	2	1 b	1	101 a	19	1
	5 - 15	1	1 BC	1	82 A	8	0
	15 - 30	1	0	1	44	5	0
	30 - 50	1	0	1	27	2	0
Pasture	0 - 5	99	1 b	2	36 b	20	16
	5 - 15	79	1 BC	3	35 B	11	8
	15 - 30	45	1	1	14	7	3
	30 - 50	21	1	2	10	4	1
Planted pine	0 - 5	9	0 c	2	21 b	17	1
	5 - 15	7	0 C	2	17 B	11	1
	15 - 30	4	0	3	15	8	1
	30 - 50	1	0	3	13	4	1
ANOVA		--- P > F ---					
Land use/management (LM)		0.3068	0.0044	0.0578	0.0020	0.7985	0.4106
Depth (D)		0.0012	<.0001	0.0555	0.0417	<.0001	0.1376
LM*D		0.1963	0.0218	0.5850	0.0043	0.2210	0.1421

† Conservation = conservation row crop system; Conventional = conventional row crop system; Longleaf = longleaf pine/wiregrass forest; Pasture = grazed pasture system; Planted pine = managed pine plantation.

‡ P, B, Cu, Fe, Mn, Zn = Mehlich I extractable phosphorus, boron, copper, iron, manganese, and zinc.

§ Simple effect comparisons of LM LS-means by 0-5 cm (lowercase) and 5-15 cm (uppercase) depths; numbers with the same letter are not significantly different at the 0.05 confidence level.

Table 7. Select soil physical properties averaged by depth for three repetitions (one conservation row crop system) of Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils within five long-term land use/managements (LM) in the Wiregrass region of the Alabama Coastal Plain.

LM†	Depth	ρ_b‡		Sand	Silt	Clay	WDC	CDR	WSA	
	cm	-------Mg m^{-3}-------		--------------------------------%----------------------------------					--------------%---------------	
Conservation	0 - 5	1.41 ab§	1.62 a¶	79	16	5	1.6	32	88 ab	92 a
	5 - 15	1.59 AB		81	15	4	3.8	99	94 A	
	15 - 30	1.63		80	13	7	4.5	66	-	
	30 - 50	1.63		78	13	9	7.5	80	-	
Conventional	0 - 5	1.60 a	1.60 a	82	10	7	5.1	69	79 c	83 c
	5 - 15	1.63 A		83	11	6	5.6	85	85 B	
	15 - 30	1.67		77	12	12	10.6	90	-	
	30 - 50	1.53		65	13	23	7.7	33	-	
Longleaf	0 - 5	0.97 d	1.34 c	75	20	5	2.7	56	87 b	90 b
	5 - 15	1.32 C		75	19	5	3.9	75	92 A	
	15 - 30	1.40		74	18	8	4.4	57	-	
	30 - 50	1.40		68	18	14	2.1	32	-	
Pasture	0 - 5	1.28 bc	1.51 b	80	11	9	2.3	26	94 a	95 a
	5 - 15	1.56 B		80	11	9	5.3	59	96 A	
	15 - 30	1.57		74	11	15	9.7	66	-	
	30 - 50	1.50		68	11	21	6.5	33	-	
Planted pine	0 - 5	1.22 c	1.48 b	82	12	6	3.6	56	88 b	92 b
	5 - 15	1.51 B		81	12	7	3.9	57	94 A	
	15 - 30	1.68		78	13	9	7.7	82	-	
	30 - 50	1.37		69	13	18	3.6	30	-	
ANOVA		--				P > F	---			
Land use/management (LM)		<.0001		0.4313	<.0001	0.0850	0.0726	0.2218	0.0095	
Depth (D)		<.0001		<.0001	0.2811	<.0001	0.0402	0.0086	<.0001	
LM*D		0.0003		0.1083	0.0262	0.4475	0.9212	0.6794	0.0264	

† Conservation = conservation row crop system; Conventional = conventional row crop system; Longleaf = longleaf pine/wiregrass forest; Pasture = grazed pasture system; Planted pine = managed pine plantation.

‡ ρ_b = soil bulk density; Sand, Silt, and Clay = particle size separates (0.05-2.0, 0.002-0.05, <0.002 mm, respectively); WDC = water dispersible clay; CDR = clay dispersion ratio (Clay/WDC); WSA = water stable aggregates.

§ Simple effect comparisons of LM LS-means by 0-5 cm (lowercase) and 5-15 cm (uppercase) depths; numbers with the same letter are not significantly different at the 0.05 confidence level.

¶ Main effect comparisons of LM LS-means; numbers with the same letter are not significantly different at the 0.05 confidence level.

Table 8. Select use-invariant and management-dependent soil properties with coefficient of variation (CV) for thirteen repetitions (ten for active carbon, field capacity, wilting point, and available water holding capacity) of Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils within five long-term land use/managements (LM) in the Wiregrass region of the Alabama Coastal Plain.

Use-invariant				Management-dependent							
Property†	Location‡	CV	Statistics§	Property	Depth	CV	Statistics	Property	Depth	CV	Statistics
		%			cm	%			cm	%	
Physical				Physical				Nutrient			
Sand (%)	CS	6	r(6-18), μ(14), m(17)	SS (kPa)	0 - 50	27	r(7-43), μ(20), m(18)	P (mg kg^{-1})	0 - 50	189	r(63-189), μ(109), m(92)
Silt (%)	CS	17		ρ_b (Mg m^{-3})	0 - 50	7		Fe (mg kg^{-1})	0 - 50	63	
Clay (%)	CS	18		WDC (%)	0 - 50	43		Ca (mg kg^{-1})	0 - 50	64	
Mineralogical				CDR (%)	0 - 50	26		Mg (mgkg^{-1})	0 - 50	92	
CEC ($cmol_c$ kg^{-1})	CS	15	r(11-38), μ(22), m(21)	WSA (%)	0 - 5	9		K (mg kg^{-1})	0 - 50	139	
ECEC($cmol_c$ kg^{-1})	CS	21			5 - 15	7		Hydraulic			
Gibbsite (%)	Upper CS	38		Chemical				$\Theta_{g,\ 10kPa}$	0 - 6	43	r(17-74), μ(37), m(33)
Kaolinite (%)	Upper CS	11		TOC (g kg^{-1})	0 - 50	26	r(25-64), μ(41), m(43)	(kg kg^{-1})	15-21	20	
Fe_2O_3 (%)	Upper CS	25		TON (g kg^{-1})	0 - 50	53		$\Theta_{g,\ 1.5MPa}$	0 - 6	74	
Morphological				POMC (g kg^{-1})	0 - 50	30		(kg kg^{-1})	15-21	33	
Depth to argillic/kandic (cm)		25	r(21-27), μ(24), m(25)	POMN (g kg^{-1})	0 - 50	64		AWHC	0 - 6	32	
Depth to plinthite (cm)		27		AC (mg kg^{-1})	0 - 50	43		(kg kg^{-1})	15-21	17	
Depth to chroma ≤ 3 (cm)		21		CEC($cmol_c$ kg^{-1})	0 - 50	25		Conductivity			
				ECEC($cmol_c$ kg^{-1})	0 - 50	47		K_{sat}	15	124	r(71-164), μ(120), m(124)
								(cm hr^{-1})	30	164	
									50	71	

† Sand, Silt, and Clay = particle size separates (0.05-2.0, 0.002-0.05, <0.002 mm, respectively); CEC = cation exchange capacity (NH_4OAc, pH 7) per kg clay; ECEC = effective cation exchange capacity (NH_4OAc, pH 7) per kg clay; Gibbsite and Kaolinite = clay fraction (<0.002 mm) gibbsite and kaolinite; Fe_2O_3 = dithionite-citrate-bicarbonate extractable iron converted to iron oxide basis; Depth to argillic/kandic = depth from soil surface to argillic/kandic diagnostic subsurface horizon; Depth to plinthite = depth from soil surface to occurrence of ≥ 5% nodular plinthite; Depth to chroma ≤ 3 = depth from soil surface to occurrence of iron depletions with Munsell chroma ≤ 3; SS = soil strength; ρb = soil bulk density; WDC = water dispersible clay; CDR = clay dispersion ratio (calculated as total clay/WDC); WSA = water stable aggregates; TOC and TON = total soil organic carbon and nitrogen; POMC and POMN = particulate organic matter (>53 μm) associated carbon and nitrogen; AC = active carbon; CEC = cation exchange capacity (NH_4OAc, pH 7) per kg soil; ECEC = effective cation exchange capacity (NH_4OAc, pH 7) per kg soil; P and Fe = Mehlich I extractable phosphorus and iron; Ca, Mg, and K = NH_4OAc, pH 7 extractable bases; $\Theta_{g,\ 10kPa}$ = gravimetric soil water content at field capacity; $\Theta_{g,\ 1.5MPa}$ = gravimetric soil water content at wilting point; AWHC = available water holding capacity (calculated as $\Theta_{g,\ 10kPa} - \Theta_{g,\ 1.5\ MPa}$); K_{sat} = saturated hydraulic conductivity.

‡ CS = control section (first 50 cm of argillic/kandic horizon); Upper CS = first horizon with evidence of clay translocation, i.e., Bt1 or Btv1.

§ Range (r), mean (μ), and median (m) values of CV for respected group of properties.

Table 9. Pearson linear correlation coefficients among select chemical and physical properties across all applicable depths (0-5, 5-15, 15-30, and 30-50 cm) for thirteen (ten for active carbon) repetitions of Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils within five long-term land use/managements (LM) in the Wiregrass region of the Alabama Coastal Plain.

†	TOC	TON	POMC	POMN	AC	CEC	ECEC	BS	AS	P	Fe	WSA	WDC	CDR	ρ_b	Sand	Silt	Clay
TOC	1																	
TON	***0.80***‡	1																
POMC	***0.98***	***0.71***	1															
POMN	***0.78***	***0.99***	***0.72***	1														
AC	***0.92***	***0.78***	***0.88***	***0.72***	1													
CEC	***0.89***	***0.84***	***0.84***	***0.82***	***0.75***	1												
ECEC	***0.61***	***0.84***	***0.50***	***0.80***	***0.61***	***0.82***	1											
BS	-0.10	0.14	-0.19	0.11	-0.08	0.09	***0.52***	1										
AS	0.03	-0.14	0.11	-0.10	-0.02	-0.09	***-0.43***	***-0.93***	1									
P	***0.46***	***0.76***	***0.32***	***0.70***	***0.54***	***0.65***	***0.88***	***0.45***	***-0.33***	1								
Fe	***0.57***	0.20	***0.63***	0.21	***0.61***	***0.43***	0.01	***-0.57***	***0.61***	0.00	1							
WSA	0.08	0.23	0.02	0.18	0.26	0.10	0.01	-0.18	0.08	0.12	0.07	1						
WDC	***-0.33***	-0.22	***-0.33***	-0.22	***-0.40***	-0.20	0.00	***0.43***	***-0.35***	0.02	***-0.29***	0.05	1					
CDR	-0.13	-0.23	-0.12	-0.23	-0.24	-0.23	-0.14	0.21	-0.12	-0.05	0.04	-0.15	***0.62***	1				
ρ_b	***-0.69***	***-0.39***	***-0.75***	***-0.40***	***-0.62***	***-0.55***	-0.13	***0.58***	***-0.49***	-0.03	***-0.64***	0.00	***0.49***	***0.37***	1			
Sand	***0.27***	0.16	0.19	0.13	***0.42***	-0.01	0.06	0.18	-0.23	0.12	0.02	-0.31	-0.08	***0.51***	0.11	1		
Silt	0.23	-0.04	***0.31***	-0.01	0.06	0.18	-0.18	***-0.71***	***0.81***	-0.17	***0.72***	0.06	***-0.30***	-0.05	***-0.57***	***-0.30***	1	
Clay	***-0.40***	-0.14	***-0.36***	-0.12	***-0.44***	-0.08	0.03	0.19	-0.20	-0.04	***-0.40***	0.37	0.24	***-0.50***	0.19	***-0.86***	-0.22	1
SS	***-0.33***	-0.02	***-0.40***	-0.06	-0.11	-0.23	0.00	***0.27***	***-0.27***	0.25	***-0.33***	***0.54***	0.25	0.06	***0.57***	-0.01	***-0.32***	0.18

† TOC and TON = total soil organic carbon and nitrogen (g kg^{-1}); POMC and POMN = particulate organic matter (>53 µm) associated carbon and nitrogen (g kg^{-1}); AC = active carbon (mg kg^{-1}); CEC = cation exchange capacity, NH_4OAc, pH 7 (cmol$_c$ kg soil^{-1}); ECEC = effective cation exchange capacity (cmol$_c$ kg soil^{-1}); BS = percent base saturation; AS = percent aluminum saturation; P and Fe = Mehlich 1 extractable phosphorus and iron (mg kg^{-1}); WSA = percent water stable aggregates; WDC = percent water dispersible clay; CDR = clay dispersion ratio (total clay/WDC); ρ_b = soil bulk density (Mg m^{-3}); Sand, Silt, and Clay = percent particle size separates (0.05-2.0, 0.002-0.05, <0.002 mm, respectively); SS = soil strength (kPa).

‡ Coefficients in bold and italic font are significant at the 0.05 confidence level.

Figures

Figure 1-1. Study site locations with associated Level IV ecoregions of the Alabama Coastal Plain. CRC = conservation row crop system; RC = conventional row crop system; LL = longleaf pine/wiregrass forest; Pasture = grazed pasture system; PP = managed pine plantation.

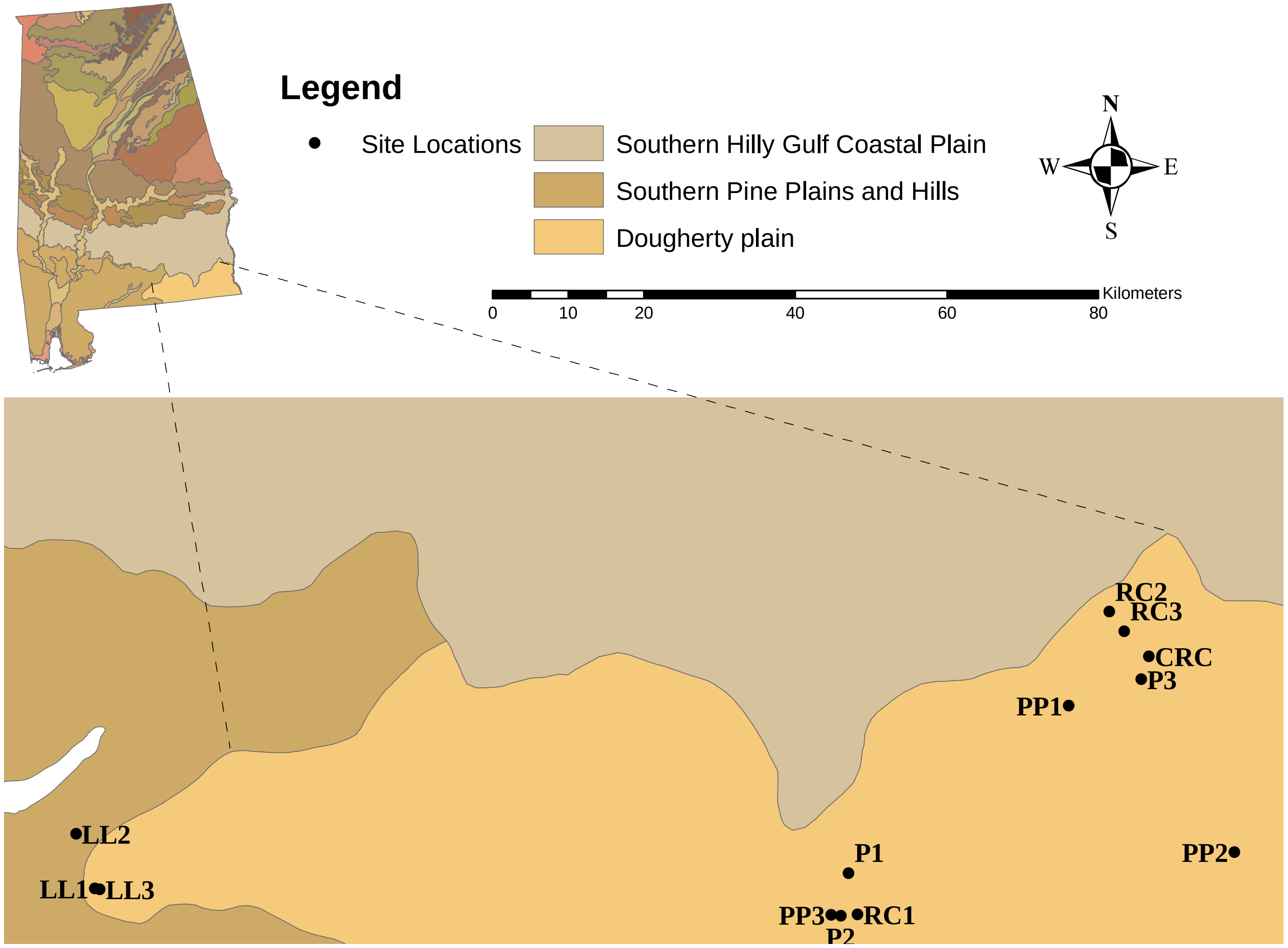


Figure 1-2. Total organic carbon and nitrogen (0-50 cm) averaged for three repetitions (one conservation row crop system) of Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils within five long-term land use/managements (LM) of the Alabama Coastal Plain. Columns within a parameter with the same letter are not significantly different at the 0.05 confidence level. TOC = total soil organic carbon; TON = total soil organic nitrogen; CRC = conservation row crop system; RC = conventional row crop system; LL = longleaf pine/wiregrass forest; P = grazed pasture system; PP = managed pine plantation.

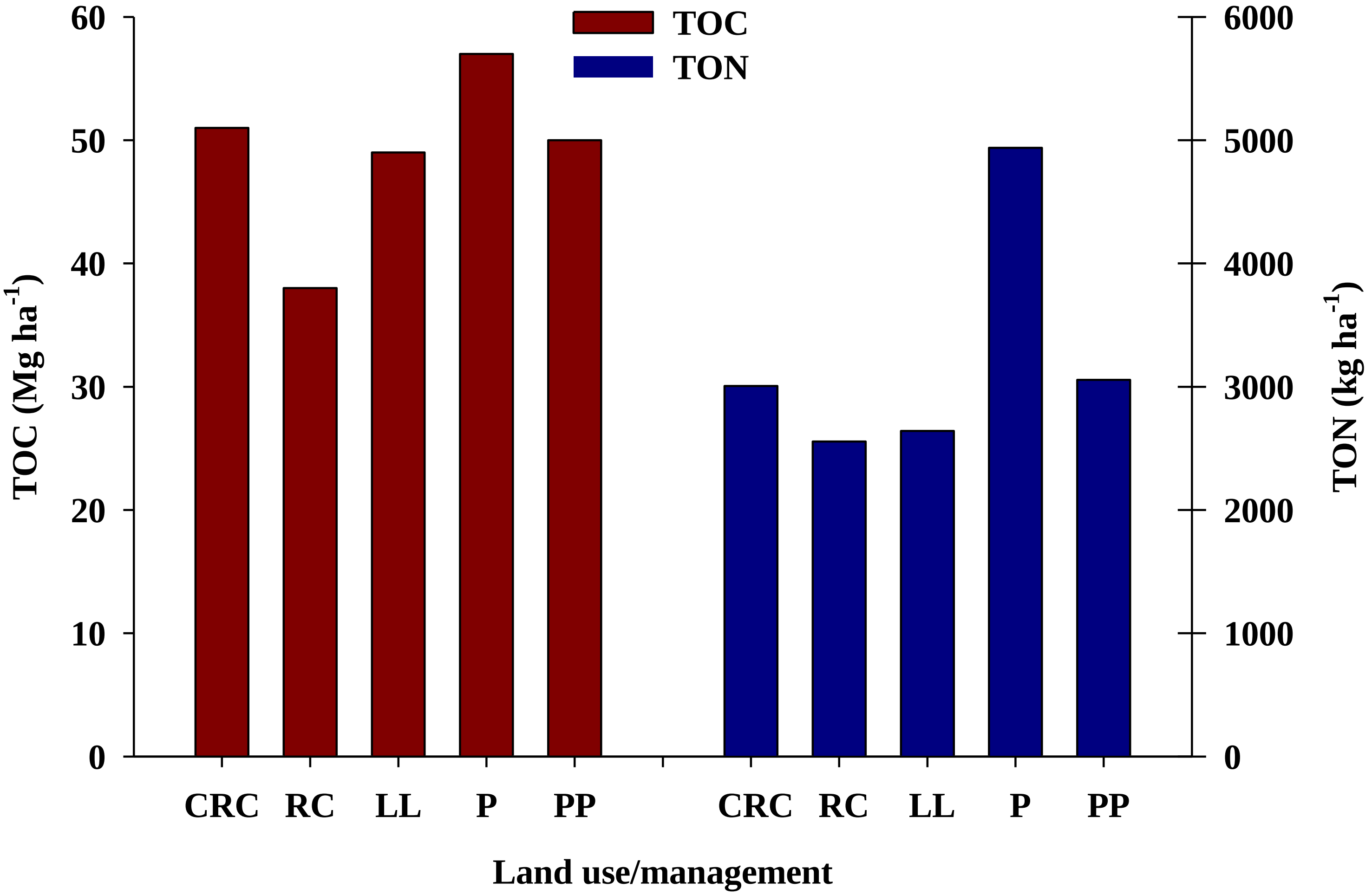


Figure 1-3. Particulate organic matter (> 53 µm) carbon and nitrogen (0-50 cm) averaged for three repetitions (one conservation row crop system) of Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils within five long-term land use/managements (LM) of the Alabama Coastal Plain. Columns within a parameter with the same letter are not significantly different at the 0.05 confidence level. POMC = particulate organic matter carbon; POMN = particulate organic matter nitrogen; CRC = conservation row crop system; RC = conventional row crop system; LL = longleaf pine/wiregrass forest; P = grazed pasture system; PP = managed pine plantation.

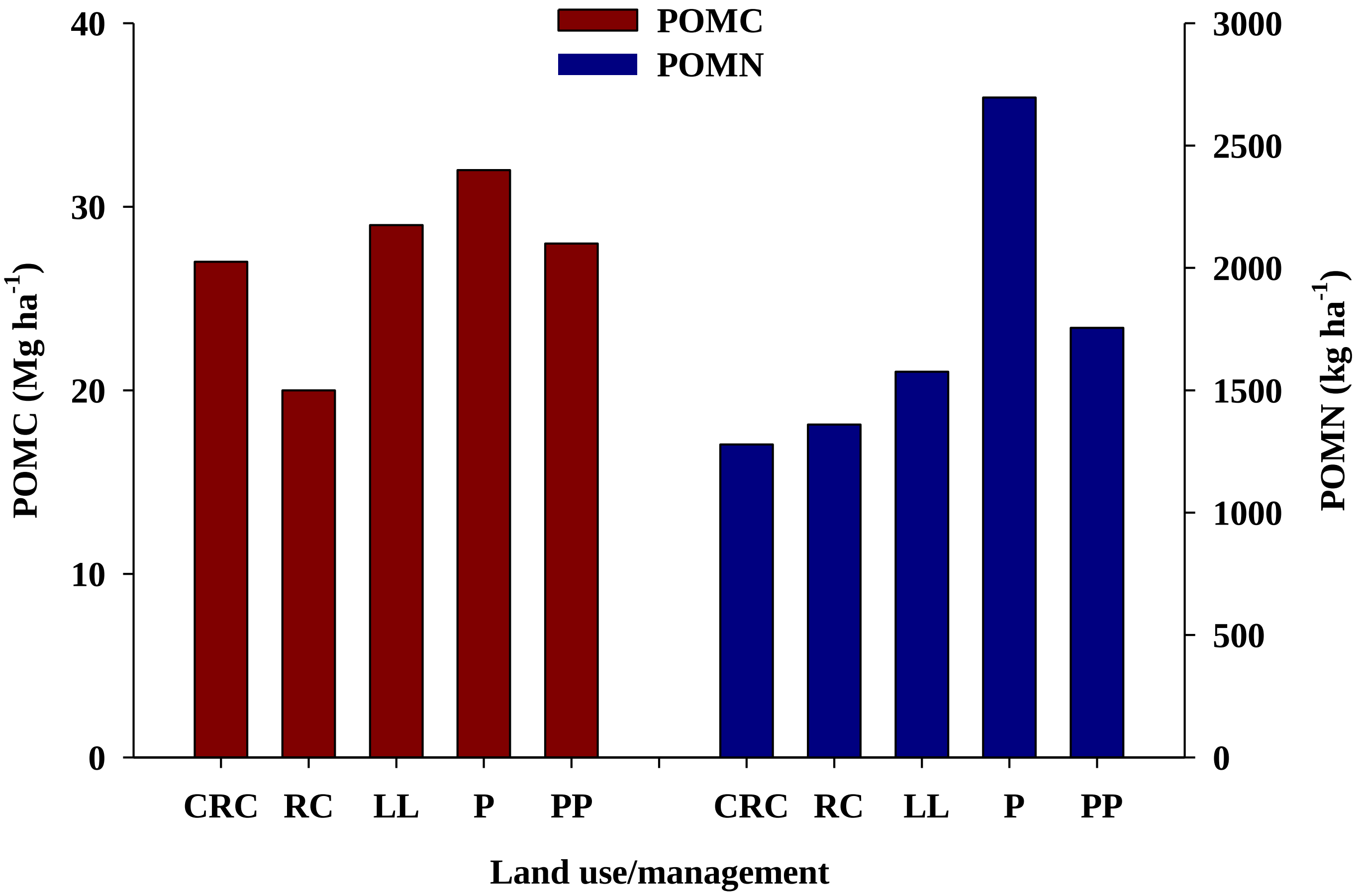


Figure 1-4. Active carbon (0-50 cm; kg ha^{-1}) averaged for three repetitions (one conservation row crop system) of Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils within four long-term land use/managements (LM) of the Alabama Coastal Plain. Columns with the same letter are not significantly different at the 0.05 confidence level. AC = active carbon; CRC = conservation row crop system; RC = conventional row crop system; P = grazed pasture system; PP = managed pine plantation.

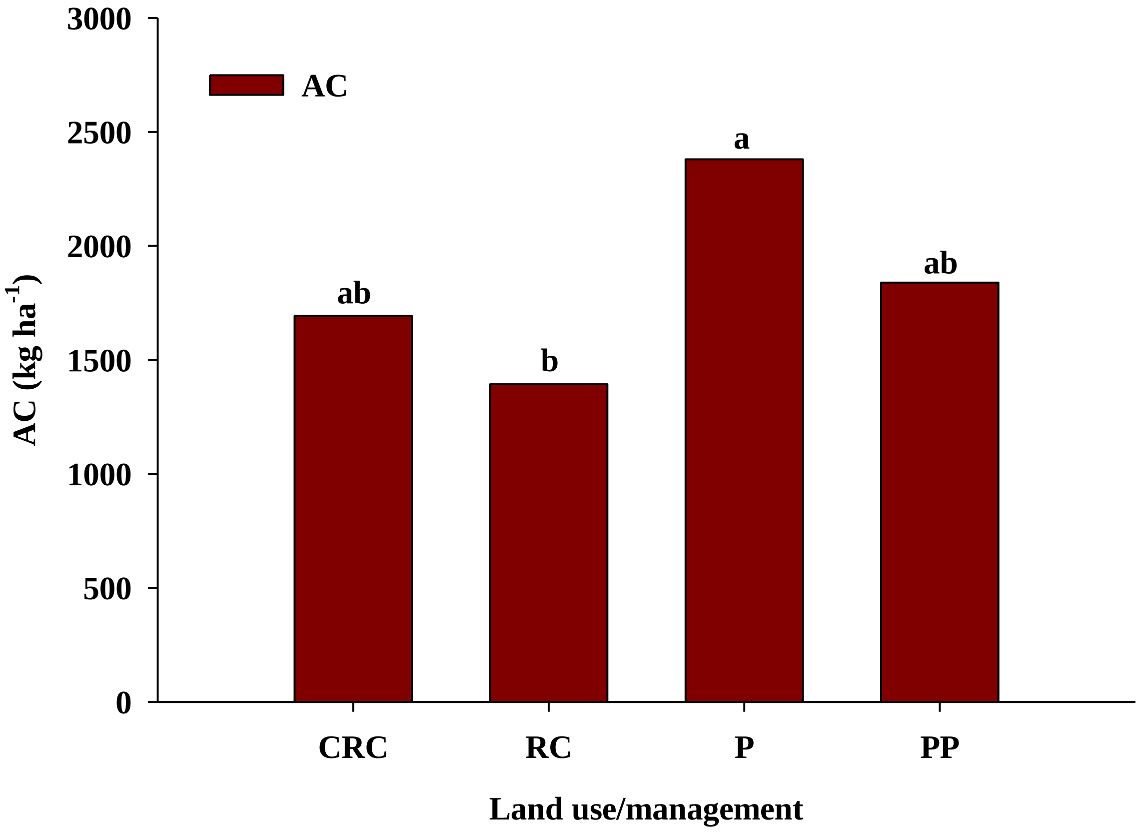


Figure 1-5. Stratification ratios (0-5 cm: 30-50 cm) of carbon and nitrogen pools averaged for three repetitions (one conservation row crop system) of Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils within five long-term land use/managements of the Alabama Coastal Plain. Columns within a parameter with the same letter are not significantly different at the 0.05 confidence level. TOC and TON = total soil organic carbon and nitrogen (g kg^{-1}); POMC and POMN = particulate organic matter (>53μm) carbon and nitrogen (g kg^{-1}); MC and MN = mineral (>53μm) carbon and nitrogen (g kg^{-1}); AC = active carbon (mg kg^{-1}); CRC = conservation row crop system; RC = conventional row crop system; LL = longleaf pine/wiregrass forest; P = grazed pasture system; PP = managed pine plantation; nd = not determined.

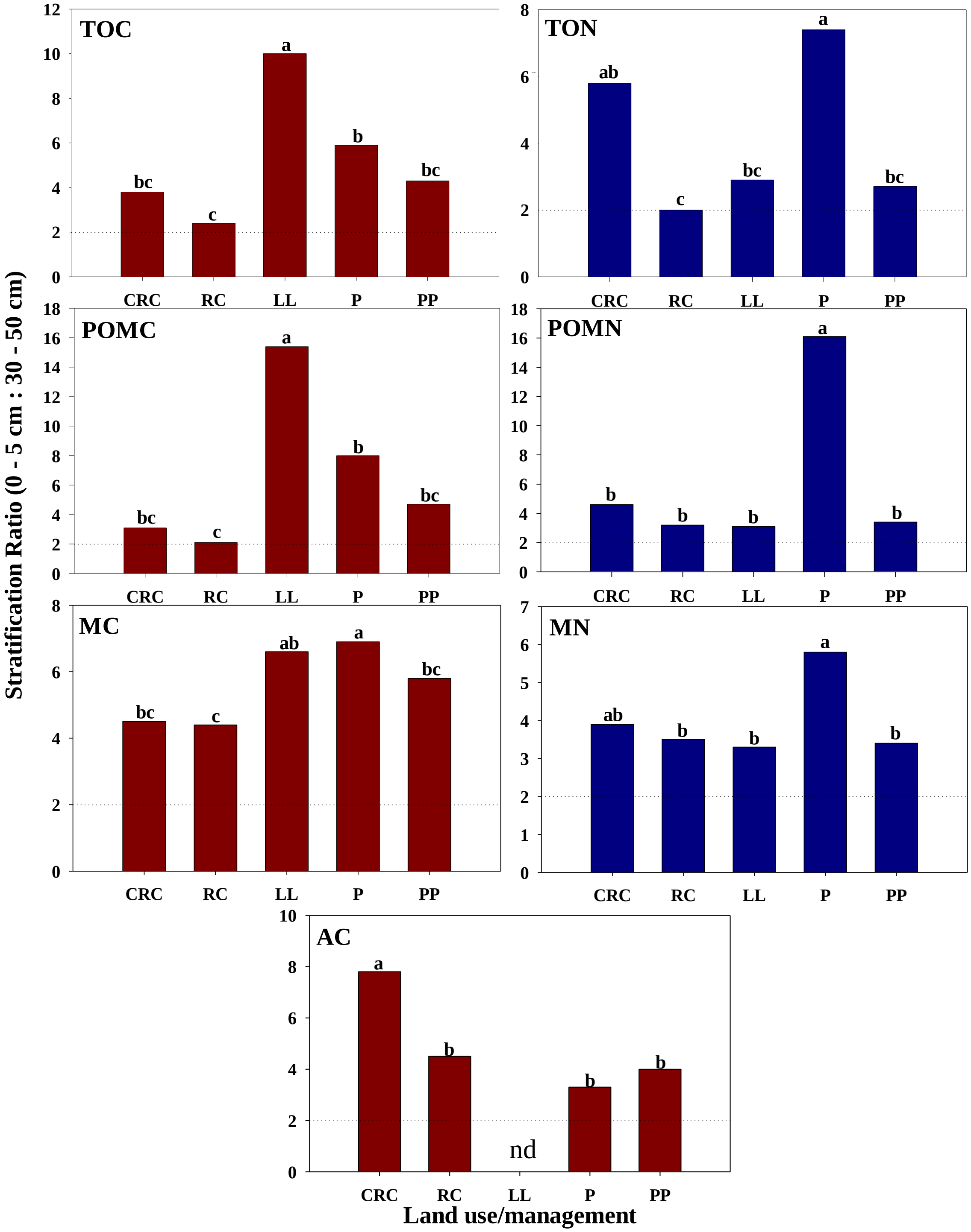


Figure 1-6. Cation exchange capacity and effective cation exchange capacity (0-5 cm) averaged for three repetitions (one conservation row crop system) of Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils within five long-term land use/managements (LM) of the Alabama Coastal Plain. Columns within a parameter with the same letter are not significantly different at the 0.05 confidence level. CEC = cation exchange capacity (NH$_4$OAc, pH 7); ECEC = effective cation exchange capacity (NH$_4$OAc, pH 7 extractable bases (Ca, Mg, K, and Na) plus KCl extractable Al); CRC = conservation row crop system; RC = conventional row crop system; LL = longleaf pine/wiregrass forest; P = grazed pasture system; PP = managed pine plantation.

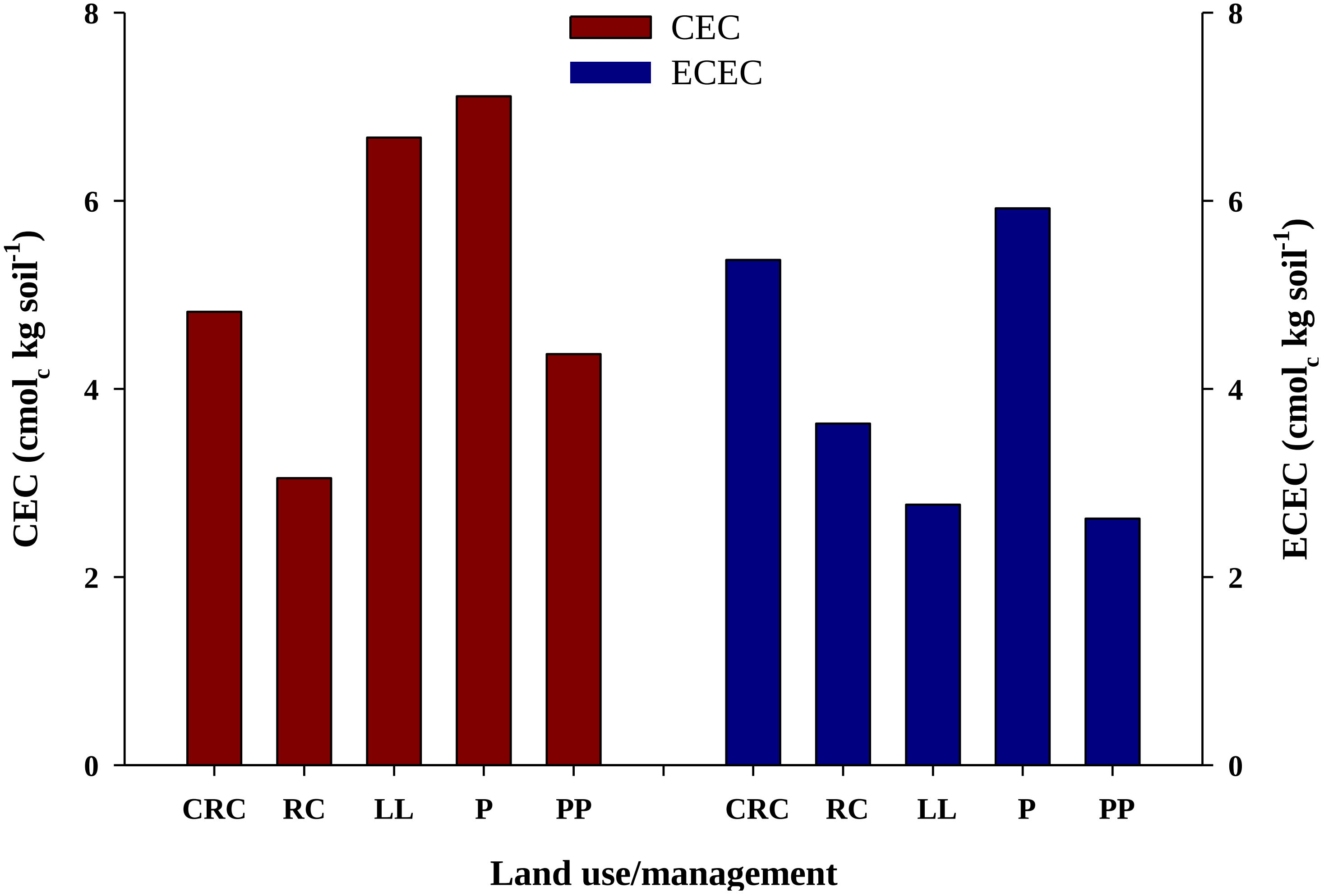


Figure 1-7. Soil exchangeable bases (0-50 cm) averaged for three repetitions (one conservation row crop system) of Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils within five long-term land use/managements (LM) of the Alabama Coastal Plain. Columns within a parameter with the same letter are not significantly different at the 0.05 confidence level. Ca = calcium; Mg = magnesium, K = potassium; CRC = conservation row crop system; RC = conventional row crop system; LL = longleaf pine/wiregrass forest; P = grazed pasture system; PP = managed pine plantation.

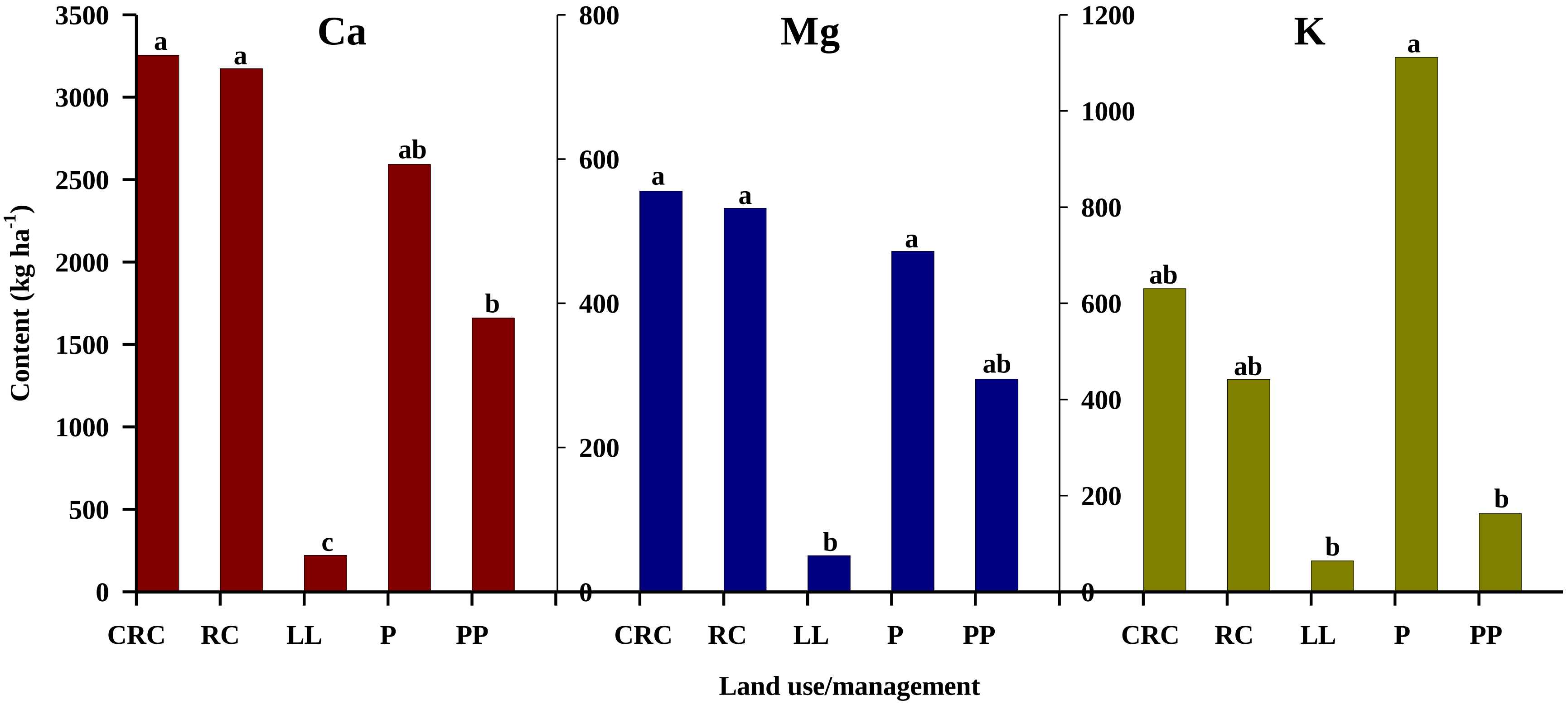


Figure 1-8. Mehlich 1 extractable nutrients (0-50 cm) averaged for three repetitions (one conservation row crop system) of Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils within five long-term land use/managements (LM) of the Alabama Coastal Plain. Columns within a parameter with the same letter are not significantly different at the 0.05 confidence level. P = phosphorus; B = boron, Cu = copper; Fe = iron, Mn = manganese; Zn = zinc; RC = conventional row crop system; LL = longleaf pine/wiregrass forest; P = grazed pasture system; PP = managed pine plantation; CRC = conservation row crop system.

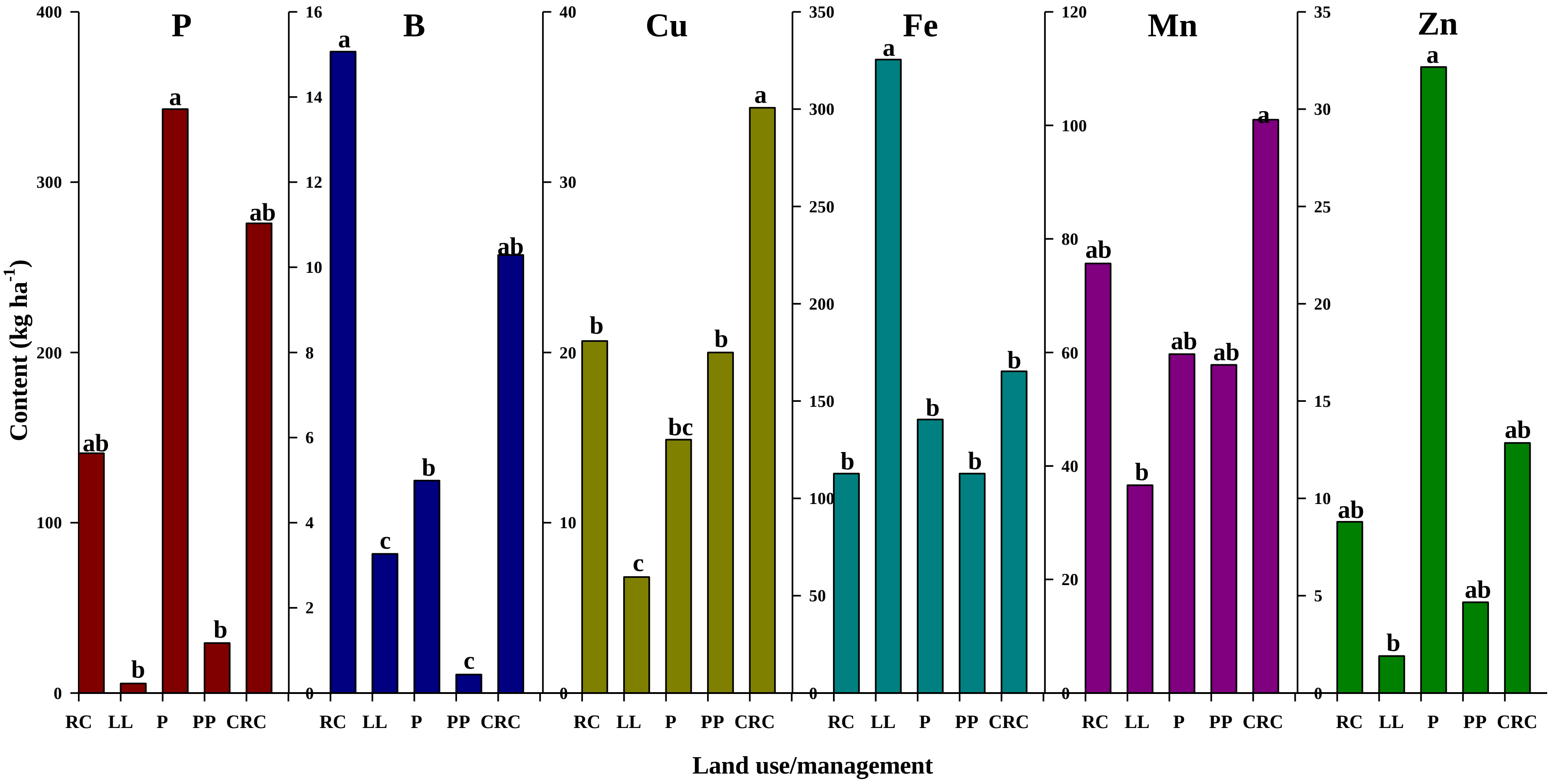


Figure 1-9. Soil strength (0-50 cm) averaged for three repetitions (one conservation row crop system) of Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils within five long-term land use/managements of the Alabama Coastal Plain. Bars represent Fisher's LSD at a confidence level of 0.05. CRC = conservation row crop system; RC = conventional row crop system; LL = longleaf pine/wiregrass forest; P = grazed pasture system; PP = managed pine plantation.

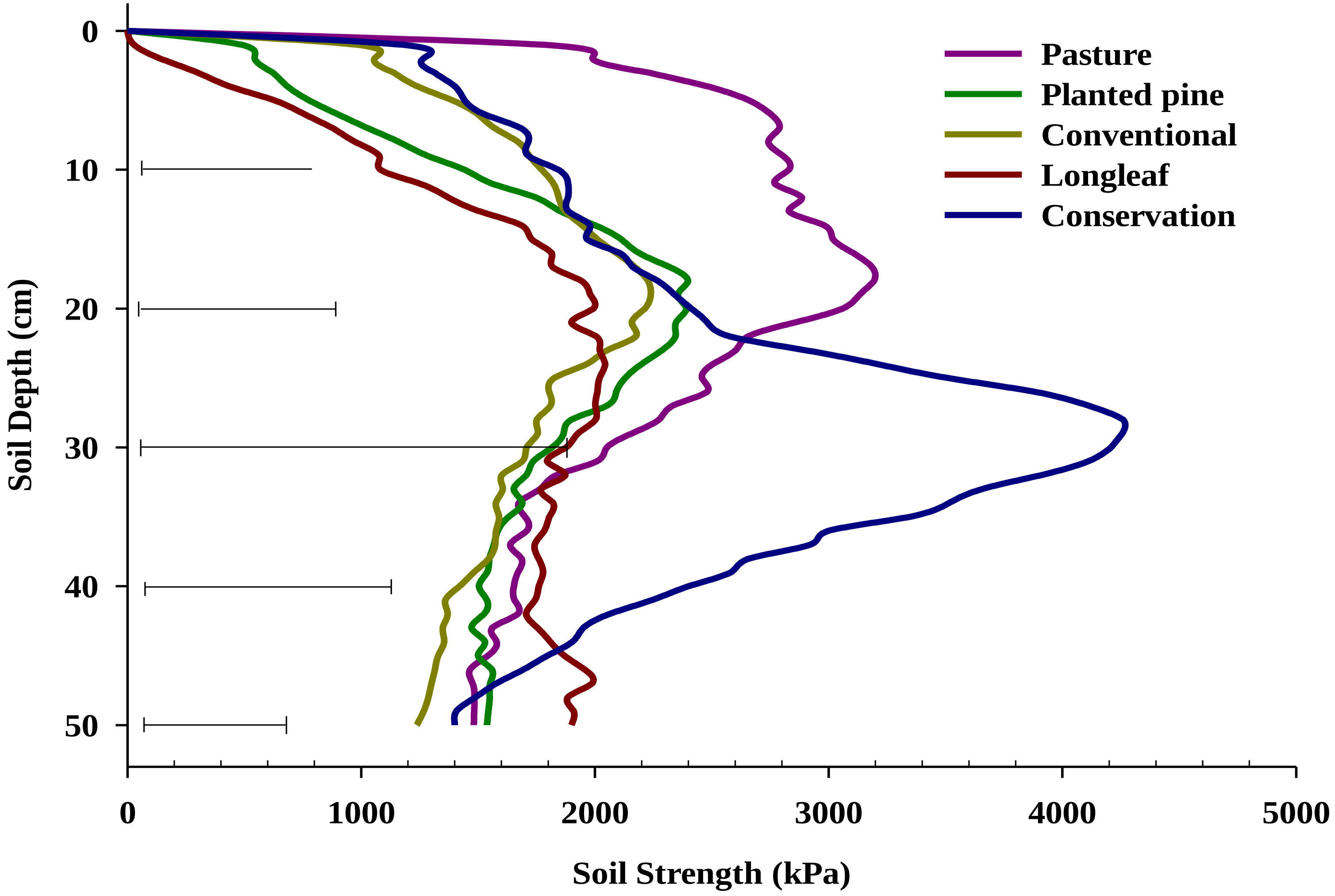


Figure 1-10. Use-invariant properties (0-180 cm) averaged for thirteen repetitions of Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils within five long-term land use/managements (LM) in the Wiregrass region of the Alabama Coastal Plain. Bars represent standard errors of 20 cm averages. Sand, Silt, and Clay = particle size separates (0.05-2.0, 0.002-0.05, <0.002 mm, respectively); CEC = cation exchange capacity expressed on a clay basis; ECEC = effective cation exchange capacity expressed on a clay basis.

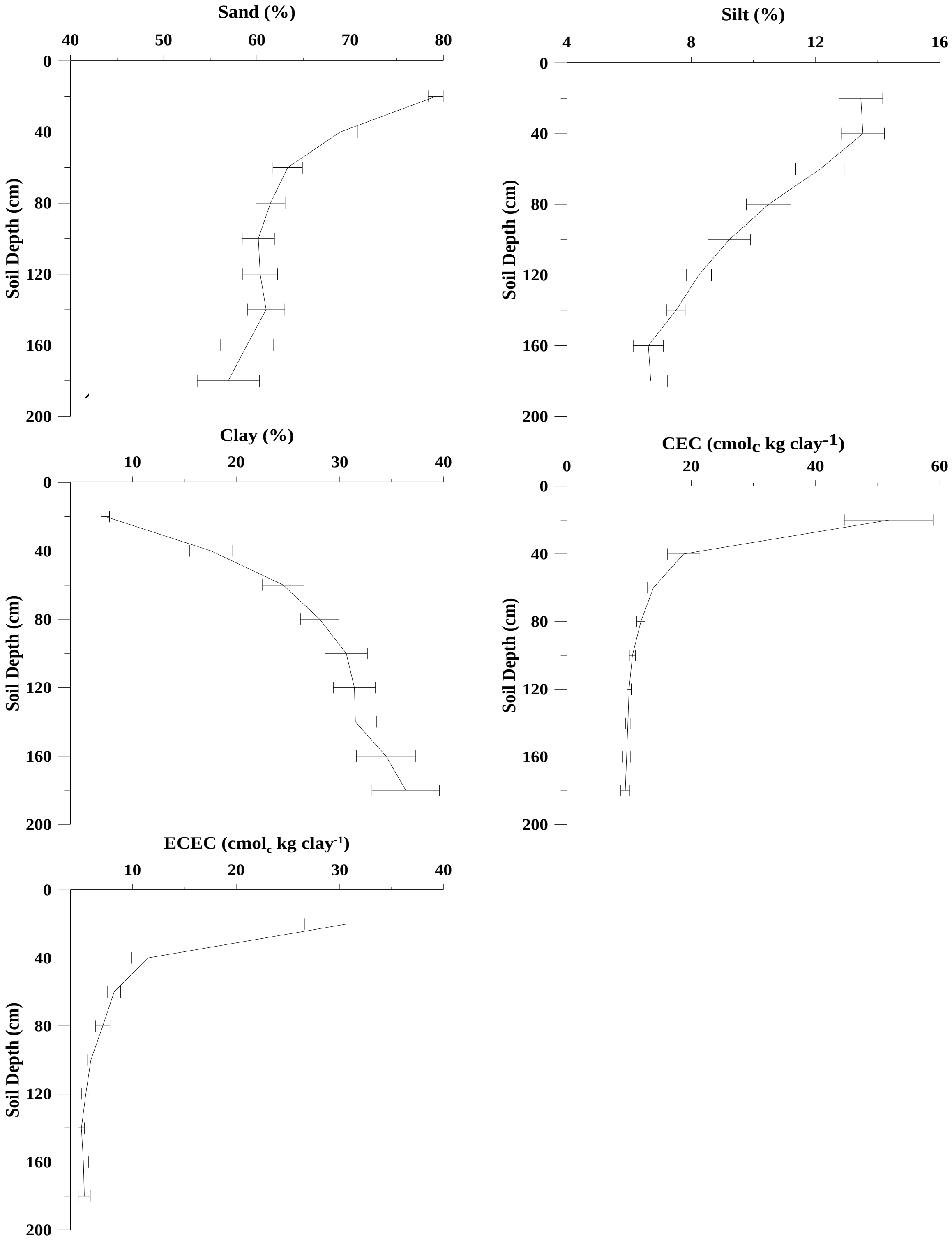


Figure 1-11. Physical management-dependent soil properties (0-50 cm) averaged for thirteen repetitions of Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils within five long-term land use/managements (LM) in the Wiregrass region of the Alabama Coastal Plain. Bars represent standard errors of sampling depth (0-5, 5-15, 15-30, and 30-50 cm) averages. WDC = water dispersible clay; CDR = clay dispersion ratio (total clay/WDC).

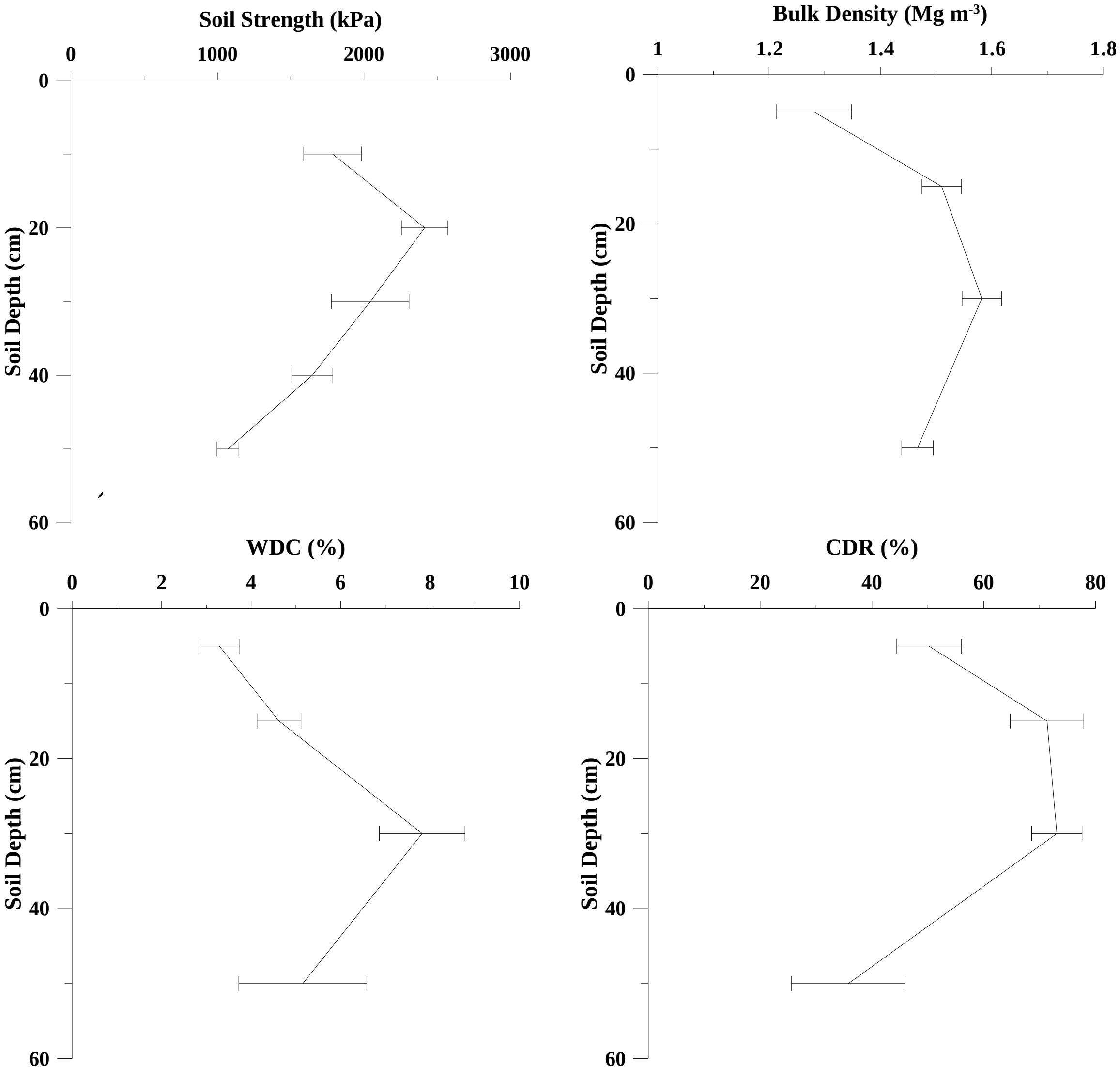


Figure 1-12. Carbon pools (0-50 cm) averaged for thirteen repetitions of Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils within five long-term land use/managements (LM) in the Wiregrass region of the Alabama Coastal Plain. Bars represent standard errors of sampling depth (0-5, 5-15, 15-30, and 30-50 cm) averages. TOC and TON = total soil organic carbon and nitrogen, respectively; POMC and POMN = particulate organic matter (>53 μm) associated carbon and nitrogen, respectively; AC = active carbon.

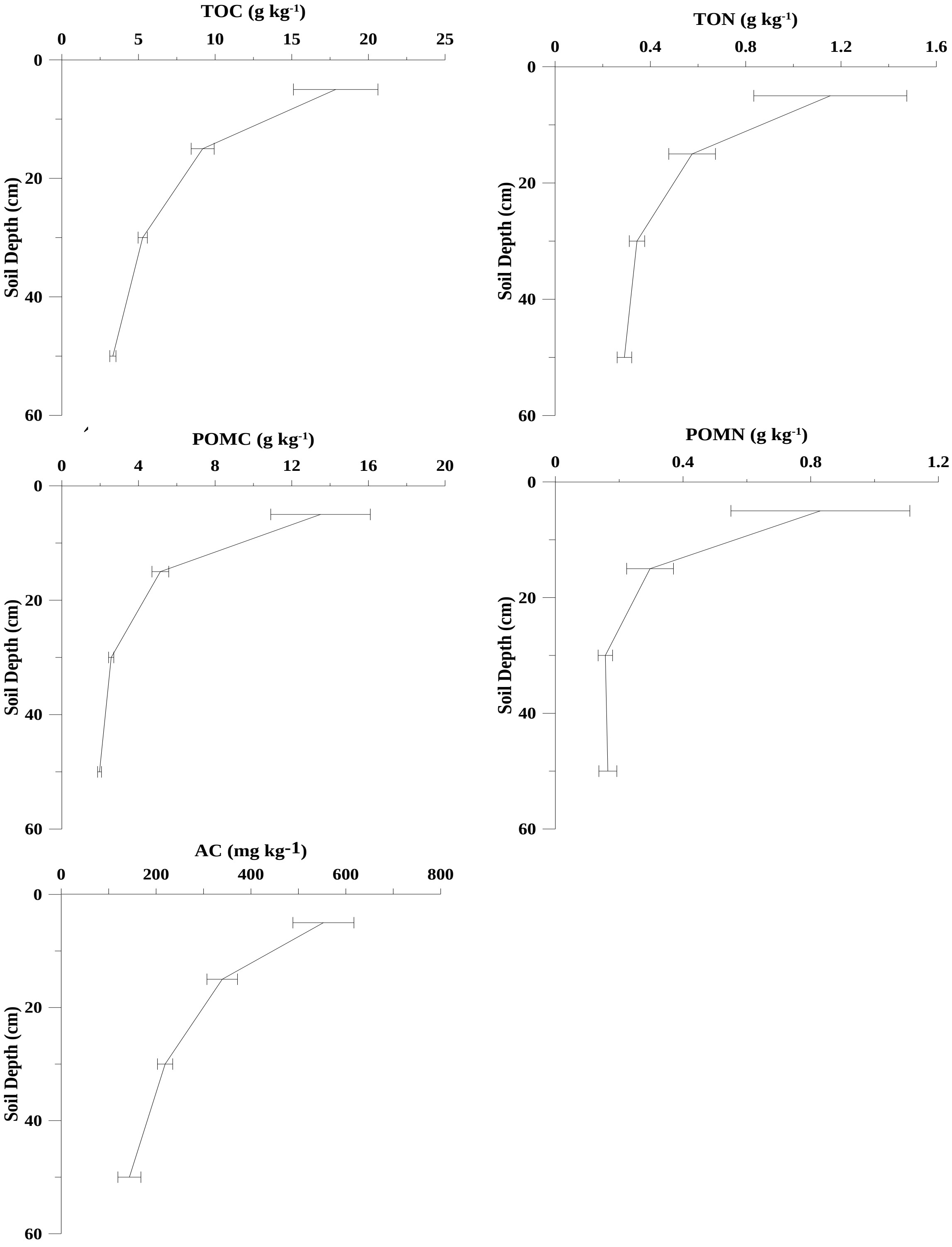


Figure 1-13. Chemical and hydraulic management-dependent properties (0-50 cm) averaged for thirteen repetitions of Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils within five long-term land use/managements (LM) in the Wiregrass region of the Alabama Coastal Plain. Bars represent standard errors of sampling depth (0-5, 5-15, 15-30, and 30-50 cm for CEC/ECEC; 15, 30, and 50 cm for K_{sat}) averages. CEC = cation exchange capacity expressed on a soil basis; ECEC = effective cation exchange capacity expressed on a soil basis; K_{sat} = saturated hydraulic conductivity.

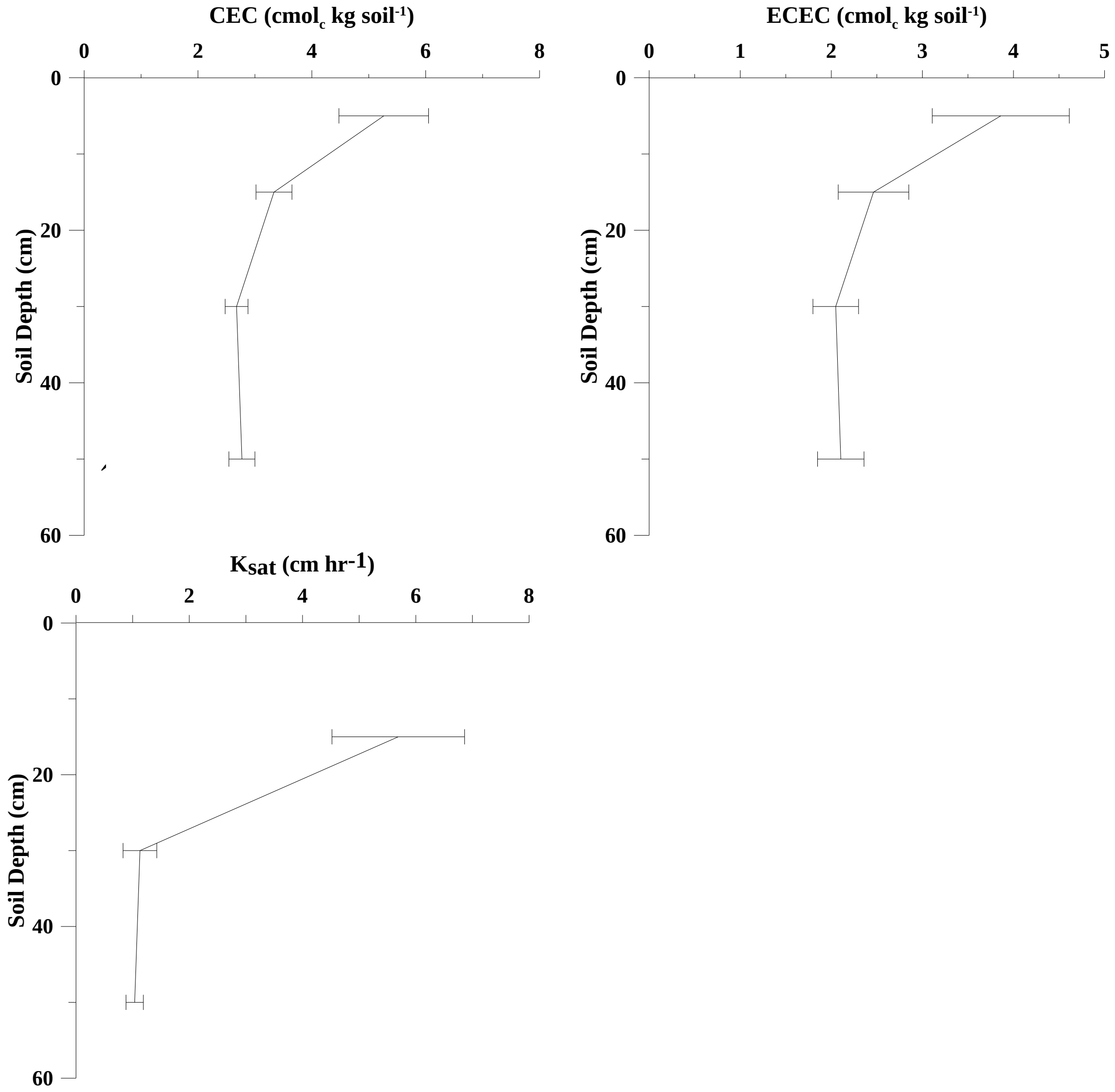
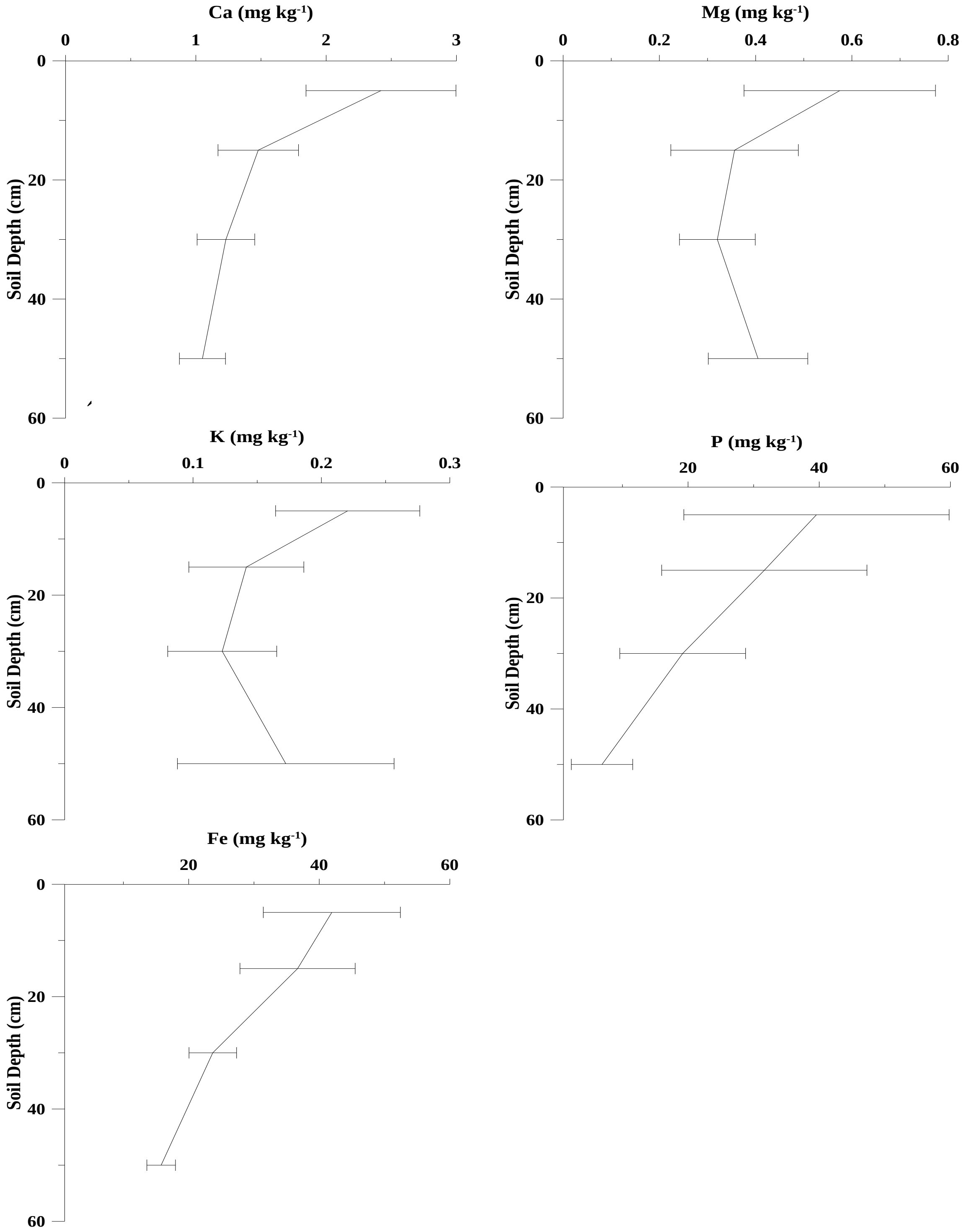


Figure 1-14. Chemical (nutrient) management-dependent properties (0-50 cm) averaged for thirteen repetitions of Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils within five long-term land use/managements (LM) in the Wiregrass region of the Alabama Coastal Plain. Bars represent standard errors of sampling depth (0-5, 5-15, 15-30, and 30-50 cm) averages. Ca = NH_4OAc, pH 7 extractable calcium; Mg = NH_4OAc, pH 7 extractable magnesium; K = NH_4OAc, pH 7 extractable potassium; P = Mehlich 1 extractable phosphorus; Fe = Mehlich 1 extractable iron.



III. Surface hydraulic property relationships and Pedotransfer Functions for southeastern U.S. Coastal Plain Plinthic Kandiudults

Abstract

With the initial survey of the soil resource nearly complete, future goals of the National Cooperative Soil Survey will concentrate on improving soil interpretations. Soil interpretations have largely been developed from an inventory of use-invariant soil properties, with little consideration of anthropogenic influences. Soil hydraulic properties (e.g., AWHC and K_{sat}) are of great importance to ecosystem function and used widely within soil interpretations. Due to the time-consuming and costly nature of measurement, hydraulic properties are often estimated. Recent research has shown that management can have vast effects on near-surface soil properties, but to what extent these effects have occurred on hydraulic properties for southeastern Coastal Plain soils is unclear. In the Wiregrass region, which has a broad range of natural and agroecosystems, hydraulic properties are especially critical because of short-term drought conditions due to high permeability and low water holding capacities of surface soils. Therefore, for a benchmark prime farmland map unit in the Wiregrass region of Alabama, objectives of this research were to: 1) document the amount of variability in hydraulic properties with respect to natural and agroecosystem, 2) develop improved relationships between management-dependent soil properties and near-surface soil hydraulic properties within the context of soil change, and 3) describe the variability of near-surface hydraulic properties across repetitions of the same map unit.

Select near-surface (0-50 cm) soil hydraulic properties within Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) consociations were measured under long-term (> 10 years) conventional and conservation row cropping, pasture, pine plantation, and old-growth Longleaf pine (*Pinus palustris*) forests. Saturated hydraulic conductivity was significantly affected by management at the 15 and 50 cm depths. Longleaf pine forests had the highest conductivities while systems with higher soil compaction (conservation row crop and grazed pasture systems) had the lowest conductivities (longleaf K_{sat} was 11 and 4.5 times greater than pasture sites at 15 and 50 cm, respectively). We found K_{sat} was related to carbon pools, bulk density, and soil strength. Surface (0-6 cm) AWHC was highest for pasture sites, intermediate for planted pine sites, and lowest for conventional row crop sites. Field capacity, wilting point, and AWHC were correlated with most investigated management-dependent properties. Regression-based algorithms explained more variability for 0-15 cm than the deeper depths. Surface (0-6 cm) field capacity and permanent wilting point variability was adequately described for (R^2 = 0.59-0.85), with management-dependent properties explaining more variability than use-invariant properties. However, a combination of management-dependent and use-invariant properties described more variability of several hydraulic properties, including K_{sat}.

Near-surface hydraulic properties are systematically affected by management in these soils, and because these properties are correlated with many more easily-measured parameters, a combination of relatively dynamic and static data can be used to estimate these properties. These less cost-prohibitive estimates can supplement current hydraulic data as our soil database is enhanced with the inventory of management-dependent properties, facilitating more reliable and accurate soil interpretations and management schemes.

Abstract Abbreviations: AWHC = available water holding capacity, K_{sat} = saturated hydraulic conductivity, R^2 = coefficient of determination.

Introduction

Soil surveys are the foundation of natural resource planning and management. These surveys generally use static, use-invariant properties to characterize the spatial variability of soil resources by means of the soil-landscape paradigm (i.e., soils are a function of climate, parent material, relief, and organisms within the context of time). The *'once-over'* soil survey in the U.S. is nearly complete, resulting in a shift in survey objectives. The National Cooperative Soil Survey (NCSS) is shifting from a mapping and inventory emphasis to an update and maintenance mode. With this shift in objectives, emphasis will be placed on improvement of soil interpretations within the context of soil change.

Soil Survey interpretations convey suitabilities and limitations of soil-landscape units (Buol et al., 2003). Although soil survey has emphasized the spatial depiction of soils (utilizing inherent, use-invariant properties) for inventory purposes, the decade-scale temporal variability in near-surface properties largely induced by management may be more critical from an interpretation perspective. In particular, soil hydraulic properties (e.g., saturated hydraulic conductivity and infiltration rates) are of importance due to their role in ecosystem function and the hydrologic cycle. Thus, an improved understanding of variability within soil hydraulic properties can greatly improve soil survey interpretations and land use management.

Soil change (temporal variation in soil properties at a specific location) results from both natural and anthropogenic processes (Tugel et al., 2005), whereas dynamic soil properties are components of soil change directly related to decadal to centurial human and natural impacts (Tugel et al., 2008). The NCSS defines a management-dependent property as a type of dynamic soil property which changes on a human time-scale due to anthropogenic disturbances (Soil Survey Staff, 2010a). It is well documented that near-surface soil properties have been largely affected by land use and management during the anthropocene (Brye and West, 2005; Halfmann, 2005; Zhou et al., 2008; Kibunja et al., 2010), but at what magnitude these effects occur on southeastern U.S. Coastal Plain soils is unclear.

The Wiregrass region of Alabama has a broad spectrum of agro- and natural ecosystems ranging from native longleaf pine forests, to pastures, to row crop lands. Much of the agricultural land is considered prime farmland, and many of the prime farmland soils in the Wiregrass region are found throughout the entire southeastern Coastal Plain region. Although many of these soils are considered productive under proper management, the upper 50 cm in most of these upland soils are coarse textured with relatively high permeability and low water holding capacity. Thus, short-term droughts during the growing season often limit ecosystem productivity. Considering the importance of the hydrology of these soils, documentation of land use impacts on near-surface soil hydraulic properties can increase our knowledge on sustainability of our soil and water resources. Furthermore, by addressing a complete range of agroecosystems (with associated range of anthropogenic influences) for the same map unit, we can establish better relationships of use-dependent properties within the context of soil change.

Characterization of hydraulic properties is problematic as they are highly variable (both spatially and temporally). However, they sometimes are correlated with other soil properties (e.g., C pools and bulk density). Estimating hydraulic properties from other soil properties is often accomplished through the development of Pedotransfer Functions (PTFs). Pedotransfer functions are algorithms that describe soil-water relationships based on basic, easily measured soil properties (Bouma and van Lanen, 1987), are commonly classified into two groups (class and continuous) (Wösten et al., 1995), and are developed using various techniques. Class PTFs are relatively easier and inexpensive to develop using categorical data, whereas continuous PTFs predict values based on measured data (e.g., estimating hydraulic conductivity from the percentages of clay and organic matter).

Simple regression models have been used to accurately predict a range of hydraulic parameters (Wösten et al., 1995). Other researchers have incorporated multivariate techniques (e.g., principal component analysis) to identify input parameters for PTF development (Lin et al., 1999). Yet still, more intensive methods including artificial neural networks (ANNs) (Minasny et al., 1999), ‘group methods of data handling’ (GMDH) (Pachepsky et al., 1998), and support vector machines (Twarakavi et al., 2009) are used to develop PTFs. Pedotransfer functions have had mixed success predicting hydraulic parameters: Sobieraj et al. (2001) had little success using continuous PTFs to estimate saturated hydraulic conductivity of Typic Hapludults; Shaw et al.

(2000) successfully developed continuous PTFs relating particle size to saturated hydraulic conductivity and transport properties for some southeastern sandy Kandiudults; and Scheinost et al. (1997) and Rawls et al. (2001) developed PTFs that accurately predicted water retention parameters from more easily measured soil properties.

Therefore, for a prime farmland map unit in the Wiregrass region of Alabama, the objectives of this research are to: 1) document the amount of variability in hydraulic properties between multiple agro- and natural ecosystems, 2) develop improved relationships between dynamic soil properties and near-surface soil hydraulic properties within the context of soil change, and 3) describe the variability of near-surface hydraulic properties across repetitions of the same map unit.

Materials and Methods

An on-farm survey was performed on a representative map unit (benchmark soil) across varying land uses (common for the Southeastern U.S. Coastal Plain) in the Wiregrass Region of the Alabama Coastal Plain. Samples were taken at random from three repetitions (one for conservation row crop system) of map unit/land use combinations. Land use and or management (discussed in detail below) included conservation and conventional row crop systems, native (old-growth) longleaf pine/wiregrass forests, managed pine plantations, and pastures. Only one site could be found that had been under consistent conservation tillage for ≥ 10 years. Therefore, there were 13 research sites (Figure 2-1) evaluating five natural and agroecosystem land use/managements.

Site Selection:

A Geographic Information System (GIS) approach was used for preliminary site reconnaissance. A combination of Alabama Gap Analysis Project (AL GAP) data (Kleiner et al., 2007), historical land use data (Price et al., 2006), National Resource Conservation Service (NRCS) Soil Survey Geographic (SSURGO) order 2 inventories, land owner interviews, and digital ortho-quadrangle photography was used to select sites of interest. Criteria for site selection included: 1) a Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) map unit, 2) 'A' slopes (0 – 2%), and 3) long-term (≥10 years) land use/management. On-site examination of the land use as well as soil map unit verification (described below) followed preliminary reconnaissance. Land use data (≈ 40 years old) utilizing the Enhanced Historical Land-Use and Land-Cover Data Sets of the U.S. Geological Survey (Price et al., 2006) documented historical land use (Table 18 in Appendix).

Land use/managements:

The land use and/or management treatments in this study included a range of natural- and agroecosystems (as described below) that have been in place ≥ 10 years. Ideally, it would be best if all sites had achieved "steady-state" conditions with regard to management-dependent soil properties and land use/management. However, logistically it is difficult to impossible to establish sites that meet all criteria due to the dynamic land management of this region, and 10 years of relatively consistent management is considered long-term for this region. Multiple managements can occur within each representative land use in this region (e.g., both conservation and conventional row crop systems). For the purpose of this study, the Land Use/Management/Ecosystem will be abbreviated as LM, and will consist of:

Conservation row crop – system consisted of an irrigated, strip tilled peanut (*Arachis hypogaea*), cotton (*Gossypium hirsutum*), corn (*Zea* spp.) rotation that had been in place since 1999. A KMC strip till rig with coulters and rolling baskets was utilized. Prior to 2004, the cover crop was planted with a grain drill after disking one or two times. In 2004, cover crops were no-till drilled with no prior disking. Since 1996, the plot was grazed by brood cows and calves during the winter.

Conventional row crop – systems consisted of non-irrigated peanut and cotton rotations. The soil was chisel plowed and disked prior to planting of both crops. In some years, winter cover crops were sown after fall harvest and disking, and included either rye (*Secale cereale*), wheat (*Triticum* spp.), or oat (*Avena sativa*). Systems had been in place for > 11 years.

Longleaf pine/wiregrass forest – sites consisted of varying age (old-growth) longleaf pine forests located in the Conecuh National Forest. Understory vegetation consisted of mixed native bunch grass (dominated by wiregrass) and successional species depending on fire management. Fire, whether prescribed or natural, is important to the maintenance of these ecosystems. Ground cover had been minimally disturbed since stand establishment suggesting these sites had never been cultivated. The Longleaf database for the site indicates that at a minimum, these stands have been present for 69 years.

Pasture – sites predominately consisted of Bahiagrass (*Paspalum notatum)* stands grazed by beef cattle year round. All pastures had been in place for > 20 years.

Planted pine plantation – sites consisted of first or second rotation planted slash (*Pinus elliottii*) or loblolly (*Pinus taeda*) pine trees managed for pole and/or saw timber. The understory was periodically burned with the majority of soil disturbance occurring during site preparation. Based on interviews and conservative estimates of tree age, all sites had been in place for > 15 years.

Pedon characterization:

Soils were described, sampled, and characterized at each site to verify sites were representative of Dothan map units. Soils were obtained from horizons of representative *type* pedons for laboratory analysis to verify map unit placement (Soil Survey Staff, 2010b)., Samples were air-dried, ground, separated into coarse- (>2 mm) and fine- (≤2 mm) earth fractions, and analyzed for: percent coarse fragments (%>2 mm); particle size distribution using the <2-mm pipette method following soil organic matter removal of surface horizons (upper two) using a 30% H_2O_2 solution and dispersion with a $(NaPO_3)_6$ and Na_2CO_3 solution; cation exchange capacity (CEC) and base saturation (Ca, Mg, K, and Na) by the NH_4OAc (pH 7) method using an autoextractor and analyzed with atomic adsorption spectroscopy (AAS); extractable aluminum (Al) using 1.0 *M* KCl with an autoextractor (12 hour extraction) and measured with inductively coupled plasma (ICP) spectrometry; and effective cation exchange capacity (ECEC) was calculated by summing the NH_4OAc bases and KCl Al (Soil Survey Investigation Staff, 2004).

Thermogravimetric analysis (TGA) was performed to determine the clay (<0.002 mm) mineralogy of the upper control section utilizing a TGA Q50 Thermogravimetric Analyzer (TA Instruments—Waters LLC, New Castle, DE, USA). Kaolinite and gibbsite were quantified using the theoretical water content of both minerals (14 and 34.2 %, respectively). Dithionite-citrate-bicarbonate (DCB) extractable iron and aluminum were determined as per Jackson (2005). Iron percentages were reported on an iron oxide basis. Pedons were classified according to Soil Taxonomy (Soil Survey Staff, 2010b). The Appendix contains pedon field descriptions and tables 18-30 contain laboratory characterization data.

Field Procedures:

Sampling

Thirteen sites (Figure 2-1) were sampled for chemical, physical, and hydraulic analyses. All sampling was performed within an approximate 100 m^2 area centered on each site's characterized pedon location. At row crop sites, where distinguishable, samples were taken from untrafficked interrows. Organic 'O' horizons were sampled in forested (longleaf pine/wiregrass and planted pine) sites (two 0.25 m^2 quadrats) and transported in cloth sample bags. Organic horizons were removed prior to mineral soil sampling.

Composite soil samples (10 samples taken with an 8-cm bucket auger or 5-cm cylindrical core) were taken at four depth increments (0-5, 5-15, 15-30, and 30-50 cm) and transported in cloth sample bags. Approximately 400 g of each composite sample (0-5, 5-15, 15-30, and 30-50 cm) were placed in sealed plastic bags and transported in cold storage for active carbon analysis. Active carbon samples were not taken from the three longleaf pine/wiregrass forest sites due to different sampling seasons.

Bulk density was sampled utilizing the core method outlined by Blake and Hartge (1986). Three bulk density samples were obtained within each site location using: 1) a truck-mounted Giddings Hydraulic Probe (Giddings Machine Company, Inc., Fort

Collins, CO, USA) or 2) a slide hammer with cylindrical sleeves (one planted pine site due to vehicle inaccessibility) at 0-5, 5-15, 15-30, and 30-50 cm depths and transported in sealed plastic bags. The same diameter core was sampled with both methods of extraction. Three samples at each site were taken with a shovel (to reduce sampling disturbance) at two depths (0-5 and 5-15 cm) and placed in cloth sample bags for determination of water stable aggregates (WSA).

Excluding longleaf pine/wiregrass sites, two replications of undisturbed soil cores (8.5 cm diameter, 6 cm height) were taken at two depths (0-6 cm and 15-21 cm) to develop moisture release curves. Cores were wrapped in cheese cloth, placed in sealed plastic bags, and transported in cold storage. Samples for moisture determination were also taken from 0-50 cm and transported in sealed plastic bags.

In-situ Measurements

Soil strength (0-50 cm) measurements were taken using a CP40II recording cone penetrometer (ICT International Pty Ltd, Armidale, New South Wales, 2350, Australia). Cone index values consist of a composite of 20 insertions with measurements recorded at 1 cm increments. Three replications of saturated hydraulic conductivity (K_{sat}) were taken at three depths (15, 30, and 50 cm to bottom of borehole) within each site using a compact constant head permeameter (Amoozegar, 1989; Ammoozemeter; Ksat, Inc., Raleigh, NC). Tap water (EC = 227 μS cm^{-1} for longleaf pine/wiregrass forest sites 1 and 3; EC = 176 μS cm^{-1} all other sites) was used for K_{sat} determination. Replicates were averaged to obtain representative site-depth values.

Laboratory Procedures:

Soil Carbon

Organic 'O' horizons were air-dried, weighed, and ground to pass a 1-mm sieve. Two grab samples from each quadrat were analyzed for C and N by dry combustion (LECO CN-2000). Average values from these two quadrats were calculated to acquire a site value.

Active carbon samples (0-5, 5-15, 15-30 and 30-50 cm) were removed from cold storage the day following sampling and moist soils were passed through a 2-mm sieve. Active carbon was determined using a 0.02 *M* $KMnO_4$ (with the addition of 0.1 *M* $CaCl_2$) solution and analyzed colorimetrically following the protocol by Weil et al. (2003).

Total soil organic carbon (TOC) and total soil organic nitrogen (TON) were determined on composite samples (0-5, 5-15, 15-30 and 30-50 cm) by dry combustion (LECO CN-2000). Ground (mortar and pestle) samples were replicated (sub-samples) and values averaged to acquire a representative site-depth value. Carbon to nitrogen ratios (C:N) were calculated using C and N concentrations.

Particulate organic matter C and N (>53 μm) (POMC and POMN) were determined using composite samples (0-5, 5-15, 15-30 and 30-50 cm) by the soil dispersion and wet sieving method outlined by Cambardella and Elliot (1992). Ground (mortar and pestle) sub-samples were analyzed for C and N by dry combustion; values were averaged to acquire a representative site-depth value. Mineral-associated C and N (<53 μm) (MC and MN) were determined by difference (e.g., TOC – POMC).

Chemical

Composite soil samples (0-5, 5-15, 15-30 and 30-50 cm) were air-dried, ground and passed through a 2-mm sieve prior to chemical analyses. The methods for CEC, ECEC, base saturation (%) and extractable Al measured on these samples were described previously. Mehlich 1 extractable nutrients (P, Fe, Mn, Zn, Cu, and B) were extracted via the double acid method outlined by Mehlich (1953). Soil pH was measured in 1:1 (w/v) soil to water and 1:2 (w/v) soil to 0.01 *M* $CaCl_2$ solutions (Soil Survey Investigation Staff, 2004).

Physical

Composite soil samples (0-5, 5-15, 15-30, and 30-50 cm) were air-dried and ground to pass a 2-mm sieve prior to determination of the particle size distribution (PSD) and water dispersible clay (WDC). Determination of the PSD using the <2-mm pipette method followed soil organic matter removal using a 30% H_2O_2 solution and dispersion with a $(NaPO_3)_6$ and Na_2CO_3 solution (Soil Survey Investigation Staff, 2004). A modification of the <2-mm pipette method (no organic matter removal or dispersion) was utilized to determine WDC. The clay dispersion ratio (CDR) was calculated as per Igwe (2005). Water stable aggregates were determined according to methods of Kemper and Rosenau (1986) with the use of a humidifier apparatus. Three replications were averaged to acquire a representative site-depth value. Bulk density samples were dried at 105°C prior to weighing and calculations were made according to the method outlined by Blake and Hartge (1986). Replications were averaged to obtain each representative site-depth value.

Hydraulic

Soil moisture contents at thirteen matric potentials (0, 1, 2, 4, 8, 12.5, 20, 33, 50, 80, 100, 300, and 1500 kPa) were obtained (Dane and Hopmans, 2002) and used to develop moisture release curves. Tempe cells (model 1405; Soil Moisture Equipment Corporation, Santa Barbara, CA, USA) were used to obtain moisture contents at low potentials (0-80 kPa) after saturating with 0.01 *M* $CaCl_2$ solution. Compressed air (via a Soil Moisture Model 505 20 Bar compressor; Soil Moisture Equipment Corporation) distributed by a precision manifold (0700G5 zero to one bar precision manifold; Soil Moisture Equipment Corporation) was utilized to obtain desired matric potentials.

At high matric potentials (100 – 1500 kPa), 5 and 15 bar high flow ceramic plates and extractors (model 1600 5 bar and model 1500 15 bar ceramic plate extractors; Soil Moisture Equipment Corporation) were used. Cores were removed from Tempe cells and placed on saturated ceramic plates and re-wetted prior to all extractions. After cores had been subjected to all 13 pressure steps (0-1500 kPa), they were oven dried at 105°C and both gravimetric and volumetric water contents were calculated with coarse fragment corrections. Available water holding capacity (AWHC) was determined by difference (i.e., $\Theta_{g\ 10\ kPa} - \Theta_{g\ 1500\ kPa}$).

Retention Curve Analysis:

Soil water retention curves were developed using RETC software (van Genuchten et al., 1991) using volumetric water contents obtained above (n=13). The van Genuchten retention curve model (van Genuchten, 1980) with the Mualem based restriction ($m = 1 - 1/n$) (Mualem, 1976) was utilized (equation 1):

$$\Theta(h) = \Theta_r + \frac{(\Theta_s - \Theta_r)}{[1 + (\alpha h)^n]^m}$$

where $\Theta(h)$ is the measured volumetric water content at pressure h, and Θ_s and Θ_r are the saturated and residual water contents, respectively. Parameters α, *n*, and *m* are empirical constants affecting the shape of the retention curve (van Genuchten et al., 1991). The constant α is related to the inverse of the air-entry pressure, and *n* is related to the pore-size distribution (Schaap et al., 2001). Shape parameters α and *n* were fitted while satiated water contents were used for saturated water contents (Θ_s), and water contents at 1.5 MPa (wilting point) were used for residual water contents (Θ_r). Data input into RETC to obtain retention curves (Figures 2-3 and 2-4) consisted of replicate averages within LM. van Genuchten fitting parameters were developed for individual replicates as opposed to replicate averages.

Regression Analysis:

Multiple regression analysis was used to relate soil hydraulic properties to more readily measured management-dependent (Table 15) and use-invariant (Table16) soil properties (PROC REG; SAS Institute Inc., 2003). Multicollinearity was assessed using the variance inflation factor (VIF); VIFs lower than 10 were included in our models as this indicates reduced collinearity (Alin, 2010). Stepwise model selection was implemented and variables were retained at a $P \leq 0.15$. The coefficient of determination (R^2) and root mean square error (RMSE) were used to assess models. Due to sampling and depth considerations, various approaches were used to develop models:

Management-dependent properties

1) The first model (Model 1) related hydraulic properties at 0-15 cm to TOC, ρ_b, WDC, WSA and SS.
2) The second model (Model 2) related hydraulic properties at 15-50 cm (and K_{sat} across all depths) to TOC, ρb, WDC, and SS.

Use-invariant properties

3) The third model (Model 3) related K_{sat} (across all depths) to texture (sand and clay fractions), and percent gibbsite, kaolinite, and iron oxides measured from type pedons.

4) The fourth model (Model 4) related hydraulic properties (0-50 cm) to texture (sand and clay fractions), and CEC and ECEC (both expressed on a clay basis) measured from type pedons.

Management-dependent and Use-invariant

5) The fifth model (Model 5) related hydraulic properties at 0-15 cm to TOC, ρ_b, WDC, WSA, SS, texture (sand and clay fractions), and CEC and ECEC (clay basis).

6) The sixth model (Model 6) related hydraulic properties at 15-50 cm (and K_{sat} across all depths) to TOC, ρb, WDC, SS, texture (sand and clay fractions), and CEC and ECEC (clay basis).

7) The seventh model (Model 7) related K_{sat} (across all depths) to TOC, ρb, WDC, SS, texture (sand and clay fractions), and percent gibbsite, kaolinite, and iron oxides.

Statistical Analysis:

When depth was a factor (i.e., multiple depths), the experimental design consisted of an augmented split plot design with the whole plot in randomized complete blocks; management was the whole-plot factor while depth was the sub-plot factor. The blocking factor consisted of relative classes based on surface (0-50 cm) soil texture. Analysis of variance consisted of mixed models methodology using SAS® PROC GLIMMIX (SAS Institute Inc., 2003) where management, depth and their two-way interaction were fixed effects and block, block by depth and block by management two-way interactions were random effects. The conservation row crop system was not replicated (n=1), therefore the pooled variance for the remaining crop systems was used to calculate a standard error.

The residual covariance was modeled due to correlated error structure caused by lack of randomization among depth; the best fitting model was selected using Akaike's information corrected criterion (AICC) (Bolker et al., 2008; Guertal et al., 2009; SAS Institute Inc., 2010). Land use/managements were compared within depths using the SLICEDIFF option of the LSMEANS statement.

When depth was not a factor (i.e., 0-50 cm or similar comparisons), the experimental design consisted of a randomized complete block design. Again, the blocking factor consisted of relative classes based on surface (0-50 cm) soil texture. Analysis of variance consisted of mixed models methodology using SAS$^{®}$ PROC MIXED (SAS Institute Inc., 2003) where management was the sole fixed effect, and block and the two-way interaction were the random effects. Land use/managements were compared using the PDIFF option of the LSMEANS statement.

Pearson linear correlation coefficients were calculated for select properties using SAS$^{®}$ PROC CORR (SAS Institute Inc., 2003). All significant results were based on a confidence level of 0.05.

Results and Discussion

Soils

All upland sites contained very deep, well-drained soils formed in unconsolidated fluvio-marine sediments. Soils contained ochric epipedons and argillic and kandic subsurface diagnostic horizons. Surface textures ranged from loamy sand to sandy loam and control section particle size families were fine-loamy (>15% fine sand or coarser with 18-35% clay) for all thirteen sampled pedons (Table 10). All profiles contained ≥5% nodular plinthite within 150 cm, placing the soils in Plinthic subgroups. Clay mineralogy was dominated (>50%) by kaolinite and gibbsite (Table 10). Twelve of the thirteen characterized pedons classified as Ultisols, with one pasture site as an Alfisol (Table 10). Elevated base saturation (>35%) in the lower solum of pedon S2009AL-067-3 (Table 28 in the Appendix) was anthropogenically induced (cultural Alfisol) as two pedons sampled on an adjacent fence row (where amendment applications were less and corresponding base saturation was lower) were both Ultisols. Thus, sampled pedons fit within the Dothan series criteria.

Soil Hydraulic Properties

Saturated Hydraulic Conductivity

Saturated hydraulic conductivity (K_{sat}) tended to decrease between 15 and 30 cm, and increase at 50 cm (Figure 2-2). Significant LM effects for K_{sat} at 15 cm (*P*=0.0002) and 50 cm (*P*=0.0001) were observed (Table 11). The K_{sat} at 15 cm was significantly higher for the longleaf sites (16.86 cm hr^{-1}) compared with all other LMs. At 30 cm, K_{sat} values ranged from 0.14 cm hr^{-1} (conventional row crop) to 3.03 cm hr^{-1} (longleaf).The longleaf and conservation row crop sites had significantly higher K_{sat} values than the other LMs at 50 cm. Similarly, Price et al. (2010) found native forests to have greater K_{sat} values (0-25) relative to pasture systems for some Ultisols in North Carolina. The relatively higher surface (15 and 30 cm) K_{sat} values for the forested sites are likely due to differing plant rooting and macropore development, i.e., coarser roots in forested sites (Field Descriptions 5-7 and 11-13) facilitates more preferential flow. In addition, Wang et al. (2010) suggested that organic matter under pine systems may exhibit hydrophobicity that results in increased preferential flow, which may facilitate higher conductivities at forested sites.

Available Water Holding Capacity

Water content at field capacity ($\Theta_{g,\ 10kPa}$) had a significant management by depth interaction (*P*=0.0045), while no significant effects were found for wilting point ($\Theta_{g,\ 1500kPa}$) water contents (Table 12). The field capacity (0-6 cm) of pasture sites (0.21 kg kg^{-1}) was significantly higher than row crop systems (0.10 and 0.11 kg kg^{-1} for conventional and conservation row crop, respectively). No other differences among systems or depths were observed for field capacity. Fesha et al. (2002) also found water content at field capacity and wilting point (0-20 cm) to be highest for pastures relative to planted pine and row crop management for Alabama Coastal Plain Typic Paleudults.

The AWHC of these soils were significantly affected by LM (*P*=0.0331), depth (*P*=0.0005), and their interaction (*P*=0.0060) (Table 12). The AWHC (0-6 cm) of pasture sites (0.10 kg kg^{-1}) was significantly higher than all other LMs, with planted pine (0.08 kg kg^{-1}) also higher than the conventional row crop system (0.06 kg kg^{-1}). When comparing AWHC from 0-21 cm, the conventional row crop system (0.05 kg kg^{-1}) was lower than the forested (0.07 kg kg^{-1}) and pasture sites (0.08 kg kg^{-1}) (Table 12). Zhou et al. (2008) also found pasture sites had higher AWHC relative to row crop and forested systems for Typic Hapludults in the Northern U.S. Piedmont. Relative increases in AWHC across LMs were likely due to higher SOM contents.

Soil Water Retention

Retention parameters (Θ_s, Θ_r, α, and n) and associated coefficient of determinations from least squares fitting of soil water retention curves from RETC are found in Table 13. Coefficient of determinations for all site-depth combinations indicate retention models adequately fit the observed data (R^2>0.98). Figures 2-3 and 2-4 illustrate retention curves by LM for surface (0-6 cm) and subsurface (15-21 cm) depths, respectively.

The air-entry value (the point at which desaturation begins) is inversely proportional to maximum pore size (Dane and Hopmans, 2002) and the van Genuchten shape parameter α (van Genuchten and Nielsen, 1985). The air-entry value can be identified on the retention curve as the instance the water content drops below Θ_s. The air-entry values (0-20 cm) for row crop systems were relatively higher than forest and pasture sites (Table 13, Figure 2-3, and Figure 2-4). The van Genuchten shape parameter *n* was highest for the conservation row crop system (1.64) at 0-6 cm, lowest for pasture sites (1.47) at 0-6 cm, and tended to increase with depth (Table 13). McVay et al. (2006) found similar trends for both shape parameters from a Mollisol (0-5 cm) with similar C concentrations under row crop and grassland systems. Intact root systems and increased SOC in pasture and forested sites may increase macroporosity and pore connectivity, requiring lower matric potentials to initiate desaturation relative to row crop systems.

Surface (0-6 cm) saturated water content (Θ_s) ranged from 0.32 (conventional) to 0.43 $m^3 m^{-3}$ (planted pine) (Table 13). The pasture surface Θ_s (0.41 $m^3 m^{-3}$) was similar to planted pine sites. At deeper depths (15-21 cm), Θ_s was less variable and ranged from 0.28 (conventional) to 0.33 $m^3 m^{-3}$ (pasture). Residual water content (Θ_r) from 0-20 cm was 38, 57, and 83% higher for pasture sites (0.11 $m^3 m^{-3}$) compared to conservation (0.08 $m^3 m^{-3}$), conventional (0.07 $m^3 m^{-3}$), and planted pine (0.06 $m^3 m^{-3}$), respectively. McVay et al. (2006) also found that Θ_s and Θ_r did not statistically differ among land use systems, but grassland was higher than both conventional and conservation row crop systems. Although tillage can increase soil porosity, C inputs can have greater effects (Kay and VandenBygaart, 2002).

Hydraulic and Soil Property Correlation

Overall, K_{sat} (for all depths) was significantly correlated to C pools [TOC (0.44), POMC (0.48), and AC (0.31)], WDC (-0.29), ρ_b (-0.62), silt and clay contents (0.62 and -0.41, respectively), and SS (-0.53) (Table 14). The positive correlation of C with K_{sat} is likely a function of increased porosity (and aggregation) with greater amounts of organic matter (Kay and VandenBygaart, 2002). The negative correlation among Ksat, ρ_b, and SS indicate that as compaction increases and porosity decreases, conductivity decreases. In addition, the percentage of soil separates and amount of WDC can affect mean soil pore size (e.g., decrease with increase in clay) and/or impact pore infilling, ultimately affecting K_{sat}.

Water content at field capacity (Θg, 10kPa) was significantly related to TOC (0.95), POMC (0.94), AC (0.85), WDC (-0.52) and ρ_b (-0.71). Positive (C pools) and negative (ρ_b and WDC) correlations among these properties are likely a product of porosity (increases in C tend to increase porosity; porosity decreases with increased ρ_b) and aggregate stability (increased WDC decreases aggregate stability). Similar relationships (although weaker) among management-dependent properties and water content at wilting point (Θg, 1.5MPa) were observed (Table 14). Weaker correlations of Θg at 1.5MPa relative to Θg at 10kPa among the C pools, ρ_b, and WDC indicate the dominant influence of porosity and aggregation on field capacity. Conversely, the stronger correlation of Θg at 1.5MPa to texture indicates the relative dependence of wilting point on soil texture.

The AWHC was significantly correlated to all measured management-dependent properties except soil strength (Table 14). Positive correlations were observed with TOC (0.89), POMC (0.90), AC (0.93), and WSA (0.63), while a negative correlation existed with ρ_b (-0.81). Because AWHC is calculated from both field capacity and wilting points, similar relationships would be expected. We found AWHC decreased 2.38 g kg^{-1} with every reduction of 1.0 g TOC, which is similar to the relationship reported by the Soil Survey Investigations Staff (1995) (1.0 g organic C ≈ 3.5 and 1.5 g H_2O at 33 and 1500 kPa, respectively).

The van Genuchten moisture retention curve parameters exhibited minimal correlation with management-dependent soil properties (Table 14). Soil strength (-0.48) was the sole parameter correlated with α. The negative relationship between SS and α indicates that as compaction increases, the air-entry value does as well (air-entry value is the inverse of α). There were no significant correlations among *n* and investigated soil properties.

Regression Analysis

Regression based algorithms were developed to characterize relationships among near-surface hydraulic properties and other more readily measurable soil properties. Management-dependent and use-invariant properties were used to develop seven models that described variability of K_{sat} and soil water retention parameters. Of the two management-dependent models developed, Model 1 included WSA as an independent parameter. Two use-invariant models were developed: Model 3 used actual measured mineralogy data, where Model 4 used CEC and ECEC (expressed on a clay basis), as these data are more readily measured and can be used to infer soil mineralogy. Models 5, 6, and 7 used both management-dependent and use-invariant properties as regressors. Comparisons were made among models to distinguish which type, or combination, of parameters could be used to best predict near-surface hydraulic properties.

Management-dependent

The regression equation describing K_{sat} at 15 cm using management-dependent properties included TOC, WSA, and ρ_b (Model 1; Table 15). The model had an $R^2 = 0.69$ and RMSE = 4.26 with 58, 8, and 3% of the variation explained by ρ_b, WSA, and TOC, respectively. The conductivities at 30 and 50 cm (Model 2; Table 15) were described less efficiently ($R^2 = 0.50$ and 0.28, respectively). The variation in K_{sat} at 30 cm was explained by SS (7%), WDC (8%), and ρ_b (35%), where TOC described 28% of the K_{sat} variability at 50 cm. Lower amounts of described K_{sat} variability by management-dependant properties at 50 cm is likely due to less impacts of management at this depth. Across all depths, K_{sat} variability was described ($R^2 = 0.50$; RMSE = 3.49) by SS (5%), TOC (8%), and ρ_b (37%) (Table 15). Similarly, Fesha (2004) found that SS and TOC were significant variables accounting for variability in K_{sat} (0-20 cm) for some Alabama Typic Paleudults.

Total soil organic carbon explained the majority of the variability for surface (0-6 cm) and subsurface (15-21) water contents at field capacity ($\Theta_{g\ 10\ kPa}$) (Table 15). Model 1 estimated surface $\Theta_{g\ 10kPa}$ well ($R^2 = 0.85$; RMSE = 0.025), with TOC describing all the variability. Subsurface $\Theta_{g\ 10kPa}$ was explained moderately well using Model 2 ($R^2 = 0.54$ and RMSE = 0.013), with 39 and 14% of the variability described by TOC and WDC, respectively. The variability in the surface water content at wilting point ($\Theta_{g\ 1.5MPa}$) was described by TOC (70%) and ρ_b (4%). The model described the variability well (R^2 =

0.74), but the RMSE (0.025) was relatively high. Similar to our findings, Rawls et al. (2004) reported six studies that found TOC to explain much of the variability in field capacity and wilting point water contents.

As a whole, the variability in retention curve parameters α and n was not accounted for using management-dependent properties within the investigated map unit. Soil strength was the sole parameter to describe α at 0-6 cm. The regression model had an $R^2 = 0.27$ and a RMSE = 0.024 (Table 15). There were no significant regression equations for n developed by Models 1 or 2 (Table 15). Dashtaki et al. (2010) also developed PTFs relating van Genuchten parameters to ρ_b. Similar to our results, the authors had greater success describing α rather than n, and found the variability of α was partially explained by ρ_b.

Use-invariant

Although it is well recognized texture distribution with depth is affected by management (e.g., tillage), the overall texture distribution with depth for these soils did not vary greatly between the natural and agroecosystems. In addition, considering texture changes due to weathering are minimal, we considered texture and mineralogy to be less dynamic and management-dependent (i.e., use-invariant) than properties mentioned above.

Across all depths, texture and mineralogy somewhat poorly described the variability in K_{sat} ($R^2 = 0.38$; RMSE = 0.64) (Model 3; Table 16). Most of the variability was described by clay content (26%). Similarly, Puckett et al. (1985) found clay content was the best estimator of K_{sat} for Alabama Coastal Plain soils. The variation in K_{sat} for all depths was described moderately well ($R^2 = 0.48$; RMSE = 3.58) using CEC (33%) and

ECEC (14%) expressed on a clay basis (Model 4). This model also adequately explained the variability in K_{sat} at 30 cm (R^2 0.70) (Table 16). Clay and ECEC (on a clay basis) each elucidated 34% of the variability at this depth.

The variability in $\Theta_{g\ 10\ kPa}$ and $\Theta_{g\ 1.5MPa}$ was described adequately using Model 4 (R^2 ranged from 0.45-0.74; RMSE ranged from 0.01-0.04) (Table 16). Clay content described the majority of $\Theta_{g\ 1.5MPa}$ variation at both depths and $\Theta_{g\ 10\ kPa}$ variation at 15-21 cm. Surface (0-6 cm) $\Theta_{g\ 1.5MPa}$ and $\Theta_{g\ 10\ kPa}$ were best estimated by sand and clay contents and CEC (clay basis), where clay content and CEC alone were the best regressors at 15-21 cm. Pachepsky and Rawls (1999) also found CEC on a clay basis to be a vital component of field capacity and wilting point estimation. Use-invariant data were of little use for predicting the van Genuchten shape parameters.

Management-dependent versus Use-invariant

Considering K_{sat} across all depths, texture and exchange capacity (clay basis) (Model 4; R^2 = 0.48 and RMSE = 3.58) described slightly less variability than the investigated management-dependent properties (Model 2; R^2 = 0.50 and RMSE = 3.49). However, texture and measured mineralogy (Model 3) had a much lower RMSE (0.644). Taking depth into consideration, the variability in K_{sat} was explained better by management-dependent properties at 15 and 50cm and by use-invariant properties at 30 cm [Models 1 and 2 (Table 15) versus Model 4 (Table 16)].

Surface (0-6 cm) $\Theta_{g\ 10\ kPa}$ and $\Theta_{g\ 1.5MPa}$ were the best predicted parameters across all models with R^2 values ranging from 0.59 to 0.85 (Tables 15 and 16). Management-dependent properties better described surface $\Theta_{g\ 10\ kPa}$ (R^2 = 0.85 and RMSE = 0.025) relative to use-invariant properties (R^2 = 0.59 and RMSE = 0.043). For surface $\Theta_{g\ 1.5MPa}$, models based on management-dependent and use-invariant properties were comparable (R^2 = 0.74 and RMSE = 0.025 versus R^2 = 0.74 and RMSE = 0.026, respectively). There was little difference between the models developed from either management-dependent (Model 2) or use-invariant (Model 4) properties for $\Theta_{g\ 10\ kPa}$ and $\Theta_{g\ 1.5MPa}$ at 15-21 cm (Tables 15 and 16). Although all models did poorly, management-dependent properties (Model 1) described relatively more variability of α.

Management-dependent and Use-invariant

The regression equations developed from a combination of management-dependent and use-invariant soil properties (Models 5, 6, and 7) are found in Table 17. Using a combination of management-dependent and use-invariant properties as regressors, more variability of $\Theta_{g\ 1.5MPa}$ (at both depths) was described [R^2 = 0.87 (0-6 cm) and R^2 = 0.47 (15-21 cm)]. A better relationship with α (0-6 cm) was also observed, as the R^2 value increased from 0.12 (use-invariant) and 0.27 (management-dependent) to 0.36 (management-dependent and use-invariant). Similarly, the highest R^2 (0.61) and lowest RMSE (0.53) for K_{sat} (Model 7) used a combination of management-dependent and use-invariant properties. Most of this variability was described by TOC (47%) and sand content (5%).

Conclusions

Considerable systematic variation of near-surface hydraulic properties was observed as a function of land use system in this prime farmland map unit of the Wiregrass region. Saturated hydraulic conductivity was significantly affected by land use at the 15 and 50 cm depths. The native vegetation (longleaf pine forest) had the highest conductivities at these depths, while management systems with higher soil compaction had the lowest conductivities. The available water holding capacity in surface horizons was also significantly affected by land use. The available water holding capacity at the surface (0-6 cm) was highest for pasture sites, intermediate for planted pine sites, and lowest for the conventional row crop system. Soil water retention parameters (e.g., saturated volumetric water content and α) were not significantly different among land use systems, however, pasture and forested sites tended to have higher surface porosity and lower air-entry values.

Significant correlation was observed among some near-surface hydraulic and dynamic and use-invariant soil properties. Saturated hydraulic conductivity at the soil surface was related to carbon pools, bulk density, texture, and soil strength, suggesting the role of porosity on saturated hydraulic conductivity. Field capacity, wilting point, and available water holding capacity were correlated with most of management-dependent properties investigated. Strong correlations were observed with the carbon pools and bulk density, where water stable aggregates and water dispersible clay had weaker relations with hydraulic parameters. The van Genuchten shape parameter α was correlated to soil strength, indicating compaction reduces the air-entry value for these soils.

Regression-based algorithms were developed to relate surface hydraulic properties to more readily measured properties with varying degrees of success. Overall, the developed equations explained surface (0-15 cm) relations better than deeper depths for the investigated map unit. Variability in surface (0-6 cm) field capacity and wilting point water contents was best described with our developed regression equations, with management-dependent properties being best suited for independent parameters. While using solely management-dependent or use-invariant properties to develop models, saturated hydraulic conductivity at 30 cm was best described by use-invariant soil properties. Collectively, the combination of use-invariant and management-dependent properties described the most variability of saturated hydraulic conductivity and other properties. In aggregate, depending on the parameter of interest, both management-dependent and use-invariant data equally estimate near-surface hydraulic properties. However, models developed from the combination of the two outperform and should be used when direct measurements are unavailable.

Current goals of the National Cooperative Soil Survey include improvement of soil interpretations within the context of anthropogenic soil change. Near-surface soil hydraulic properties are of utmost importance due to their wide use in soil interpretations and overall role in ecosystem productivity. For a benchmark soil map unit, we found considerable systematic variation of soil hydraulic properties as a function of natural and agroecosystem, much of which is anthropogenically induced. As the characterization of near-surface soil hydraulic properties and inventory of management-dependent properties continues, more reliable and accurate soil databases, land interpretations, and management schemes can be developed that consider anthropogenic effects.

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Table 10. Pedon and site identification, long-term land use/management (LM), classification and coordinates of investigated soils in the Wiregrass region of the Alabama Coastal Plain.

Pedon ID	Site ID	LM†	Taxonomic Classification‡	Latitude	Longitude
S2009AL-067-2	CRC	Conservation	Fine-loamy, kaolinitic, thermic Plinthic Kandiudult	31°22'44.2"N	85°18'47.8"W
S2009AL-061-4	RC1	Conventional	Fine-loamy, kaolinitic, thermic Plinthic Kandiudult	31°4'25.9"N	85°39'32.6"W
S2009AL-067-4	RC2	Conventional	Fine-loamy, kaolinitic, thermic Plinthic Kandiudult	31°25'54.6"N	85°21'28.9"W
S2009AL-067-5	RC3	Conventional	Fine-loamy, kaolinitic, thermic Plinthic Kandiudult	31°24'26.7"N	85°20'30.4"W
S2010AL-039-1	LL1	Longleaf	Fine-loamy, kaolinitic, thermic Plinthic Kandiudult	31°6'6"N	86°33'41"W
S2010AL-039-2	LL2	Longleaf	Fine-loamy, kaolinitic, thermic Plinthic Kandiudult	31°9'59"N	86°35'5"W
S2010AL-039-4	LL3	Longleaf	Fine-loamy, kaolinitic, thermic Plinthic Kandiudult	31°6'60"N	86°33'22"W
S2009AL-061-3	P1	Pasture	Fine-loamy, kaolinitic, thermic Plinthic Kandiudult	31°7'21.6"N	85°40'9.2"W
S2009AL-061-1	P2	Pasture	Fine-loamy, kaolinitic, thermic Plinthic Kandiudult	31°4'18.6"N	85°40'45.8"W
S2009AL-067-3	P3	Pasture	Fine-loamy, kaolinitic, thermic Plinthic Kandiudalf§	31°21'1.7"N	85°19'17.1"W
S2009AL-067-1	PP1	Planted Pine	Fine-loamy, kaolinitic, thermic Plinthic Kandiudult	31°19'4.6"N	85°24'32"W
S2009AL-069-1	PP2	Planted Pine	Fine-loamy, kaolinitic, thermic Plinthic Kandiudult	31°8'49.5"N	85°12'41.7"W
S2009AL-061-2	PP3	Planted Pine	Fine-loamy, kaolinitic, thermic Plinthic Kandiudult	31°4'18.6"N	85°41'22.4"W

† Conservation = conservation row crop system; Conventional = conventional row crop system; Longleaf = longleaf pine/wiregrass forest; Pasture = grazed pasture system; Planted pine = managed pine plantation.

‡ As per Soil Taxonomy (Soil Survey Staff, 2010).

§ Verified cultural Alfisol.

Table 11. Saturated hydraulic conductivities (K_{sat}) averaged by depth for three repetitions (one conservation row crop system) of Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils within five long-term land use/managements (LM) in the Wiregrass region of the Alabama Coastal Plain. Numbers with the same letter are not significantly different at the 0.05 confidence level.

LM†	K_{sat}		
	15 cm	30 cm	50 cm
	cm hr^{-1}		
Conservation	0.50 b	0.17	1.70 a
Conventional	1.56 b	0.14	0.80 b
Longleaf	16.86 a	3.03	2.11 a
Pasture	1.50 b	0.18	0.47 b
Planted pine	4.57 b	1.49	0.54 b
ANOVA	P > F		
Land use/management (LM)	0.0002	0.0940	0.0001

† Conservation = conservation row crop system; Conventional = conventional row crop system; Longleaf = longleaf pine/wiregrass forest; Pasture = grazed pasture system; Planted pine = managed pine plantation.

Table 12. Select soil hydraulic properties averaged by depth for three repetitions (one conservation row crop system) of Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils within four long-term land use/managements (LM) in the Wiregrass region of the Alabama Coastal Plain.

LM†	Depth	$\Theta_{g,\ 10kPa}$‡		$\Theta_{g,\ 1.5\ MPa}$		AWHC	
	cm	-----------------------------	--------------	kg kg^{-1}	--------------	-----------------------------	
Conservation	0 - 6	0.11 b§	0.10	0.04	0.04	0.06 bc	0.06 ab¶
	15 - 21	0.10 A		0.04		0.06 A	
Conventional	0 - 6	0.10 b	0.09	0.04	0.04	0.06 c	0.05 b
	15 - 21	0.09 A		0.04		0.05 A	
Pasture	0 - 6	0.21 a	0.16	0.10	0.08	0.10 a	0.08 a
	15 - 21	0.11 A		0.06		0.05 A	
Planted pine	0 - 6	0.13 ab	0.11	0.05	0.04	0.08 b	0.07 a
	15 - 21	0.09 A		0.04		0.05 A	
ANOVA		--------------------	--------------------	$P > F$	--------------------	--------------------	
Land use/management (LM)		0.1031		0.1966		0.0331	
Depth (D)		0.0565		0.5004		0.0005	
LM*D		0.0045		0.0559		0.0060	

† Conservation = conservation row crop system; Conventional = conventional row crop system; Pasture = grazed pasture system; Planted pine = managed pine plantation.

‡ $\Theta_{g,\ 10kPa}$ = gravimetric soil water content at field capacity (at 0 and 15 cm depths); $\Theta_{g,\ 1.5\ MPa}$ = gravimetric soil water content at the wilting point (at 0 and 15 cm depths); AWHC = available water holding capacity ($\Theta_{g,\ 10kPa}$ - $\Theta_{g,\ 1.5\ MPa}$).

§ Simple effect comparisons of LM LS-means by 0 - 6 cm (lowercase) and 15 - 21 cm (uppercase) depths; numbers with the same letter are not significantly different at the 0.05 confidence level.

¶ Main effect comparisons of LM LS-means; numbers with the same letter are not significantly different at the 0.05 confidence level.

Table 13. Soil water retention parameters averaged by depth for three repetitions (one conservation row crop system) of Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils within four long-term land use/managements (LM) in the Wiregrass region of the Alabama Coastal Plain.

LM†	Depth	Θ_s‡		Θ_r		α		*n*		r^2
	cm	----------------------------m^3 m^{-3}		----------------------------						
Conservation	0 - 6	0.33	0.31	0.09	0.08	0.03	0.03	1.64	1.57	0.983
	15 - 21	0.29		0.07		0.03		1.51		0.985
Conventional	0 - 6	0.32	0.30	0.07	0.07	0.06	0.05	1.53	1.56	0.982
	15 - 21	0.28		0.07		0.04		1.54		0.992
Pasture	0 - 6	0.41	0.37	0.13	0.11	0.04	0.05	1.47	1.54	0.995
	15 - 21	0.33		0.09		0.05		1.57		0.995
Planted pine	0 - 6	0.43	0.37	0.06	0.06	0.08	0.06	1.55	1.52	0.995
	15 - 21	0.31		0.06		0.05		1.57		0.990
ANOVA		--		P > F		--				
Land use/management (LM)		0.0908		0.2822		0.2254		0.9345		
Depth (D)		0.0375		0.2248		0.3359		1.0000		
LM*D		0.0649		0.1508		0.0665		0.4196		

† Conservation = conservation row crop system; Conventional = conventional row crop system; Pasture = grazed pasture system; Planted pine = managed pine plantation.

‡ Θ_s = saturated volumetric water content (assumed equivalent to satiated volumetric water content); Θ_r = residual volumetric water content (assumed equivalent to volumetric water content at wilting point (1.5MPa); α and *n*= fitted (via RETC) van Genuchten empirical shape parameters; r^2 = coefficient of determination for regression of observed versus fitted values.

Table 14. Pearson linear correlation coefficients among select hydraulic, chemical, and physical soil properties across all applicable depths (see Materials and Methods) for thirteen repetitions of Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils within five long-term land use/managements (LM) in the Wiregrass region of the Alabama Coastal Plain.

†	K_{sat}	Θ_{g10}‡	$\Theta_{g, 1.5}$	AWHC	Θ_s	Θ_r	α	*n*	TOC	POMC	AC	CEC	WSA	WDC	ρ_b	Sand	Silt	Clay
K_{sat}	1																	
$\Theta_{g, 10}$	0.13	1																
$\Theta_{g, 1.5}$	-0.06	***0.94***§	1															
AWHC	0.40	***0.84***	***0.60***	1														
Θ_s	***0.62***	***0.71***	***0.55***	***0.79***	1													
Θ_r	-0.20	***0.90***	***0.98***	***0.55***	0.42	1												
α	***0.57***	-0.09	-0.18	0.07	***0.45***	-0.32	1											
n	0.08	-0.34	-0.25	-0.40	-0.06	-0.28	-0.01	1										
TOC	***0.44***	***0.95***	***0.84***	***0.89***	***0.80***	***0.78***	-0.05	-0.23	1									
POMC	***0.48***	***0.94***	***0.82***	***0.90***	***0.80***	***0.76***	-0.02	-0.24	***0.98***	1								
AC	***0.31***	***0.85***	***0.67***	***0.93***	***0.83***	***0.62***	0.06	-0.27	***0.92***	***0.88***	1							
CEC	0.22	***0.94***	***0.94***	***0.71***	***0.63***	***0.91***	-0.19	-0.25	***0.89***	***0.84***	***0.75***	1						
WSA	-0.09	0.50	0.37	***0.63***	0.35	0.39	-0.39	-0.19	0.08	0.02	0.26	0.10	1					
WDC	***-0.29***	***-0.52***	-0.31	***-0.71***	***-0.62***	-0.25	-0.19	0.24	***-0.33***	***-0.33***	***-0.40***	-0.20	0.05	1				
ρ_b	***-0.62***	***-0.71***	***-0.53***	***-0.81***	***-0.90***	***-0.44***	-0.30	0.06	***-0.69***	***-0.75***	***-0.62***	***-0.55***	0.00	***0.49***	1			
Sand	0.08	-0.01	-0.18	0.26	0.30	-0.26	0.38	-0.13	***0.27***	0.19	***0.42***	-0.01	-0.31	-0.08	0.11	1		
Silt	***0.62***	0.05	0.01	0.09	0.01	0.03	-0.27	0.21	0.23	***0.31***	0.06	0.18	0.06	***-0.30***	***-0.57***	***-0.30***	1	
Clay	***-0.41***	-0.01	0.18	-0.31	-0.31	0.25	-0.26	0.04	***-0.40***	***-0.36***	***-0.44***	-0.08	0.37	0.24	0.19	***-0.86***	-0.22	1
SS	***-0.53***	-0.04	0.06	-0.18	-0.43	0.14	***-0.48***	0.03	***-0.33***	***-0.40***	-0.11	-0.23	***0.54***	0.25	***0.57***	-0.01	***-0.32***	0.18

† K_{sat} = saturated hydraulic conductivity (cm hr^{-1}); $\Theta_{g, 10}$ and $\Theta_{g, 1.5}$ = gravimetric soil water content at field capacity (10 kPa) and wilting point (1.5MPa), respectively (kg kg^{-1}); AWHC = available water holding capacity ($\Theta_{g, 10kPa}$ - $\Theta_{g, 1.5 MPa}$); Θ_s = saturated volumetric water content (m^3 m^{-3}; assumed equivalent to satiated volumetric water content); Θ_r = residual volumetric water content (m^3 m^{-3}; assumed equivalent to volumetric water content at wilting point (1.5MPa); α and *n* = fitted (via RETC) van Genuchten empirical shape parameters; TOC = total soil organic carbon (g kg^{-1}); POMC = particulate organic matter (>53 μm) associated carbon (g kg^{-1}); AC = Active Carbon (mg kg^{-1}); CEC = NH_4AOc, pH7 cation exchange capacity ($cmol_c$ kg $soil^{-1}$);WSA = percent water stable aggregates; WDC = percent water dispersible clay; ρ_b = soil bulk density (Mg m^{-3}); Sand, Silt, and Clay = percent particle size separates (0.05-2.0, 0.002-0.05, <0.002 mm, respectively); SS = soil strength (kPa).

‡ $\Theta_{g, 10}$, $\Theta g_{1.5}$, AWHC, Θ_s, Θ_r, α, *n*, and AC sampled for 10 replications of Dothan soils within four LM (see Materials and Methods).

§ Coefficients in bold and italic font are significant at the 0.05 confidence level.

Table 15. Coefficient of determination (R^2) and root mean square error (RMSE) for regression models relating soil hydraulic properties to physical and chemical management-dependent soil properties for thirteen (Ksat) or ten (Θg, α, and n) repetitions of Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils across long-term land use/managements (LM) in the Wiregrass region of the Alabama Coastal Plain.

Dependent parameter†	units	Model‡	R^2	RMSE	*P*-value
		<u>Model 1</u>			
$K_{sat,\ 15}$	cm hr^{-1}	104.74 - (0.44*TOC) - (74.13*ρ_b) - (0.29*WSA)	0.69	4.262	<.0001
$\Theta_{g\ 10\ kPa}$ (0-6 cm)	kg kg^{-1}	0.049 + (0.006*TOC)	0.85	0.025	<.0001
$\Theta_{g\ 1.5\ MPa}$ (0-6 cm)	kg kg^{-1}	-0.119 + (0.005*TOC) + (0.075*ρ_b)	0.74	0.025	<.0001
α (0-6 cm)		0.084 + (0.021*SS)	0.27	0.024	0.0201
n (0-6 cm)		ns			
		<u>Model 2</u>			
$K_{sat,\ 30}$	cm hr^{-1}	12.01 - (0.86*SS) - (4.57*ρ_b) - (0.22*WDC)	0.50	1.367	<.0001
$K_{sat,\ 50}$	cm hr^{-1}	3.40 - (0.71*TOC)	0.28	0.824	0.0006
K_{sat}	cm hr^{-1}	21.78 - (1.84*SS) + (0.35*TOC) - (12.17*ρ_b)	0.50	3.493	<.0001
$\Theta_{g\ 10\ kPa}$ (15-21 cm)	kg kg^{-1}	-0.040 + (0.020*TOC) + (0.003*WDC)	0.54	0.013	0.0013
$\Theta_{g\ 1.5\ MPa}$ (15-21 cm)	kg kg^{-1}	0.129 + (0.002*WDC) + (0.011*SS) - (0.076*ρ_b)	0.42	0.012	0.0298
α (15-21 cm)		ns			
n (15-21 cm)		ns			

† $K_{sat,\ 15}$, $K_{sat,\ 30}$, and $K_{sat,\ 50}$ = saturated hydraulic conductivity at 15, 30, and 50 cm, respectively; K_{sat} = saturated hydraulic conductivity across all depths; $\Theta_{g\ 10\ kPa}$ and $\Theta_{g\ 1.5\ MPa}$ = gravimetric water contents at field capacity (10 kPa) and wilting point (1.5 MPa), respectively; α and n = fitted (via RETC) van Genuchten empirical shape parameters.

‡ Model 1 = model developed using total soil organic carbon (TOC; g kg^{-1}), soil bulk density (ρ_b; Mg m^{-3}), percent water dispersible clay (WDC), percent water stable aggregates (WSA) and soil strength (SS; MPa) at associated depth; Model 2 = model developed using TOC, WDC, ρ_b, and SS.

Table 16. Coefficient of determination (R^2) and root mean square error (RMSE) for regression models relating soil hydraulic properties to physical, chemical, and mineralogical use-invariant soil properties for thirteen (Ksat) or ten (Θg, α, and n) repetitions of Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils across long-term land use/managements (LM) in the Wiregrass region of the Alabama Coastal Plain.

Dependent parameter†	units	Model‡	R^2	RMSE	*P*-value
		Model 3			
K_{sat}	cm hr^{-1}	17.17 – (0.18*Sand) - (0.17*Clay) - (0.32*Fe_2O_3)	0.38	0.644	<.0001
		Model 4			
$K_{sat, 15}$	cm hr^{-1}	196.17 - (2.08*Sand) - (3.50*Clay)	0.33	4.910	<.0001
$K_{sat, 30}$	cm hr^{-1}	5.69 - (0.20*Clay) + (0.07*CEC) - (0.20*ECEC)	0.70	1.056	<.0001
$K_{sat, 50}$	cm hr^{-1}	ns			
K_{sat}	cm hr^{-1}	-0.22 + (0.24*CEC) - (0.24*ECEC)	0.48	3.580	<.0001
$\Theta_{g\ 10\ kPa}$ (0-6 cm)	kg kg^{-1}	-1.900 + (0.019*Sand) + (0.050*Clay) + (0.003*CEC)	0.59	0.043	0.0020
$\Theta_{g\ 10\ kPa}$ (15-21 cm)	kg kg^{-1}	0.0002 + (0.008*Clay) + (0.0008*CEC)	0.60	0.013	0.0004
$\Theta_{g\ 1.5\ MPa}$ (0-6 cm)	kg kg^{-1}	-1.685 + (0.017*Sand) + (0.04*Clay) + (0.003*CEC)	0.74	0.026	<.0001
$\Theta_{g\ 1.5\ MPa}$ (15-21 cm)	kg kg^{-1}	-0.025 + (0.007*Clay) + (0.0004*CEC)	0.45	0.012	0.0063
α (0-6 cm)		0.108 - (0.007*Clay)	0.12	0.027	0.1373
α (15-21 cm)		ns			
n (0-6 cm)		ns			
n (15-21 cm)		ns			

† $K_{sat, 15}$, $K_{sat, 30}$, and $K_{sat, 50}$ = saturated hydraulic conductivity at 15, 30, and 50 cm, respectively; K_{sat} = saturated hydraulic conductivity across all depths; $\Theta_{g\ 10\ kPa}$ and $\Theta_{g\ 1.5\ MPa}$ = gravimetric water contents at field capacity (10 kPa) and wilting point (1.5 MPa), respectively; α and n = fitted (via RETC) van Genuchten empirical shape parameters.

‡ Model 3 = model developed using percent soil particle size separates Sand and Clay (0.05 - 2.0 and <0.002 mm, respectively), percent gibbsite (Gibbsite), percent kaolinite (Kaolinite), and percent iron oxides (Fe_2O_3); Model 4 = model developed using Sand, Clay, effective cation exchange capacity on a clay basis (ECEC), and cation exchange capacity on a clay basis (CEC).

Table 17. Coefficient of determination (R^2) and root mean square error (RMSE) for regression models relating soil hydraulic properties to management-dependent and use-invariant soil properties for thirteen (K_{sat}) or ten (Θ_g, α, and n) repetitions of Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils across long-term land use/managements (LM) in the Wiregrass region of the Alabama Coastal Plain.

Dependent parameter†	units	Model‡	R^2	RMSE	*P*-value
		Model 5			
$K_{sat,\ 15}$	cm hr^{-1}	77.49 - (0.76*TOC) - (50.09*ρ_b) + (1.10*WDC) + (0.09*CEC)	0.67	3.916	<.0001
$\Theta_{g\ 10\ kPa}$ (0-6 cm)	kg kg^{-1}	0.049 + (0.006*TOC)	0.85	0.025	<.0001
$\Theta_{g\ 1.5\ MPa}$ (0-6 cm)	kg kg^{-1}	-0.963 + (0.009*Sand) + (0.027*Clay) + (0.001*ECEC) + (0.001*CEC) + (0.002*TOC)	0.87	0.020	<.0001
α (0-6 cm)		0.117 - (0.0001*CEC) - (0.025*SS)	0.36	0.023	0.0224
n (0-6 cm)		ns			
		Model 6			
$K_{sat,\ 30}$	cm hr^{-1}	6.29 - (0.16*Clay) + (0.10*CEC) - (0.18*ECEC) - (0.89*SS)	0.40	0.997	<.0001
$K_{sat,\ 50}$	cm hr^{-1}	14.96 - (0.13*Sand) – (0.14*Clay) - (0.06*ECEC) - (0.56*TOC)	0.46	0.730	<.0001
K_{sat}	cm hr^{-1}	0.138 + (0.15*TOC) – (7.04*ρ_b) – (1.10*SS) + (0.16*CEC) – (0.17*ECEC)	0.62	3.080	<.0001
$\Theta_{g\ 10\ kPa}$ (15-21 cm)	kg kg^{-1}	-0.040 + (0.020*TOC) + (0.003*WDC)	0.54	0.013	0.0013
$\Theta_{g\ 1.5\ MPa}$ (15-21 cm)	kg kg^{-1}	0.143 - (0.082*ρ_b) + (0.020*SS) – (0.001*CEC)	0.47	0.012	0.0024
α (15-21 cm)		ns			
n (15-21 cm)		ns			
		Model 7			
K_{sat}	cm hr^{-1}	14.14 – (0.33*TOC) + (1.24*ρ_b) – (0.49*SS) – (0.14*Sand) – (0.17*Clay)	0.61	0.526	<.0001

† $K_{sat,\ 15}$, $K_{sat,\ 30}$, and $K_{sat,\ 50}$ = saturated hydraulic conductivity at 15, 30, and 50 cm, respectively; K_{sat} = saturated hydraulic conductivity across all depths; $\Theta_{g\ 10\ kPa}$ and $\Theta_{g\ 1.5\ MPa}$ = gravimetric water contents at field capacity (10 kPa) and wilting point (1.5 MPa), respectively; α and n = fitted (via RETC) van Genuchten empirical shape parameters.

‡ Model 5 = model developed using total soil organic carbon (TOC; g kg^{-1}), soil bulk density (ρ_b; Mg m^{-3}), percent water dispersible clay (WDC), percent water stable aggregates (WSA), soil strength (SS; MPa), percent soil particle size separates Sand and Clay (0.05 - 2.0 and <0.002 mm, respectively), effective cation exchange capacity on a clay basis (ECEC), and cation exchange capacity on a clay basis (CEC); Model 6 = model developed using TOC, ρ_b, WDC, SS, Sand, Clay, ECEC, and CEC; Model 7 = model developed using TOC, ρ_b, WDC, SS, Sand, Clay, percent gibbsite (Gibbsite), percent kaolinite (Kaolinite), and percent iron oxides (Fe_2O_3).

Figures

Figure 2-1. Study site locations with associated Level IV ecoregions of the Alabama Coastal Plain; CRC = conservation row crop system; RC = conventional row crop system; LL = longleaf pine/wiregrass forest; Pasture = grazed pasture system; PP = managed pine plantation.

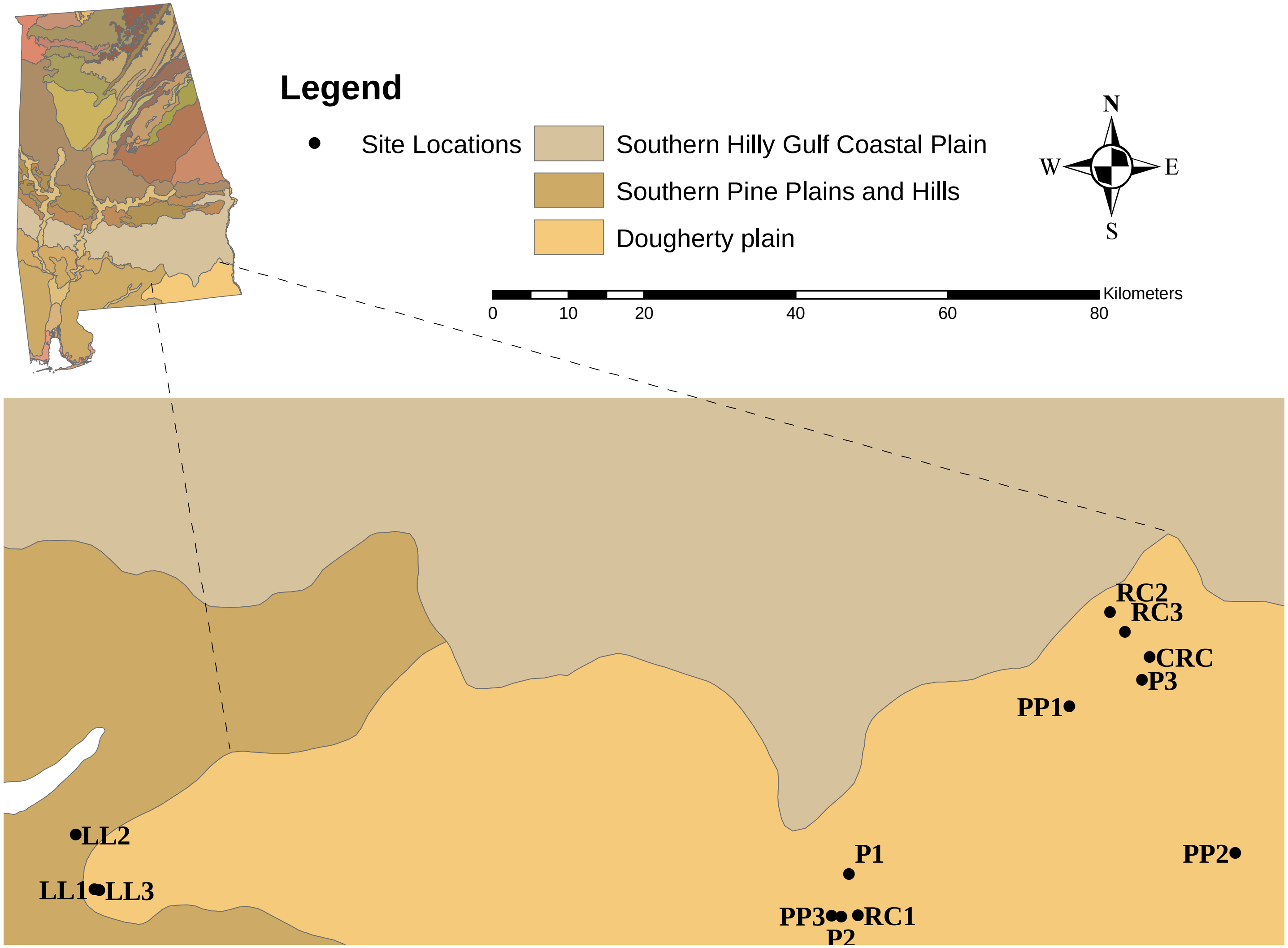


Figure 2-2. Saturated hydraulic conductivity (K_{sat}) averaged by depth (measured at 15, 30, and 50 cm; cm hr^{-1}) for three repetitions (one conservation row crop system) of Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils within five long-term land use/managements (LM) of the Alabama Coastal Plain. Bars represent Fisher's LSD at a confidence level of 0.05. Pasture = grazed pasture system; Planted pine = managed pine plantation; Conventional = conventional row crop system; Conservation = conservation row crop system; Longleaf = longleaf pine/wiregrass forest.

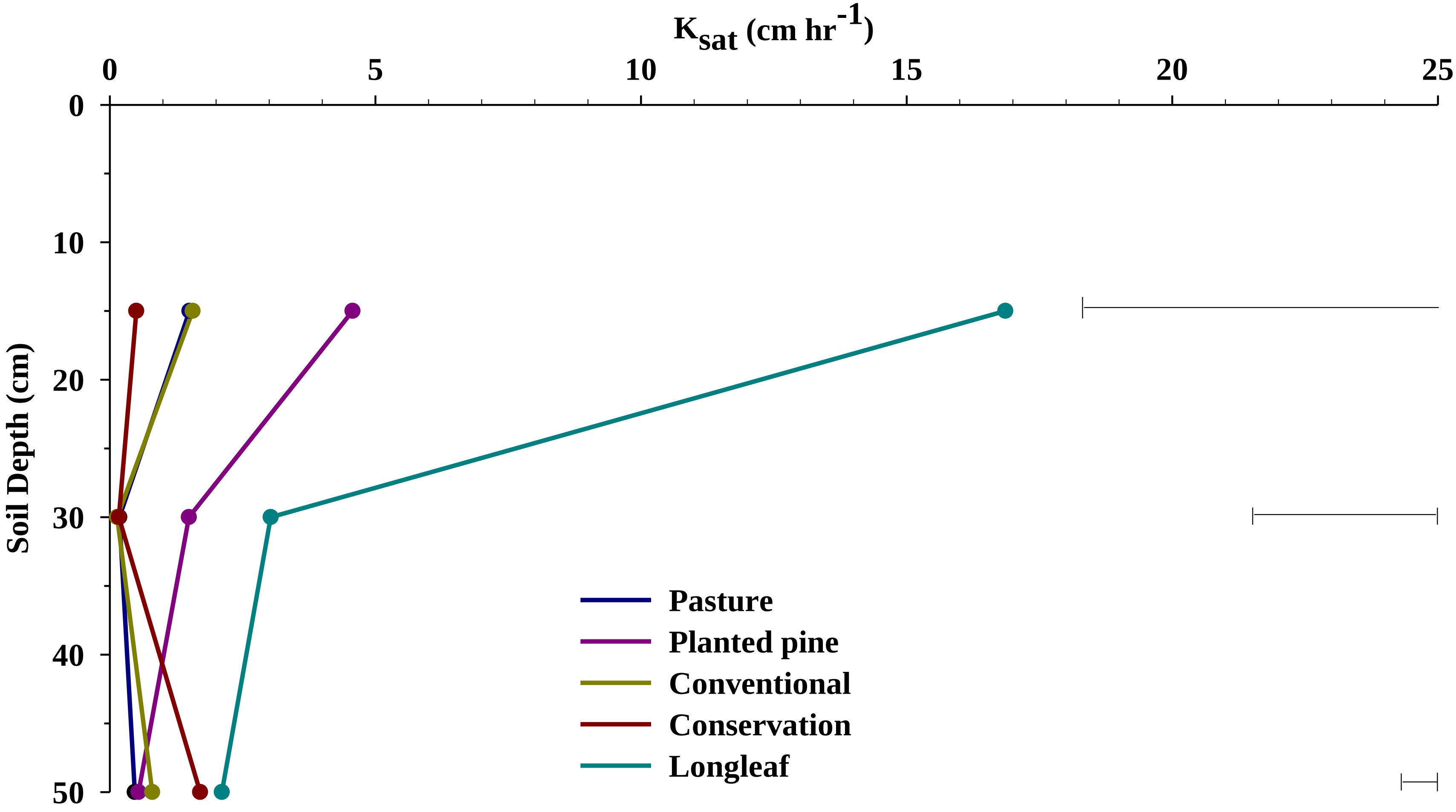


Figure 2-3. Soil water retention curves (via RETC) (0-6 cm) averaged for three repetitions (one conservation row crop system) of Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils within four long-term land use/managements (LM) of the Alabama Coastal Plain. Pasture = grazed pasture system; Planted pine = managed pine plantation; Conventional = conventional row crop system; Conservation = conservation row crop system.

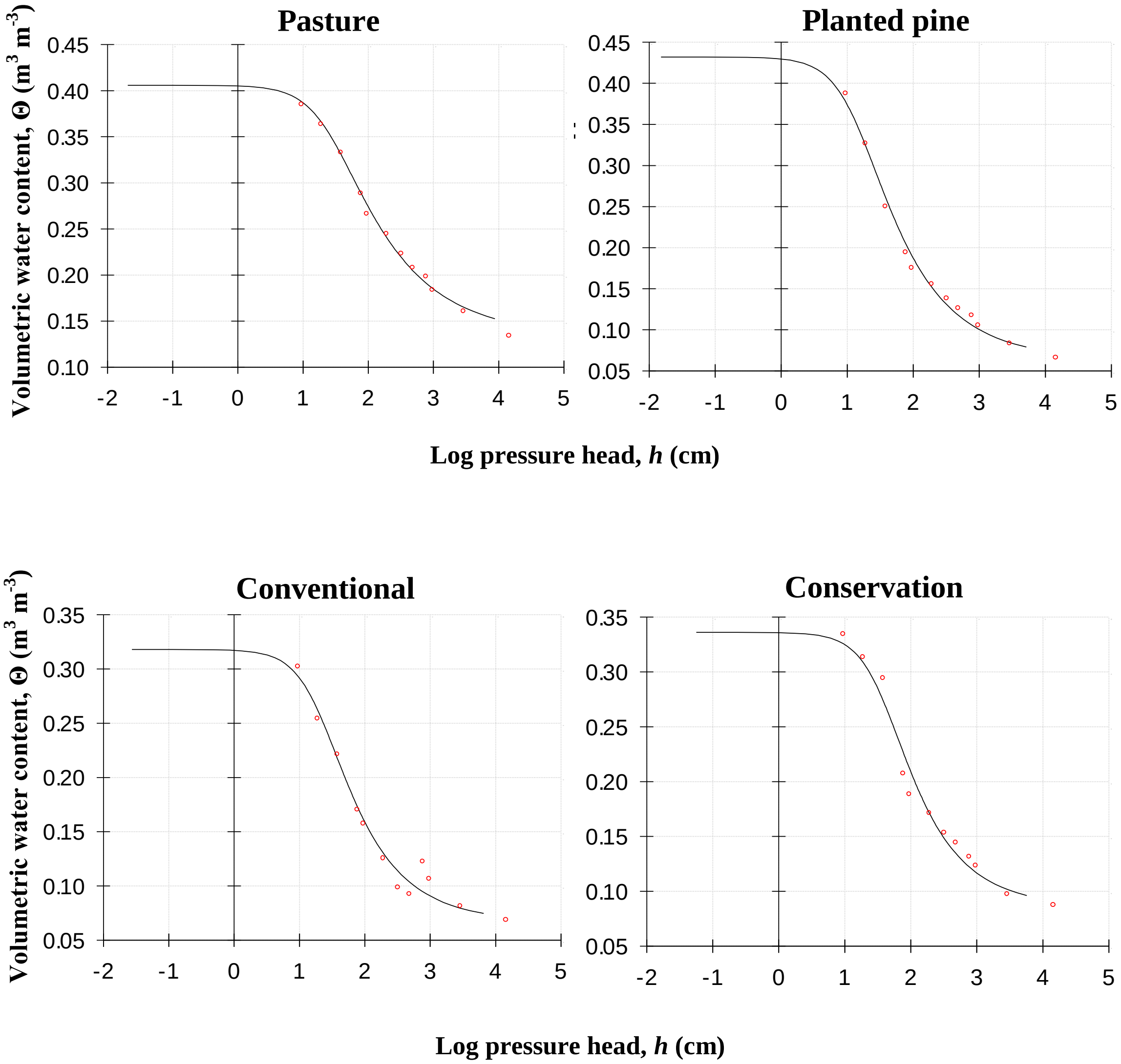
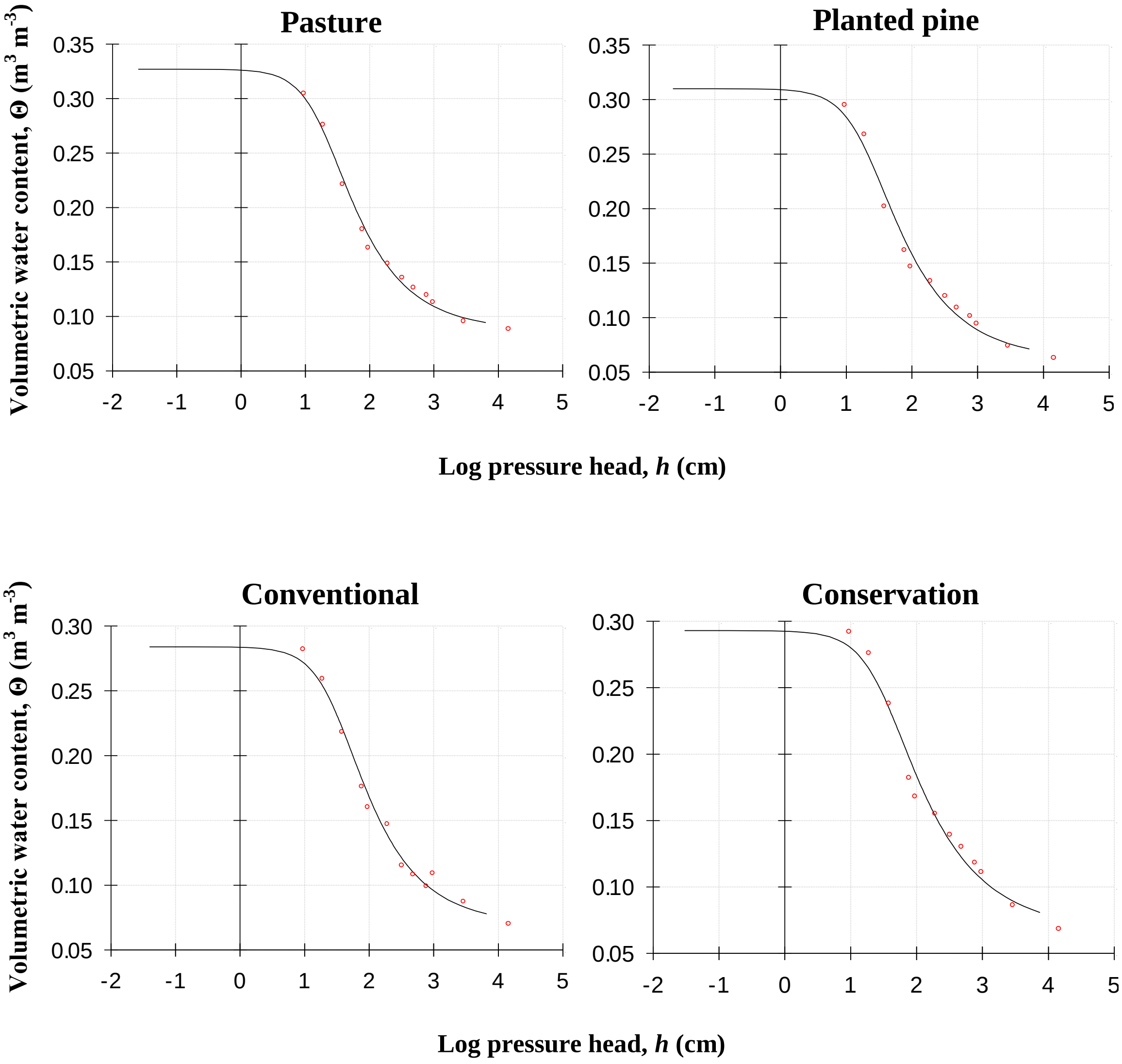


Figure 2-4. Soil water retention curves (via RETC) (15-21 cm) averaged for three repetitions (one conservation row crop system) of Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils within four long-term land use/managements (LM) of the Alabama Coastal Plain. Pasture = grazed pasture system; Planted pine = managed pine plantation; Conventional = conventional row crop system; Conservation = conservation row crop system.



Appendix

Table 18. Site identification (ID), current land use/management (LM), and Anders Level II land use classification for thirteen Dothan A map units within the Wiregrass region of the Alabama Coastal Plain.

Site ID	Current LM	Anders Level II land use
CRC	Conservation row crop system	Cropland and Pasture
RC1	Conventional row crop system	Cropland and Pasture
RC2	Conventional row crop system	Cropland and Pasture
RC3	Conventional row crop system	Cropland and Pasture
LL1	Longleaf pine/wiregrass forest	Mixed Forest Land
LL2	Longleaf pine/wiregrass forest	Mixed Forest Land
LL3	Longleaf pine/wiregrass forest	Mixed Forest Land
P1	Pasture	Cropland and Pasture
P2	Pasture	Cropland and Pasture
P3	Pasture	Cropland and Pasture
PP1	Planted pine plantation	Mixed Forest Land
PP2	Planted pine plantation	Evergreen Forest Land
PP3	Planted pine plantation	Mixed Forest Land

Soil Description 1; S2009AL-067-2 (Site ID: CRC), Fine-loamy, kaolinitic, thermic Plinthic Kandiudult. Henry County, Alabama, June 3, 2009.

Ap -- 0 to 31 centimeters; brown (10YR 4/3) loamy fine sand; weak fine granular structure; very friable; about 4 percent, by volume, ironstone; many fine roots; moderately acid (pH 6.02).

EB -- 31 to 44 cm; dark yellowish brown (10YR 4/6) fine sandy loam; weak medium subangular blocky structure; friable; about 1 percent, by volume, ironstone; many fine roots; slightly acid (pH 6.22).

BE -- 44 to 55 cm; yellowish brown (10YR 5/6) fine sandy loam; weak medium subangular blocky structure; friable; about 4 percent, by volume, ironstone; common fine roots; slightly acid (pH 6.18).

Bt -- 55 to 72 cm; yellowish brown (10YR 5/6) fine sandy loam; weak medium subangular blocky structure; friable; about 1 percent, by volume, ironstone; common fine roots; few faint clay films on ped faces; moderately acid (pH 5.98).

Btv1 -- 72 to 94 cm; yellowish brown (10YR 5/6) sandy clay loam; moderate medium subangular blocky structure; friable; few fine roots; common faint clay films on ped faces; about 5 percent, by volume, strong brown (7.5YR 5/8) and red (2.5YR 4/6) plinthite nodules; few medium faint strong brown (7.5YR 5/6) and few medium prominent red (2.5YR 4/6) masses of iron accumulations; moderately acid (pH 6.06).

Btv2 – 94 to 115 cm, brownish yellow (10YR 6/6) sandy clay loam; moderate medium subangular blocky structure; friable; common faint clay films on ped faces; about 8 percent, by volume, strong brown (7.5YR 5/8) and red (2.5YR 4/6) plinthite nodules; common medium faint strong brown (7.5YR 5/6) and few medium prominent red (2.5YR 4/6) masses of iron accumulations; slightly acid (pH 6.26).

Btv3 – 115 to 136 cm, brownish yellow (10YR 6/6) sandy clay loam; moderate medium subangular blocky structure; friable; about 10 percent, by volume, strong brown (7.5YR 5/8) and red (2.5YR 4/6) plinthite nodules; many medium faint strong brown (7.5YR 5/6) and few medium prominent red (2.5YR 4/6) masses of iron accumulations; strongly acid (pH 5.57).

BC – 136 to 150+ cm, brownish yellow (10YR 6/6) sandy clay loam; weak medium subangular blocky structure; friable; about 7 percent, by volume, strong brown (7.5YR 5/8) and red (2.5YR 4/6) plinthite nodules; many medium faint strong brown (7.5YR 5/6) and few medium prominent red (2.5YR 4/6) masses of iron accumulations; common medium distinct light yellowish brown (10YR 6/4) areas of iron depletions; strongly acid (pH 5.18).

Remarks: Soil Drainage Class 3, well drained. Absence of soil color of chroma two or less at a depth of 150cm.

Table 19. Standard Characterization; S2009AL-067-2 (Site ID: CRC), Fine-loamy, kaolinitic, thermic Plinthic Kandiudult.

Horizon	Lower Depth	Particle Size Distribution			Sand Size Distribution					Coarse Fragments		pH
		Sand	Silt	Clay	2 - 1.0	1.0 -.5	0.5 -.25	0.25 -.1	0.1 -.05	Gravimetric	Volumetric†	H_2O
	(cm)	-------------------------------% < 2mm of Whole Soil---------------------------------								-% > 2mm of Whole Soil-		------1:1------
Ap	31	78.7	14.6	6.7	1.1	8.5	24.1	31.9	13.1	7.2	4.4	6.02
EB	44	76.8	14.6	8.6	1.3	8.8	22.7	32.0	12.0	1.4	0.9	6.22
BE	55	75.0	13.3	11.8	0.8	7.6	21.5	31.7	13.4	8.0	5.0	6.18
Bt	72	68.2	11.9	20.0	0.8	7.1	19.4	28.4	12.4	1.9	1.2	5.98
Btv1	94	61.2	9.1	29.7	1.0	6.5	17.9	25.9	10.0	2.1	1.3	6.06
Btv2	115	58.5	7.7	33.8	0.3	6.4	17.3	24.3	10.2	0.3	0.2	6.26
Btv3	136	59.8	8.4	31.9	0.7	5.8	16.9	25.7	10.6	0.2	0.1	5.57
BC	150+	62.3	8.0	29.8	0.9	7.6	18.1	25.5	10.1	0.4	0.3	5.18

Horizon	Organic Matter	Exchangeable Cations					Cation Exchange Capacity					Base Saturation
		Ca‡	Mg	K	Al	Na	ECEC	CEC-7	CEC-8.2	ECEC	CEC-7	NH_4OAc (pH7)
	(%)	-------------------------------------cmol$_c$ kg soil^{-1}--								-----cmol$_c$ kg clay^{-1}-----		-------%--------
Ap	1.6	1.77	0.94	0.27	0.09	0.07	3.14	4.19	4.14	46.99	62.75	73
EB	0.3	0.61	0.41	0.21	0.04	0.11	1.38	2.08	2.50	16.11	24.33	64
BE	0.3	0.66	0.34	0.24	0.04	0.06	1.35	2.31	3.16	11.44	19.62	57
Bt	0.3	0.72	0.76	0.33	0.04	0.05	1.90	3.19	4.54	9.51	15.96	58
Btv1	0.3	1.11	1.20	0.31	0.06	0.07	2.75	4.18	5.66	9.25	14.07	64
Btv2	0.2	0.89	1.24	0.13	0.06	0.07	2.39	4.34	5.97	7.07	12.85	54
Btv3	0.2	0.67	1.00	0.08	0.07	0.06	1.87	3.65	5.39	5.87	11.45	49
BC	0.2	0.61	0.94	0.10	0.12	0.12	1.89	3.36	3.67	6.34	11.28	53

† Volumetric coarse fragment content estimated via NRCS rock/pararock fragment mass to volume conversion spreadsheet (Soil Survey Staff, 2010).

‡ Ca, Mg, K, and Na = NH_4OAc, pH 7.0 extractable calcium, magnesium, potassium, and sodium; Al = KCl extractable aluminum; ECEC = effective cation exchange capacity; CEC-7 = cation exchange capacity, NH_4OAc, pH 7.0; CEC-8.2 = cation exchange capacity, Sum of Cations (estimated after Hajek et al., 1972); Base Saturation = NH_4OAc, pH 7.0 base saturation.

Soil Description 2; S2009AL-061-4 (Site ID: RC1), Fine-loamy, kaolinitic, thermic Plinthic Kandiudult. Geneva County, Alabama, August 25, 2009.

Ap -- 0 to 24 centimeters; brown (10YR 4/3) loamy fine sand; weak fine granular structure; very friable; about 1 percent, by volume, ironstone; many fine roots; slightly acid (pH 6.12).

Bt – 24 to 52 cm; yellowish brown (10YR 5/6) sandy clay loam; weak medium subangular blocky structure; friable; about 2 percent, by volume, ironstone; many fine roots; few faint clay films on ped faces; slightly acid (pH 6.37).

Btv1 -- 52 to 85 cm; brownish yellow (10YR 6/6) sandy clay loam; moderate medium subangular blocky structure; friable; about 2 percent, by volume, ironstone; common fine roots; common faint clay films on ped faces; about 5 percent, by volume, strong brown (7.5YR 4/6) plinthite nodules; common medium distinct strong brown (7.5YR 4/6) masses of iron accumulations; neutral (pH 6.56).

Btv2 -- 85 to 118 cm; brownish yellow (10YR 6/6) sandy clay loam; moderate medium subangular blocky structure; friable; about 2 percent, by volume, ironstone; common fine roots; common faint clay films on ped faces; about 10 percent, by volume, strong brown (7.5YR 4/6) and red (2.5YR 4/6) plinthite nodules; common medium distinct strong brown (7.5YR 4/6) and few medium prominent red (2.5YR 4/6) masses of iron accumulation; strongly acid (pH 5.39).

Btv3 -- 118 to 152 cm; brownish yellow (10YR 6/8) sandy clay loam; moderate medium subangular blocky structure; friable; few fine roots; common faint clay films on ped faces; about 15 percent, by volume, strong brown (7.5YR 4/6) and red (2.5YR 4/6) plinthite nodules; many medium distinct strong brown (7.5YR 4/6) and common medium prominent red (2.5YR 4/6) masses of iron accumulations; common medium prominent light yellowish brown (10YR 6/4) and few medium prominent pale brown (10YR 6/3) areas of iron depletions; very strongly acid (pH 4.96).

Btv4 – 152 to 180+ cm, brownish yellow (10YR 6/8) sandy clay loam; moderate medium subangular blocky structure; friable; few faint clay films on ped faces; about 8 percent, by volume, strong brown (7.5YR 4/6) and red (2.5YR 4/6) plinthite nodules; many medium distinct strong brown (7.5YR 4/6) and many medium distinct red (2.5YR 4/6) masses of iron accumulations; common medium prominent very pale brown (10YR 7/3) and few medium prominent light gray (10YR 7/2) areas of iron depletions; very strongly acid (pH 4.64).

Remarks: Soil Drainage Class 3, well drained. Soil color of chroma two or less begins at a depth of 152cm.

Table 20. Standard Characterization; S2009AL-061-4 (Site ID: RC1), Fine-loamy, kaolinitic, thermic Plinthic Kandiudult.

Horizon	Lower Depth	Particle Size Distribution			Sand Size Distribution					Coarse Fragments		pH
		Sand	Silt	Clay	2 - 1.0	1.0 -.5	0.5 -.25	0.25 -.1	0.1 -.05	Gravimetric	Volumetric†	H_2O
	(cm)	---------------------------% < 2mm of Whole Soil-----------------------------								-% > 2mm of Whole Soil-		------1:1------
Ap	24	80.5	11.7	7.8	0.8	8.5	25.4	35.1	10.9	1.1	0.7	6.12
Bt	52	62.5	11.4	26.2	4.0	8.6	19.6	22.6	7.7	1.5	0.9	6.37
Btv1	85	65.0	10.4	24.6	0.8	7.4	21.4	26.1	9.2	1.6	1.0	6.56
Btv2	118	62.3	9.4	28.3	1.7	8.2	20.1	23.6	8.6	2.2	1.3	5.39
Btv3	152	63.0	8.6	28.4	1.9	8.9	20.9	23.0	8.2	1.2	0.7	4.96
Btv4	180+	64.0	7.4	28.5	3.3	13.3	21.6	19.2	6.7	3.6	2.2	4.64

Horizon	Organic Matter	Exchangeable Cations					Cation Exchange Capacity					Base Saturation
		Ca‡	Mg	K	Al	Na	ECEC	CEC-7	CEC-8.2	ECEC	CEC-7	NH_4OAc (pH7)
	(%)	---------------------------------cmol$_c$ kg soil^{-1}------------------------------------								-----cmol$_c$ kg clay^{-1}-----		-------%-------
Ap	1.0	1.16	0.40	0.22	0.04	0.25	2.06	2.97	3.24	26.59	38.29	68
Bt	0.5	1.12	0.87	0.20	0.03	0.06	2.28	3.45	4.47	8.71	13.21	65
Btv1	0.2	0.78	0.62	0.04	0.00	0.09	1.53	2.72	3.20	6.23	11.04	56
Btv2	0.2	0.56	0.61	0.02	0.00	0.18	1.37	2.97	4.36	4.86	10.53	46
Btv3	0.1	0.28	0.70	0.02	0.08	0.23	1.31	3.03	4.43	4.62	10.67	41
Btv4	0.1	0.49	0.24	0.03	0.44	0.41	1.61	2.91	4.67	5.66	10.19	40

† Volumetric coarse fragment content estimated via NRCS rock/pararock fragment mass to volume conversion spreadsheet (Soil Survey Staff, 2010).

‡ Ca, Mg, K, and Na = NH_4OAc, pH 7.0 extractable calcium, magnesium, potassium, and sodium; Al = KCl extractable aluminum; ECEC = effective cation exchange capacity; CEC-7 = cation exchange capacity, NH_4OAc, pH 7.0; CEC-8.2 = cation exchange capacity, Sum of Cations (estimated after Hajek et al., 1972); Base Saturation = NH_4OAc, pH 7.0 base saturation.

Soil Description 3; S2009AL-067-4 (Site ID: RC2), Fine-loamy, kaolinitic, thermic Plinthic Kandiudult. Henry County, Alabama, August 25, 2009.

Ap -- 0 to 24 centimeters; brown (10YR 4/3) loamy sand; weak fine granular structure; very friable; about 2 percent, by volume, ironstone; common fine roots; slightly acid (pH 6.37).

Bt – 24 to 48 cm; yellowish brown (10YR 5/6) sandy clay loam; weak medium subangular blocky structure; friable; about 4 percent, by volume, ironstone; few fine roots; few faint clay films on ped faces; slightly acid (pH 6.43).

Btv1 -- 48 to 64 cm; dark yellowish brown (10YR 4/6) sandy clay; moderate medium subangular blocky structure; friable; about 2 percent, by volume, ironstone; few fine roots; common faint clay films on ped faces; about 4 percent, by volume, strong brown (7.5YR 5/6) and red (2.5YR 4/6) plinthite nodules; few medium distinct strong brown (7.5YR 4/6) masses of iron accumulations; moderately acid (pH 6.01).

Btv2 -- 64 to 80 cm; brownish yellow (10YR 6/6) sandy clay; moderate medium subangular blocky structure; friable; about 3 percent, by volume, ironstone; common faint clay films on ped faces; about 8 percent, by volume, strong brown (7.5YR 5/6) and red (2.5YR 4/6) plinthite nodules; common medium distinct strong brown (7.5YR 4/6) and common medium prominent red (2.5YR 4/6) masses of iron accumulation; moderately acid (pH 5.90).

Btv3 -- 80 to 112 cm; brownish yellow (10YR 6/8) clay; strong medium subangular blocky structure; friable; about 2 percent, by volume, ironstone; common faint clay films on ped faces; about 10 percent, by volume, strong brown (7.5YR 4/6) and red (2.5YR 4/6) plinthite nodules; common medium distinct strong brown (7.5YR 4/6) and many medium prominent red (2.5YR 4/6) masses of iron accumulations; strongly acid (pH 5.57).

Btv4 – 112 to 150 cm, brownish yellow (10YR 6/8) clay; strong medium subangular blocky structure; friable; about 4 percent, by volume, ironstone; many faint clay films on ped faces; about 8 percent, by volume, strong brown (7.5YR 4/6) and red (2.5YR 4/6) plinthite nodules; few medium distinct strong brown (7.5YR 4/6) and many medium prominent red (2.5YR 4/6) masses of iron accumulations; common medium prominent light yellowish brown (2.5Y 6/4) and few medium prominent light yellowish brown (2.5Y 6/3) areas of iron depletions; strongly acid (pH 5.15).

Btv5 – 150 to 182+ cm, mixed brownish yellow (10YR 6/8), strong brown (7.5YR 4/6), and red (2.5YR 4/8) clay; moderate medium subangular blocky structure; friable; about 5 percent, by volume, ironstone; common faint clay films on ped faces; about 15 percent, by volume, strong brown (7.5YR 5/8) and red (2.5YR 4/6) plinthite nodules; common medium prominent light yellowish brown (2.5Y 6/3) and few medium prominent light brownish gray (2.5Y 6/2) areas of iron depletions; very strongly acid (pH 4.84).

Remarks: Soil Drainage Class 3, well drained. Soil color of chroma two or less begins at a depth of 150cm.

Table 21. Standard Characterization; S2009AL-067-4 (Site ID: RC2), Fine-loamy, kaolinitic, thermic Plinthic Kandiudult.

Horizon	Lower Depth	Particle Size Distribution			Sand Size Distribution					Coarse Fragments		pH
		Sand	Silt	Clay	2 - 1.0	1.0 -.5	0.5 -.25	0.25 -.1	0.1 -.05	Gravimetric	Volumetric†	H_2O
	(cm)	-----------------------------% < 2mm of Whole Soil--------------------------								-% > 2mm of Whole Soil-		------1:1------
Ap	24	81.8	10.7	7.5	2.1	12.6	33.3	28.0	5.7	2.3	1.4	6.37
Bt	48	58.2	13.8	27.9	0.9	5.7	20.2	25.1	6.4	4.1	2.5	6.43
Btv1	64	52.1	10.8	37.1	0.9	6.6	18.6	20.7	5.3	1.4	0.9	6.01
Btv2	80	47.9	8.9	43.2	1.0	5.8	17.5	18.8	4.8	1.6	1.0	5.90
Btv3	112	44.5	7.3	48.2	0.9	6.2	16.5	16.7	4.1	2.0	1.2	5.57
Btv4	150	42.7	7.2	50.0	0.9	6.0	16.3	15.5	4.0	2.0	1.2	5.15
Btv5	182+	43.9	7.2	48.9	0.8	5.3	16.5	17.0	4.4	8.5	5.3	4.84

Horizon	Organic Matter	Exchangeable Cations					Cation Exchange Capacity					Base Saturation
		Ca‡	Mg	K	Al	Na	ECEC	CEC-7	CEC-8.2	ECEC	CEC-7	NH_4OAc (pH7)
	(%)	--------------------------------------cmol$_c$ kg soil^{-1}--------------------------------------								-----cmol$_c$ kg clay^{-1}-----		-------%-------
Ap	0.8	0.88	0.50	0.11	0.02	0.08	1.60	2.66	2.66	21.23	35.40	59
Bt	0.4	0.67	1.27	0.17	0.01	0.09	2.22	4.07	4.32	7.93	14.56	54
Btv1	0.4	0.84	1.33	0.11	0.00	0.15	2.42	4.14	5.44	6.54	11.18	58
Btv2	0.4	0.78	1.18	0.05	0.01	0.14	2.16	4.42	5.56	5.00	10.23	49
Btv3	0.2	0.67	1.04	0.05	0.01	0.16	1.94	4.27	5.90	4.03	8.87	45
Btv4	0.2	1.01	0.80	0.04	0.06	0.10	2.00	4.45	6.57	3.99	8.89	44
Btv5	0.2	0.95	0.79	0.04	0.12	0.08	1.99	4.07	6.61	4.07	8.32	46

† Volumetric coarse fragment content estimated via NRCS rock/pararock fragment mass to volume conversion spreadsheet (Soil Survey Staff, 2010).

‡ Ca, Mg, K, and Na = NH_4OAc, pH 7.0 extractable calcium, magnesium, potassium, and sodium; Al = KCl extractable aluminum; ECEC = effective cation exchange capacity; CEC-7 = cation exchange capacity, NH_4OAc, pH 7.0; CEC-8.2 = cation exchange capacity, Sum of Cations (estimated after Hajek et al., 1972); Base Saturation = NH_4OAc, pH 7.0 base saturation.

Soil Description 4; S2009AL-067-5 (Site ID: RC3), Fine-loamy, kaolinitic, thermic Plinthic Kandiudult. Henry County, Alabama, September 11, 2009.

Ap -- 0 to 29 centimeters; brown (10YR 4/3) loamy sand; weak fine granular structure; very friable; about 3 percent, by volume, ironstone; common fine roots; slightly acid (pH 6.15).

Bt – 29 to 54 cm; yellowish brown (10YR 5/6) sandy loam; weak medium subangular blocky structure; friable; about 3 percent, by volume, ironstone; few fine roots; few faint clay films on ped faces; moderately acid (pH 5.73).

Btv1 -- 54 to 85 cm; brownish yellow (10YR 6/8) sandy clay loam; moderate medium subangular blocky structure; friable; about 3 percent, by volume, ironstone; common faint clay films on ped faces; about 7 percent, by volume, brown (7.5YR 5/4) and red (2.5YR 4/8) plinthite nodules; few medium prominent red (2.5YR 4/6) masses of iron accumulations; very strongly acid (pH 4.88).

Btv2 -- 85 to 119 cm; brownish yellow (10YR 6/8) sandy clay; moderate medium subangular blocky structure; friable; about 2 percent, by volume, ironstone; common faint clay films on ped faces; about 10 percent, by volume, brown (7.5YR 5/4) and red (2.5YR 4/8) plinthite nodules; common medium prominent red (2.5YR 4/6) masses of iron accumulations; common medium prominent light yellowish brown (10YR 6/4) and few medium prominent light yellowish brown (2.5Y 6/3) areas of iron depletions; very strongly acid (pH 4.86).

Btv3 -- 119 to 158 cm; brownish yellow (10YR 6/6) sandy clay; moderate medium subangular blocky structure; friable; about 4 percent, by volume, ironstone; common faint clay films on ped faces; about 12 percent, by volume, brown (7.5YR 5/4) and red (2.5YR 4/8) plinthite nodules; common medium prominent red (2.5YR 4/6) masses of iron accumulations; common medium prominent light yellowish brown (2.5Y 6/3) and few medium prominent light brownish gray (2.5Y 6/2) areas of iron depletions; very strongly acid (pH 4.76).

Btv4 – 158 to 181+ cm, mixed yellowish brown (10YR 5/6), yellow (2.5Y 7/8), and red (2.5YR 4/6) sandy clay loam; moderate medium subangular blocky structure; friable; few faint clay films on ped faces; about 13 percent, by volume, brown (7.5YR 5/4) and red (2.5YR 4/8) plinthite nodules; common medium prominent light brownish gray (2.5Y 6/2) areas of iron depletions; very strongly acid (pH 4.50).

Remarks: Soil Drainage Class 3, well drained. Soil color of chroma two or less begins at a depth of 119cm.

Table 22. Standard Characterization; S2009AL-067-5 (Site ID: RC3), Fine-loamy, kaolinitic, thermic Plinthic Kandiudult.

Horizon	Lower Depth	Particle Size Distribution			Sand Size Distribution					Coarse Fragments		pH
		Sand	Silt	Clay	2 - 1.0	1.0 -.5	0.5 -.25	0.25 -.1	0.1 -.05	Gravimetric	Volumetric†	H_2O
	(cm)	-------------------------------% < 2mm of Whole Soil-------------------------------								-% > 2mm of Whole Soil-		------1:1------
Ap	20	82.1	12.5	5.5	4.8	16.0	29.7	24.5	7.0	4.8	2.9	6.15
Bt	54	70.5	12.8	16.7	4.3	11.5	25.2	23.3	6.1	5.6	3.5	5.73
Btv1	85	57.2	9.0	33.7	2.5	10.9	21.8	16.9	5.1	6.9	4.3	4.88
Btv2	119	56.4	6.4	37.2	2.8	10.8	20.9	17.0	4.9	6.3	3.9	4.86
Btv3	158	57.3	6.6	36.1	4.4	12.7	21.5	14.8	4.0	9.0	5.6	4.76
Btv4	181+	65.7	4.1	30.2	8.5	19.3	23.4	11.6	2.9	7.5	4.7	4.50

Horizon	Organic Matter	Exchangeable Cations					Cation Exchange Capacity					Base Saturation
		Ca‡	Mg	K	Al	Na	ECEC	CEC-7	CEC-8.2	ECEC	CEC-7	NH_4OAc (pH7)
	(%)	-----------------------------------cmol$_c$ kg soil^{-1}---------------------------------------								-----cmol$_c$ kg clay^{-1}-----		-------%-------
Ap	1.1	2.78	0.14	0.11	0.08	0.04	3.15	2.80	4.36	57.78	51.31	100
Bt	0.3	1.74	0.33	0.16	0.02	0.04	2.30	2.81	4.14	13.74	16.82	81
Btv1	0.3	1.66	0.70	0.11	0.25	0.04	2.74	3.84	6.48	8.13	11.38	65
Btv2	0.3	1.52	0.61	0.04	0.26	0.02	2.45	3.61	6.19	6.59	9.69	61
Btv3	0.2	1.76	0.42	0.07	0.10	0.10	2.45	3.12	6.05	6.78	8.63	75
Btv4	0.2	0.93	0.20	0.05	0.19	0.10	1.46	2.30	4.40	4.83	7.61	55

† Volumetric coarse fragment content estimated via NRCS rock/pararock fragment mass to volume conversion spreadsheet (Soil Survey Staff, 2010).

‡ Ca, Mg, K, and Na = NH_4OAc, pH 7.0 extractable calcium, magnesium, potassium, and sodium; Al = KCl extractable aluminum; ECEC = effective cation exchange capacity; CEC-7 = cation exchange capacity, NH_4OAc, pH 7.0; CEC-8.2 = cation exchange capacity, Sum of Cations (estimated after Hajek et al., 1972); Base Saturation = NH_4OAc, pH 7.0 base saturation.

Soil Description 5; S2010AL-039-1 (Site ID: LL1), Fine-loamy, kaolinitic, thermic Plinthic Kandiudult. Covington County. Alabama, June 16, 2010.

A -- 0 to 14 centimeters; dark grayish brown (2.5Y 4/2) sandy loam; weak fine granular structure; very friable; about 3 percent, by volume, ironstone; many fine and common coarse roots; extremely acid (pH 4.30).

EB -- 14 to 26 cm; light olive brown (2.5Y 5/6) sandy loam; weak medium subangular blocky structure; very friable; common fine roots; very strongly acid (pH 4.70).

Bt -- 26 to 50 cm; yellowish brown (10YR 5/8) sandy clay loam; weak medium subangular blocky structure; friable; about 5 percent, by volume, ironstone; about 3 percent, by volume, red (2.5YR 4/6) plinthite nodules; few fine roots; few faint clay films on ped faces; very strongly acid (pH 4.66).

Btv1 – 50 to 73 cm; yellowish brown (10YR 5/8) sandy clay loam; moderate medium subangular blocky structure; friable; about 2 percent, by volume, ironstone; about 5 percent, by volume, red (2.5YR 4/6) plinthite nodules; few faint clay films on ped faces; very strongly acid (pH 4.90).

Btv2 -- 73 to 94 cm; yellowish brown (10YR 5/8) sandy clay loam; moderate medium subangular blocky structure; friable; about 5 percent, by volume, strong brown (7.5YR 5/8) and red (2.5YR 4/6) plinthite nodules; common faint clay films on ped faces; very strongly acid (pH 5.01).

Btv3 – 94 to 117 cm, yellowish brown (10YR 5/8) sandy clay loam; moderate medium subangular blocky structure; friable; about 10 percent, by volume, strong brown (7.5YR 5/8) and red (2.5YR 4/6) plinthite nodules; very strongly acid (pH 5.05); common faint clay films on ped faces.

Btv4 – 117 to 140 cm, yellowish brown (10YR 5/8) sandy clay loam; moderate medium subangular blocky structure; friable; about 10 percent, by volume, strong brown (7.5YR 5/8) and red (2.5YR 4/6) plinthite nodules; few fine prominent very pale brown (10YR 7/4) areas of iron depletions; very strongly acid (pH 5.02); common faint clay films on ped faces.

B’t – 140 to 163 cm, yellowish brown (10YR 5/8) sandy clay loam; moderate medium subangular blocky structure; friable; about 3 percent, by volume, strong brown (7.5YR 5/8) plinthite nodules; common medium faint strong brown (7.5YR 5/8) and common fine prominent red (2.5YR 4/6) masses of iron accumulations; few medium prominent very pale brown (10YR 7/4) areas of iron depletions; very strongly acid (pH 5.02).

BC – 163 to 180+ cm, mixed yellowish brown (10YR 5/8), strong brown (7.5YR 5/8), and red (2.5YR 4/6) sandy loam; weak medium subangular blocky structure; friable; common medium prominent very pale brown (10YR 7/4) and few fine prominent very pale brown (10YR 7/3) areas of iron depletions; very strongly acid (pH 4.91).

Remarks: Soil Drainage Class 3, well drained. Absence of soil color of chroma two or less at a depth of 180cm.

Table 23. Standard Characterization; S2010AL-039-1 (Site ID: LL1), Fine-loamy, kaolinitic, thermic Plinthic Kandiudult.

Horizon	Lower Depth	Particle Size Distribution			Sand Size Distribution					Coarse Fragments		pH
		Sand	Silt	Clay	2 - 1.0	1.0 -.5	0.5 -.25	0.25 -.1	0.1 -.05	Gravimetric	Volumetric†	H_2O
	(cm)	------------------------------% < 2mm of Whole Soil---------------------------------								-% > 2mm of Whole Soil-		------1:1------
A	14	74.5	19.3	6.2	1.8	6.7	19.7	33.3	12.9	2.5	1.4	4.30
EB	26	73.7	18.1	8.2	1.3	6.3	20.8	33.1	12.3	2.2	1.3	4.70
Bt	50	62.4	16.9	20.7	2.8	5.5	17.4	26.9	9.8	15.5	9.4	4.66
Btv1	73	60.8	17.1	22.1	0.8	5.4	17.5	26.9	10.2	2.7	1.6	4.90
Btv2	94	58.7	14.6	26.7	0.8	5.1	17.5	25.8	9.5	4.5	2.6	5.01
Btv3	117	61.7	12.3	26.1	1.4	6.1	19.6	25.7	8.8	10.8	6.4	5.05
Btv4	140	62.7	9.7	27.6	1.3	7.5	24.3	22.9	6.7	1.1	0.6	5.02
B't	163	63.0	5.3	31.6	1.0	9.6	30.5	17.9	4.0	0.1	0.0	5.02
BC	180+	65.2	5.1	29.7	1.2	11.8	32.8	16.4	3.0	0.2	0.1	4.91

Horizon	Organic Matter	Exchangeable Cations					Cation Exchange Capacity					Base Saturation
		Ca‡	Mg	K	Al	Na	ECEC	CEC-7	CEC-8.2	ECEC	CEC-7	NH_4OAc (pH7)
	(%)	----------------------------------cmol$_c$ kg soil^{-1}--								-----cmol$_c$ kg clay^{-1}-----		-------%-------
A	-	0.23	0.08	0.04	1.73	0.19	2.27	4.57	3.34	36.51	73.57	12
EB	-	0.05	0.01	0.01	0.74	0.13	0.94	2.17	1.87	11.40	26.40	9
Bt	-	0.05	0.04	0.02	1.14	0.11	1.37	2.55	2.13	6.62	12.30	9
Btv1	-	0.13	0.30	0.03	0.79	0.18	1.43	2.48	2.21	6.47	11.21	26
Btv2	-	0.03	0.17	0.02	0.68	0.19	1.10	2.54	2.20	4.12	9.52	17
Btv3	-	0.00	0.15	0.06	0.71	0.21	1.13	2.89	2.10	4.32	11.10	14
Btv4	-	0.01	0.19	0.01	0.76	0.16	1.13	2.97	2.15	4.11	10.77	13
B't	-	0.01	0.23	0.01	0.73	0.24	1.22	3.29	2.32	3.87	10.39	15
BC	-	0.01	0.20	0.01	0.65	0.19	1.06	2.51	1.80	3.56	8.45	16

† Volumetric coarse fragment content estimated via NRCS rock/pararock fragment mass to volume conversion spreadsheet (Soil Survey Staff, 2010).

‡ Ca, Mg, K, and Na = NH_4OAc, pH 7.0 extractable calcium, magnesium, potassium, and sodium; Al = KCl extractable aluminum; ECEC = effective cation exchange capacity; CEC-7 = cation exchange capacity, NH_4OAc, pH 7.0; CEC-8.2 = cation exchange capacity, Sum of Cations (estimated after Hajek et al., 1972); Base Saturation = NH_4OAc, pH 7.0 base saturation.

Soil Description 6; S2010AL-039-2 (Site ID: LL2), Fine-loamy, kaolinitic, thermic Plinthic Kandiudult. Covington County. Alabama, June 16, 2010.

A -- 0 to 20 centimeters; dark grayish brown (10YR 4/2) loamy fine sand; weak fine granular structure; very friable; many fine and common coarse roots; extremely acid (pH 4.30).

E -- 20 to 33 cm; olive yellow (2.5Y 6/6) loamy sand; single grained; about 2 percent, by volume, ironstone; common fine roots; very strongly acid (pH 4.85).

EB -- 33 to 44 cm; olive yellow (2.5Y 6/6) sandy loam; weak fine subangular blocky structure; friable; about 2 percent, by volume, ironstone; few fine roots; very strongly acid (pH 4.82).

Bt1 – 44 to 63 cm; yellowish brown (10YR 5/6) sandy clay loam; moderate medium subangular blocky structure; friable; few faint clay films on ped faces; very strongly acid (pH 4.91).

Bt2 -- 63 to 84 cm; yellowish brown (10YR 5/6) sandy clay loam; moderate medium subangular blocky structure; friable; common faint clay films on ped faces; very strongly acid (pH 5.00).

Btv1 – 84 to 104 cm, yellowish brown (10YR 5/6) sandy clay loam; moderate medium subangular blocky structure; friable; about 3 percent, by volume, ironstone; about 15 percent, by volume, strong brown (7.5YR 5/8) and red (2.5YR 4/6) plinthite nodules; many faint clay films on ped faces; very strongly acid (pH 4.80).

Btv2 – 104 to 127 cm, yellowish brown (10YR 5/6) sandy clay loam; moderate medium subangular blocky structure; friable; about 10 percent, by volume, strong brown (7.5YR 5/8) and red (2.5YR 4/6) plinthite nodules; few fine prominent red (2.5YR 4/6) masses of iron accumulations; common faint clay films on ped faces; very strongly acid (pH 4.98).

B’t – 127 to 144 cm, brownish yellow (10YR 6/8) sandy clay loam; weak medium subangular blocky structure; friable; common fine prominent red (2.5YR 4/6) masses of iron accumulations; very strongly acid (pH 4.96).

BC – 144 to 168 cm, brownish yellow (10YR 6/6) sandy loam; weak medium subangular blocky structure; friable; common fine prominent red (2.5YR 4/6) masses of iron accumulations; few medium distinct very pale brown (10YR 7/4) areas of iron depletions; very strongly acid (pH 4.98).

CB – 168 to 184+ cm, mixed brownish yellow (10YR 6/6), strong brown (7.5YR 5/8), and red (2.5YR 4/6) sandy loam; weak fine subangular blocky structure; firm; common medium distinct very pale brown (10YR 7/4) and few medium distinct very pale brown (10YR 7/3) areas of iron depletions; very strongly acid (pH 5.00).

Remarks: Soil Drainage Class 3, well drained. Absence of soil color of chroma two or less at a depth of 184cm.

Table 24. Standard Characterization; S2010AL-039-2 (Site ID: LL2), Fine-loamy, kaolinitic, thermic Plinthic Kandiudult.

Horizon	Lower Depth	Particle Size Distribution			Sand Size Distribution					Coarse Fragments		pH
		Sand	Silt	Clay	2 - 1.0	1.0 -.5	0.5 -.25	0.25 -.1	0.1 -.05	Gravimetric	Volumetric†	H_2O
	(cm)	----------------------------% < 2mm of Whole Soil----------------------------------								-% > 2mm of Whole Soil-		------1:1------
A	20	78.6	16.3	5.1	1.0	5.7	19.4	39.7	12.7	2.5	1.4	4.30
E	33	78.8	17.1	4.1	0.9	5.3	17.9	38.4	16.2	1.0	0.6	4.85
EB	44	75.4	17.4	7.1	0.5	3.1	14.0	39.1	18.7	0.8	0.4	4.82
Bt1	63	70.9	16.4	12.7	0.4	3.7	12.9	36.6	17.3	0.9	0.5	4.91
Bt2	84	65.5	13.9	20.6	0.7	5.3	13.8	31.4	14.2	3.4	2.0	5.00
Btv1	104	61.5	13.2	25.4	1.3	5.4	13.3	28.6	12.9	2.2	1.3	4.80
Btv2	127	60.6	10.5	28.9	1.1	4.4	12.4	30.0	12.6	0.3	0.2	4.98
B't	144	63.0	8.5	28.5	1.0	4.1	12.3	33.5	12.0	0.2	0.1	4.96
BC	168	66.7	8.1	25.3	0.4	3.5	13.1	38.7	11.0	0.1	0.1	4.98
CB	184+	62.5	8.9	28.6	0.5	4.9	15.0	30.9	11.2	0.0	0.0	5.00

Horizon	Organic Matter	Exchangeable Cations					Cation Exchange Capacity					Base Saturation
		Ca‡	Mg	K	Al	Na	ECEC	CEC-7	CEC-8.2	ECEC	CEC-7	NH_4OAc (pH7)
	(%)	----------------------------------cmol$_c$ kg soil^{-1}--								-----cmol$_c$ kg clay^{-1}-----		-------%-------
A	-	0.59	0.24	0.03	1.40	0.07	2.34	6.45	3.78	46.26	127.42	15
E	-	0.03	0.01	0.01	0.50	0.05	0.61	1.75	0.11	14.76	42.38	6
EB	-	0.03	0.02	0.01	0.56	0.05	0.66	1.44	0.11	9.28	20.09	8
Bt1	-	0.24	0.36	0.02	0.76	0.05	1.44	2.68	1.10	11.26	21.01	25
Bt2	-	0.38	0.64	0.03	0.78	0.09	1.92	2.93	2.75	9.30	14.21	39
Btv1	-	0.18	0.55	0.03	1.14	0.09	1.99	3.21	2.95	7.83	12.66	26
Btv2	-	0.02	0.14	0.02	1.28	0.04	1.49	3.07	2.18	5.16	10.60	7
B't	-	0.02	0.13	0.01	1.18	0.09	1.43	3.39	1.78	4.99	11.89	7
BC	-	0.01	0.12	0.00	1.13	0.08	1.34	2.79	1.70	5.30	11.03	8
CB	-	0.01	0.14	0.01	1.36	0.04	1.56	3.07	1.72	5.46	10.71	7

† Volumetric coarse fragment content estimated via NRCS rock/pararock fragment mass to volume conversion spreadsheet (Soil Survey Staff, 2010).

‡ Ca, Mg, K, and Na = NH_4OAc, pH 7.0 extractable calcium, magnesium, potassium, and sodium; Al = KCl extractable aluminum; ECEC = effective cation exchange capacity; CEC-7 = cation exchange capacity, NH_4OAc, pH 7.0; CEC-8.2 = cation exchange capacity, Sum of Cations (estimated after Hajek et al., 1972); Base Saturation = NH_4OAc, pH 7.0 base saturation.

Soil Description 7; S2010AL-039-4 (Site ID: LL3), Fine-loamy, kaolinitic, thermic Plinthic Kandiudult. Covington County. Alabama, June 16, 2010.

A -- 0 to 18 centimeters; very dark grayish brown (10YR 3/2) sandy loam; weak fine granular structure; very friable; many fine and common coarse roots; very strongly acid (pH 4.74).

AB -- 18 to 35 cm; dark yellowish brown (10YR 4/6) sandy loam; weak fine subangular blocky structure; very friable; common fine roots; very strongly acid (pH 4.89).

Bt -- 35 to 59 cm; yellowish brown (10YR 5/8) sandy clay loam; moderate medium subangular blocky structure; friable; few fine roots; few faint clay films on ped faces; very strongly acid (pH 4.86).

Btv1 – 59 to 84 cm; yellowish brown (10YR 5/8) sandy clay loam; moderate medium subangular blocky structure; friable; about 7 percent, by volume strong brown (7.5YR 5/8) and red (2.5YR 4/6) plinthite nodules; common faint clay films on ped faces; very strongly acid (pH 4.91).

Btv2 -- 84 to 104 cm; yellowish brown (10YR 5/8) sandy clay loam; moderate medium subangular blocky structure; friable; about 10 percent, by volume strong brown (7.5YR 5/8) and red (2.5YR 4/6) plinthite nodules; few fine prominent red (2.5YR 4/6) and common fine faint strong brown (7.5YR 5/8) masses of iron accumulations; common faint clay films on ped faces; very strongly acid (pH 5.02).

Btv3 – 104 to 128 cm, yellowish brown (10YR 5/8) sandy clay loam; moderate medium subangular blocky structure; friable; about 7 percent, by volume strong brown (7.5YR 5/8) plinthite nodules; few fine prominent red (2.5YR 4/6) and common fine faint strong brown (7.5YR 5/8) masses of iron accumulations; few medium prominent pale yellow (2.5Y 7/4) areas of iron depletions; common faint clay films on ped faces; very strongly acid (pH 5.09).

Btv4 – 128 to 142 cm, yellowish brown (10YR 5/8) sandy clay loam; moderate medium subangular blocky structure; friable; about 5 percent, by volume strong brown (7.5YR 5/8) plinthite nodules; common medium faint strong brown (7.5YR 5/8) masses of iron accumulations; common medium prominent pale yellow (10YR 7/4) and few medium prominent pale yellow (2.5Y 7/3) areas of iron depletions; few faint clay films on ped faces; very strongly acid (pH 5.07).

Btv5 – 142 to 164 cm, brownish yellow (10YR 6/6) sandy loam; weak medium subangular blocky structure; friable; about 5 percent, by volume strong brown (7.5YR 5/8) plinthite nodules; few medium distinct strong brown (7.5YR 5/8) masses of iron accumulations; common medium prominent pale yellow (10YR 7/3) and few medium prominent light gray (2.5Y 7/2) areas of iron depletions; very strongly acid (pH 5.06).

BC – 164 to 186+ cm, mixed brownish yellow (10YR 6/8) and yellow (10YR 7/6) sandy loam; weak medium subangular blocky structure; friable; about 6 percent, by volume, strong brown (7.5YR 5/8) plinthite nodules; common medium distinct strong brown (7.5YR 5/8) masses of iron accumulations; common medium prominent light gray (2.5Y 7/2) areas of iron depletions; very strongly acid (pH 5.04).

Remarks: Soil Drainage Class 3, well drained. Soil color of chroma two or less begins at a depth of 142cm.

Table 25. Standard Characterization; S2010AL-039-4 (Site ID: LL3), Fine-loamy, kaolinitic, thermic Plinthic Kandiudult.

Horizon	Lower Depth	Particle Size Distribution			Sand Size Distribution					Coarse Fragments		pH
		Sand	Silt	Clay	2 - 1.0	1.0 -.5	0.5 -.25	0.25 -.1	0.1 -.05	Gravimetric	Volumetric†	H_2O
	(cm)	-------------------------------% < 2mm of Whole Soil----------------------------------								-% > 2mm of Whole Soil-		------1:1------
A	18	74.2	17.6	8.2	1.6	11.1	21.9	29.2	10.4	0.4	0.3	4.74
AB	35	71.1	18.0	10.9	0.6	6.2	17.5	33.7	13.1	0.2	0.1	4.89
Bt	59	66.9	16.7	16.4	0.9	7.7	16.6	30.1	11.6	0.4	0.2	4.86
Btv1	84	63.7	13.6	22.7	1.7	7.8	16.2	27.6	10.4	1.3	0.7	4.91
Btv2	104	60.5	11.4	28.0	1.5	7.4	15.1	26.8	9.8	1.0	0.6	5.02
Btv3	128	61.1	9.6	29.4	2.6	10.1	15.8	24.6	8.0	0.7	0.4	5.09
Btv4	142	65.5	7.1	27.4	1.1	7.3	22.4	26.9	7.7	0.2	0.1	5.07
Btv5	164	67.4	7.5	25.1	0.8	7.6	17.1	33.4	8.6	0.2	0.1	5.06
BC	186+	65.3	7.6	27.1	0.1	5.6	14.3	35.6	9.7	0.1	0.0	5.04

Horizon	Organic Matter	Exchangeable Cations					Cation Exchange Capacity					Base Saturation
		Ca‡	Mg	K	Al	Na	ECEC	CEC-7	CEC-8.2	ECEC	CEC-7	NH_4OAc (pH7)
	(%)	-------------------------------------cmol$_c$ kg soil^{-1}--								-----cmol$_c$ kg clay^{-1}-----		-------%--------
A	-	0.44	0.16	0.04	1.11	0.08	1.82	4.61	3.36	22.28	56.32	16
AB	-	0.14	0.09	0.03	0.75	0.13	1.14	2.57	1.51	10.45	23.56	15
Bt	-	0.32	0.24	0.03	0.67	0.12	1.37	2.42	1.65	8.38	14.75	29
Btv1	-	0.18	0.27	0.02	0.92	0.12	1.51	2.44	2.27	6.65	10.73	24
Btv2	-	0.06	0.24	0.02	0.78	0.13	1.23	2.28	2.19	4.40	8.15	20
Btv3	-	0.00	0.12	0.00	0.79	0.08	1.00	2.46	2.00	3.40	8.38	9
Btv4	-	0.04	0.17	0.01	0.81	0.09	1.12	2.40	1.82	4.10	8.75	13
Btv5	-	0.05	0.20	0.00	0.87	0.13	1.26	2.49	1.50	5.03	9.93	16
BC	-	0.08	0.23	0.01	1.11	0.18	1.61	2.53	1.63	5.94	9.31	20

† Volumetric coarse fragment content estimated via NRCS rock/pararock fragment mass to volume conversion spreadsheet (Soil Survey Staff, 2010).

‡ Ca, Mg, K, and Na = NH_4OAc, pH 7.0 extractable calcium, magnesium, potassium, and sodium; Al = KCl extractable aluminum; ECEC = effective cation exchange capacity; CEC-7 = cation exchange capacity, NH_4OAc, pH 7.0; CEC-8.2 = cation exchange capacity, Sum of Cations (estimated after Hajek et al., 1972); Base Saturation = NH_4OAc, pH 7.0 base saturation.

Soil Description 8; S2009AL-061-3 (Site ID: P1), Fine-loamy, kaolinitic, thermic Plinthic Kandiudult. Geneva County, Alabama, August 5, 2009.

Ap -- 0 to 26 centimeters; brown (10YR 4/3) loamy fine sand; weak fine granular structure; very friable; about 4 percent, by volume, ironstone; many fine roots; strongly acid (pH 5.32).

Btv1 -- 26 to 43 cm; yellowish brown (10YR 5/6) sandy clay loam; weak medium subangular blocky structure; friable; about 4 percent, by volume, ironstone; many fine roots; few faint clay films on ped faces; about 5 percent strong brown (7.5YR 4/6), dark yellowish brown (10YR 4/6), and red (2.5YR 4/6) plinthite nodules; few medium faint strong brown (7.5YR 4/6) and few medium faint dark yellowish brown (10YR 4/6) masses of iron accumulations; strongly acid (pH 5.11).

Btv2 -- 43 to 66 cm; yellowish brown (10YR 5/8) sandy clay loam; moderate medium subangular blocky structure; friable; about 3 percent, by volume, ironstone; common fine roots; common faint clay films on ped faces; about 7 percent, by volume, strong brown (7.5YR 4/6), dark yellowish brown (10YR 4/6), and red (2.5YR 4/6) plinthite nodules; common medium distinct strong brown (7.5YR 4/6) and common medium distinct dark yellowish brown (10YR 4/6) masses of iron accumulations; very strongly acid (pH 5.03).

Btv3 -- 66 to 96 cm; brownish yellow (10YR 6/8) sandy clay loam; moderate medium subangular blocky structure; friable; about 3 percent, by volume, ironstone; common fine roots; common faint clay films on ped faces; about 7 percent, by volume, strong brown (7.5YR 4/6), dark yellowish brown (10YR 4/6), and red (2.5YR 4/6) plinthite nodules; common medium distinct strong brown (7.5YR 4/6) and common medium distinct dark yellowish brown (10YR 4/6) masses of iron accumulation; very strongly acid (pH 5.06).

Btv4 -- 96 to 118 cm; brownish yellow (10YR 6/8) sandy clay loam; moderate medium subangular blocky structure; friable; few fine roots; common faint clay films on ped faces; about 4 percent, by volume, strong brown (7.5YR 4/6), dark yellowish brown (10YR 4/6), and red (2.5YR 4/6) plinthite nodules; common medium distinct strong brown (7.5YR 4/6) and common medium distinct dark yellowish brown (10YR 4/6) masses of iron accumulations; common medium prominent light yellowish brown (10YR 6/4) and few medium prominent very pale brown (10YR 7/3) areas of iron depletions; strongly acid (pH 5.13).

BC – 118 to 145 cm, yellowish brown (10YR 5/8) sandy clay; moderate medium subangular blocky structure; friable; few faint clay films on ped faces; about 5 percent, by volume, strong brown (7.5YR 4/6) and red (2.5YR 4/6) plinthite nodules; common medium distinct strong brown (7.5YR 4/6) masses of iron accumulations; common medium prominent very pale brown (10YR 7/3) and few medium prominent light gray (10YR 7/2) areas of iron depletions; very strongly acid (pH 4.87).

CB – 145 to 170 cm, mixed red (2.5YR 4/6), yellowish brown (10YR 5/6), and light gray (10YR 7/2) sandy clay; weak medium subangular blocky structure; about 10 percent, by volume, red (2.5YR 4/6) and strong brown (7.5YR 4/6) plinthite nodules; few medium prominent white (2.5Y 8/1) areas of iron depletions; very strongly acid (pH 4.85).

C – 170 to 182+ cm, mixed red (2.5YR 4/6), yellowish brown (10YR 5/6), light gray (10YR 7/2), and white (2.5Y 8/1) sandy clay; massive; very strongly acid (pH 4.92).

Remarks: Soil Drainage Class 3, well drained. Soil color of chroma two or less begins at a depth of 118cm.

Table 26. Standard Characterization; S2009AL-061-3 (Site ID: P1), Fine-loamy, kaolinitic, thermic Plinthic Kandiudult.

Horizon	Lower Depth	Particle Size Distribution			Sand Size Distribution					Coarse Fragments		pH
		Sand	Silt	Clay	2 - 1	1 - .5	.5 - .25	.25 - .1	.1 - .05	Gravimetric	Volumetric†	
	(cm)	---% < 2 mm of whole soil--			------------------------% of sand fraction---------------------					-% > 2mm of whole soil-		
Ap	26	80.0	11.9	8.1	2.2	7.2	21.3	36.8	12.4	6.0	3.7	5.32
Btv1	43	66.7	10.8	22.5	1.8	7.5	18.5	29.7	9.1	1.4	0.9	5.11
Btv2	66	64.0	10.4	25.5	1.5	5.4	17.6	30.3	9.3	6.3	3.9	5.03
Btv3	96	61.6	8.3	30.1	1.9	6.3	16.9	28.0	8.4	1.9	1.2	5.06
Btv4	118	58.3	8.0	33.7	1.7	5.3	15.9	27.3	8.1	2.1	1.3	5.13
BC	145	57.2	7.1	35.6	3.8	6.4	16.6	24.0	6.5	0.3	0.2	4.87
CB	170	57.2	7.2	35.6	1.7	6.1	16.7	26.2	6.5	0.2	0.1	4.85
C	182+	55.6	6.9	37.5	2.9	6.6	16.6	22.3	7.2	0.4	0.3	4.92

Horizon	Organic Matter	Exchangeable Cations					Cation Exchange Capacity					Base Saturation
		Ca‡	Mg	K	Na	Al	ECEC	CEC-7	CEC-8.2	ECEC	CEC-7	
	(%)	---cmol$_c$ kg soil^{-1}---------------------------------------								-----cmol$_c$ kg clay^{-1}-----		%
Ap	1.4	0.55	0.12	0.12	0.14	0.18	1.11	3.01	3.29	13.72	37.09	31
Btv1	0.6	0.55	0.21	0.22	0.48	0.12	1.59	3.02	6.23	7.08	13.40	49
Btv2	0.5	0.82	0.10	0.16	0.21	0.44	1.74	2.91	7.31	6.81	11.41	44
Btv3	0.3	0.97	0.13	0.09	0.14	0.19	1.52	2.50	4.94	5.07	8.30	53
Btv4	0.2	1.11	0.19	0.06	0.49	0.06	1.90	2.42	5.45	5.65	7.17	76
BC	0.2	0.80	0.12	0.05	0.43	0.33	1.73	2.91	5.28	4.86	8.17	48
CB	0.1	0.44	0.09	0.05	0.30	0.67	1.56	2.79	4.79	4.38	7.84	32
C	0.1	0.34	0.10	0.05	0.24	0.76	1.48	2.96	4.73	3.96	7.88	25

† Volumetric coarse fragment content estimated via NRCS rock/pararock fragment mass to volume conversion spreadsheet (Soil Survey Staff, 2010).

‡ Ca, Mg, K, and Na = NH$_4$OAc, pH 7.0 extractable calcium, magnesium, potassium, and sodium; Al = KCl extractable aluminum; ECEC = effective cation exchange capacity; CEC-7 = cation exchange capacity, NH$_4$OAc, pH 7.0; CEC-8.2 = cation exchange capacity, Sum of Cations (estimated after Hajek et al., 1972); Base Saturation = NH$_4$OAc, pH 7.0 base saturation.

Soil Description 9; S2009AL-061-1 (Site ID: P2), Fine-loamy, kaolinitic, thermic Plinthic Kandiudult. Geneva County, Alabama, May 8, 2009.

Ap -- 0 to 20 centimeters; brown (10YR 4/3) loamy fine sand; weak fine granular structure; very friable; many fine roots; very strongly acid (pH 5.07).

BE -- 20 to 42 cm; brownish yellow (10YR 6/8) sandy clay loam; weak medium subangular blocky structure; friable; common fine roots; very strongly acid (pH 4.77).

Bt -- 42 to 58 cm; brownish yellow (10YR 6/8) sandy clay loam; weak medium subangular blocky structure; friable; common fine roots; few faint clay films on ped faces; few medium prominent yellowish red (5YR 4/6) masses of iron accumulations; very strongly acid (pH 4.72).

Btv1 -- 58 to 75 cm; brownish yellow (10YR 6/8) sandy clay loam; moderate medium subangular blocky structure; friable; common fine roots; common faint clay films on ped faces; about 5 percent, by volume, dark red (2.5YR 3/6) plinthite nodules; common medium prominent yellowish red (5YR 4/6) masses of iron accumulations; very strongly acid (pH 4.77).

Btv2 -- 75 to 90 cm; brownish yellow (10YR 6/8) sandy clay loam; moderate medium subangular blocky structure; friable; few fine roots; common faint clay films on ped faces; about 5 percent, by volume, dark red (2.5YR 3/6) plinthite nodules; common medium prominent yellowish red (5YR 4/6) and few medium prominent red (2.5YR 4/8) masses of iron accumulations; very strongly acid (pH 4.94).

Btv3 – 90 to 122 cm, brownish yellow (10YR 6/8) sandy clay loam; moderate medium subangular blocky structure; friable; common faint clay films on ped faces; about 10 percent, by volume, red (2.5YR 4/8) plinthite nodules; common medium prominent yellowish red (5YR 4/6) and common medium prominent red (2.5YR 4/8) masses of iron accumulations; very strongly acid (pH 4.99).

BCv – 122 to 152+ cm, mixed brownish yellow (10YR 6/8), pale yellow (2.5Y 7/4), and red (2.5YR 4/8) sandy clay loam; weak medium subangular blocky structure; about 18 percent, by volume, red (2.5YR 4/8) plinthite nodules; strongly acid (pH 5.12).

Remarks: Soil Drainage Class 3, well drained. Absence of soil color of chroma two or less at a depth of 152cm.

Table 27. Standard Characterization; S2009AL-061-1 (Site ID: P2), Fine-loamy, kaolinitic, thermic Plinthic Kandiudult.

Horizon	Lower Depth	Particle Size Distribution			Sand Size Distribution					Coarse Fragments		pH
		Sand	Silt	Clay	2.0 - 1.0	1.0 - 0.5	0.5 - 0.25	0.25 - 0.1	0.1 - 0.05	Gravimetric	Volumetric†	
	(cm)	--% < 2mm of Whole Soil----------------------------------								-% > 2mm of Whole Soil-		
Ap	20	79.4	11.2	9.4	1.5	9.2	28.4	31.5	8.8	0.7	0.4	5.07
BE	42	66.9	11.7	21.4	2.0	8.2	22.2	26.2	8.2	1.3	0.8	4.77
Bt	58	61.6	10.3	28.2	1.1	6.9	20.2	25.5	7.9	4.8	2.9	4.72
Btv1	75	61.0	6.9	32.2	1.5	7.6	21.3	23.3	7.2	1.4	0.8	4.77
Btv2	90	60.4	5.8	33.8	4.5	6.7	19.3	22.7	7.3	2.0	1.2	4.94
Btv3	122	60.3	5.7	34.0	1.4	7.5	20.8	23.6	7.0	0.0	0.0	4.99
BCv	152+	60.2	6.3	33.5	5.8	10.4	20.0	18.5	5.5	0.1	0.0	5.12

Horizon	Organic Matter	Exchangeable Cations						Cation Exchange Capacity				Base Saturation
		Ca‡	Mg	K	Na	Al	ECEC	CEC-7	CEC-8.2§	ECEC	CEC-7	
	(%)	---cmol$_c$ kg soil^{-1}--								-----cmol$_c$ kg clay^{-1}-----		%
Ap	1.8	0.95	0.17	0.17	0.09	0.48	1.86	3.56	4.65	19.82	37.95	39
BE	0.5	0.65	0.11	0.30	0.26	0.71	2.03	3.16	5.14	9.52	14.78	42
Bt	0.3	0.44	0.04	0.27	0.10	1.29	2.14	3.51	5.85	7.60	12.47	24
Btv1	0.3	0.73	0.15	0.26	0.11	0.69	1.95	3.43	5.99	6.05	10.67	37
Btv2	0.2	1.08	0.29	0.19	0.10	0.24	1.90	3.29	5.88	5.62	9.72	50
Btv3	0.2	1.15	0.20	0.03	0.06	0.20	1.65	2.99	5.22	4.85	8.80	48
BCv	0.2	0.73	0.19	0.04	0.12	0.31	1.39	3.06	4.96	4.15	9.13	35

† Volumetric coarse fragment content estimated via NRCS rock/pararock fragment mass to volume conversion spreadsheet (Soil Survey Staff, 2010).

‡ Ca, Mg, K, and Na = NH_4OAc, pH 7.0 extractable calcium, magnesium, potassium, and sodium; Al = KCl extractable aluminum; ECEC = effective cation exchange capacity; CEC-7 = cation exchange capacity, NH_4OAc, pH 7.0; CEC-8.2 = cation exchange capacity, Sum of Cations (estimated after Hajek et al., 1972); Base Saturation = NH_4OAc, pH 7.0 base saturation.

Soil Description 10; S2009AL-067-3 (Site ID: P3), Fine-loamy, kaolinitic, thermic Plinthic Kandiudalf. Henry County, Alabama, August 14, 2009.

Ap -- 0 to 28 centimeters; brown (10YR 4/3) sandy loam; weak fine granular structure; very friable; about 4 percent, by volume, ironstone; many fine roots; moderately acid (pH 5.83).

AB -- 28 to 37 cm; dark yellowish brown (10YR 4/4) sandy loam; weak medium subangular blocky structure; friable; about 2 percent, by volume, ironstone; many fine roots; moderately acid (pH 5.76).

Bt -- 37 to 61 cm; dark yellowish brown (10YR 4/6) sandy clay loam; weak medium subangular blocky structure; friable; about 3 percent, by volume, ironstone; common fine roots; few faint clay films on ped faces; about 4 percent, by volume, yellowish red (5YR 4/6) and strong brown (7.5YR 5/8) plinthite nodules; few medium prominent yellowish red (5YR 4/8) masses of iron accumulations; slightly acid (pH 6.11).

Btv1 -- 61 to 100 cm; yellowish brown (10YR 5/6) sandy clay loam; moderate medium subangular blocky structure; friable; about 2 percent, by volume, ironstone; common fine roots; common faint clay films on ped faces; about 5 percent, by volume, strong brown (7.5YR 5/8) plinthite nodules; common medium prominent yellowish red (5YR 4/8) masses of iron accumulation; slightly acid (pH 6.37).

Btv2 -- 100 to 120 cm; olive yellow (2.5Y 6/6) sandy clay loam; moderate medium subangular blocky structure; friable; few fine roots; common faint clay films on ped faces; about 8 percent, by volume, strong brown (7.5YR 5/8) and red (2.5YR 4/6) plinthite nodules; common medium prominent yellowish red (5YR 4/8) masses of iron accumulations; few medium prominent pale brown (10YR 6/3) areas of iron depletions; slightly acid (pH 6.29).

Btv3 – 120 to 154 cm, yellowish brown (10YR 5/8) sandy clay loam; moderate medium subangular blocky structure; friable; few faint clay films on ped faces; about 15 percent, by volume, strong brown (7.5YR 5/8) and red (2.5YR 4/6) plinthite nodules; common medium prominent yellowish red (5YR 4/8) and few medium prominent red (2.5YR 5/6) masses of iron accumulations; common medium prominent pale brown (10YR 6/3) and few medium prominent light gray (10YR 7/2) areas of iron depletions; moderately acid (pH 6.06).

BC – 154 to 180+ cm, mixed yellowish red (5YR 4/6), dark yellowish brown (10YR 4/6), and light gray (10YR 7/2) sandy clay; weak medium subangular blocky structure; about 7 percent, by volume, strong brown (7.5YR 5/8) and red (2.5YR 4/6) plinthite nodules; common medium prominent red (2.5YR 5/6) masses of iron accumulations; very strongly acid (pH 4.53).

Remarks: Soil Drainage Class 3, well drained. Soil color of chroma two or less begins at a depth of 120cm.

Table 28. Standard Characterization; S2009AL-067-3 (Site ID: P3), Fine-loamy, kaolinitic, thermic Plinthic Kandiudalf.

Horizon	Lower	Particle Size Distribution			Sand Size Distribution					Coarse Fragments		pH
	Depth	Sand	Silt	Clay	2 - 1.0	1.0 -.5	0.5 -.25	0.25 -.1	0.1 -.05	Gravimetric	Volumetric	H_2O
	(cm)	---------------------------% < 2mm of Whole Soil--------------------------------								-% > 2mm of Whole Soil-		-----1:1-----
Ap	28	78.8	12.2	9.0	4.6	18.4	28.3	21.7	5.8	4.9	3.0	5.83
AB	37	78.4	12.8	8.8	5.7	14.1	25.9	25.2	7.5	1.2	0.7	5.76
Bt	61	65.5	13.8	20.6	4.9	9.7	21.7	22.2	7.0	3.5	2.1	6.11
Btv1	100	61.6	12.8	25.6	0.6	5.8	21.0	26.1	8.0	0.0	0.0	6.37
Btv2	120	62.5	9.9	27.6	1.7	9.1	22.2	23.1	6.4	0.7	0.4	6.29
Btv3	154	61.4	6.4	32.2	6.2	13.0	22.3	15.7	4.1	1.1	0.7	6.06
BC	180+	50.4	4.9	44.8	5.2	14.8	18.6	9.4	2.3	0.6	0.4	4.53
Btv3†	114-147	45.5	7.6	46.9	0.2	0.9	1.6	1.3	0.4	-	-	-
BC	175	45.5	5.4	49.1	0.4	1.1	1.7	1.1	0.3	-	-	-
CB	181+	56.6	1.0	42.3	0.6	2.0	2.0	0.9	0.2	-	-	-
Btv3	117-157	46.4	6.7	46.9	0.3	1.1	1.6	1.2	0.4	-	-	-
BC	177	39.6	6.9	53.4	0.3	1.1	1.4	0.8	0.3	-	-	-
CB	184+	40.5	3.0	56.5	0.4	1.2	1.4	0.8	0.2	-	-	-

Horizon	Organic	Exchangeable Cations					Cation Exchange Capacity					Base Saturation
	Matter	Ca‡	Mg	K	Al	Na	ECEC	CEC-7	CEC-8.2	ECEC	CEC-7	NH_4OAc (pH7)
	(%)	---------------------------------$cmol_c$ kg $soil^{-1}$---------------------------------------								-----$cmol_c$ kg $clay^{-1}$-----		------%------
Ap	2.6	1.56	1.92	0.08	0.11	0.57	4.24	6.28	6.46	47.18	69.92	66
AB	1.5	0.61	1.01	0.06	0.06	0.74	2.48	4.11	4.17	28.04	46.51	59
Bt	0.9	1.13	0.71	0.77	0.02	0.16	2.79	3.59	4.79	13.52	17.39	77
Btv1	0.4	0.72	0.43	0.77	0.00	0.19	2.11	2.91	3.85	8.27	11.37	73
Btv2	0.3	0.89	0.43	0.87	0.01	0.16	2.36	2.64	4.29	8.55	9.58	89
Btv3	0.2	0.39	0.69	0.24	0.02	0.21	1.55	2.60	4.01	4.81	8.08	59
BC	0.2	0.50	0.94	0.45	0.25	0.15	2.29	3.41	4.99	5.12	7.63	60
Btv3	-	1.45	0.31	0.39	-	0.15	-	3.49	-	-	-	66
BC	-	1.30	0.28	0.39	-	0.12	-	3.57	-	-	-	58
CB	-	0.58	0.17	0.06	-	0.13	-	3.02	-	-	-	31
Btv3	-	1.58	0.09	0.26	-	0.21	-	3.63	-	-	-	59
BC	-	0.80	0.06	0.15	-	0.17	-	3.84	-	-	-	31
CB	-	0.47	0.04	0.04	-	0.18	-	4.08	-	-	-	18

† Lower horizons sampled from two pedons located on fence row adjacent to pasture for *Cultural Alfisol* verification.

‡ Ca, Mg, K, and Na = NH_4OAc, pH 7.0 extractable calcium, magnesium, potassium, and sodium; Al = KCl extractable aluminum; ECEC = effective cation exchange capacity; CEC-7 = cation exchange capacity, NH_4OAc, pH 7.0; CEC-8.2 = cation exchange capacity, Sum of Cations (estimated after Hajek et al., 1972); Base Saturation = NH_4OAc, pH 7.0 base saturation.

Soil Description 11; S2009AL-067-1 (Site ID: PP1), Fine-loamy, kaolinitic, thermic Plinthic Kandiudult. Henry County, Alabama, May 12, 2009.

Ap -- 0 to 24 centimeters; brown (10YR 4/3) fine sandy loam; weak fine granular structure; very friable; common fine and few coarse roots; moderately acid (pH 5.62).

Bt -- 24 to 59 cm; yellowish brown (10YR 5/8) sandy clay loam; weak medium subangular blocky structure; friable; about 2 percent, by volume, ironstone; common fine roots; few faint clay films on ped faces; very strongly acid (pH 4.94).

Btv1 -- 59 to 78 cm; brownish yellow (10YR 6/8) sandy clay loam; moderate medium subangular blocky structure; friable; few fine roots; common faint clay films on ped faces; about 12 percent, by volume, strong brown (7.5YR 5/8) plinthite nodules; very strongly acid (pH 5.06).

Btv2 -- 78 to 101 cm; brownish yellow (10YR 5/8) sandy clay loam; moderate medium subangular blocky structure; friable; common faint clay films on ped faces; about 7 percent, by volume, strong brown (7.5YR 5/8) plinthite nodules; common medium faint yellowish red (5YR 5/8) masses of iron accumulation; very strongly acid (pH 5.03).

Btv3 -- 101 to 120 cm; brownish yellow (10YR 6/6) sandy clay loam; moderate medium subangular blocky structure; friable; common faint clay films on ped faces; about 6 percent, by volume, strong brown (7.5YR 5/8) and red (2.5YR 4/8) plinthite nodules; common medium prominent yellowish red (5YR 5/8) and few medium prominent red (2.5YR 4/8) masses of iron accumulations; common medium prominent pale brown (10YR 6/3) and common medium prominent light gray (10YR 7/2) areas of iron depletions; very strongly acid (pH 4.95).

BCv – 120 to 150+ cm, strong brown (7.5YR 5/8) sandy clay loam; weak medium subangular blocky structure; friable; few faint clay films on ped faces; about 5 percent, by volume, strong brown (7.5YR 5/8) and red (2.5YR 4/8) plinthite nodules; common medium prominent yellowish red (5YR 5/8) and common medium prominent red (2.5YR 4/8) masses of iron accumulations; many medium prominent light gray (10YR 7/2) areas of iron depletions; very strongly acid (pH 4.90).

Remarks: Soil Drainage Class 3, well drained. Soil color of chroma two or less begins at a depth of 101cm.

Table 29. Standard Characterization; S2009AL-067-1 (Site ID: PP1), Fine-loamy, kaolinitic, thermic Plinthic Kandiudult.

Horizon	Lower Depth	Particle Size Distribution			Sand Size Distribution					Coarse Fragments		pH
		Sand	Silt	Clay	2 - 1.0	1.0 -.5	0.5 -.25	0.25 -.1	0.1 -.05	Gravimetric	Volumetric†	H_2O
	(cm)	----------------------------% < 2mm of Whole Soil---------------------------								-% > 2mm of Whole Soil-		------1:1------
Ap	24	76.5	14.7	8.8	1.1	8.5	28.1	30.1	8.7	0.0	0.0	5.62
Bt	59	62.9	12.0	25.2	0.3	5.8	22.9	26.5	7.3	0.0	0.0	4.94
Btv1	78	63.2	11.5	25.3	0.7	7.2	21.7	25.5	8.2	0.0	0.0	5.06
Btv2	101	65.3	8.2	26.5	1.1	8.4	24.4	24.2	7.3	0.0	0.0	5.03
Btv3	120	65.6	6.9	27.6	1.4	8.7	25.5	23.5	6.5	2.8	1.7	4.95
BCv	150+	67.2	6.1	26.7	1.4	10.6	28.4	21.4	5.4	0.0	0.0	4.90

Horizon	Organic Matter	Exchangeable Cations					Cation Exchange Capacity					Base Saturation
		Ca‡	Mg	K	Al	Na	ECEC	CEC-7	CEC-8.2	ECEC	CEC-7	NH_4OAc (pH7)
	(%)	--------------------------------cmol$_c$ kg soil^{-1}------------------------------------								-----cmol$_c$ kg clay^{-1}-----		--------%--------
Ap	1.2	1.26	0.49	0.05	0.07	0.06	1.93	3.77	4.49	21.95	42.92	49
Bt	0.5	0.58	0.47	0.11	1.02	0.09	2.27	2.38	5.93	9.02	9.45	53
Btv1	0.3	0.73	0.35	0.07	0.51	0.08	1.75	3.35	5.44	6.92	13.22	37
Btv2	0.2	0.89	0.18	0.03	0.39	0.07	1.56	3.27	5.04	5.88	12.33	36
Btv3	0.2	0.78	0.10	0.02	0.68	0.09	1.67	3.08	4.98	6.06	11.16	32
BCv	0.2	0.78	0.21	0.02	0.68	0.09	1.78	3.10	5.08	6.67	11.59	36

† Volumetric coarse fragment content estimated via NRCS rock/pararock fragment mass to volume conversion spreadsheet (Soil Survey Staff, 2010).

‡ Ca, Mg, K, and Na = NH_4OAc, pH 7.0 extractable calcium, magnesium, potassium, and sodium; Al = KCl extractable aluminum; ECEC = effective cation exchange capacity; CEC-7 = cation exchange capacity, NH_4OAc, pH 7.0; CEC-8.2 = cation exchange capacity, Sum of Cations (estimated after Hajek et al., 1972); Base Saturation = NH_4OAc, pH 7.0 base saturation.

Soil Description 12; S2009AL-069-1 (Site ID: PP2), Fine-loamy, kaolinitic, thermic Plinthic Kandiudult. Houston County, Alabama, May 8, 2009.

Ap -- 0 to 26 centimeters; dark grayish brown (10YR 4/2) loamy fine sand; weak fine granular structure; very friable; common fine and few coarse roots; very strongly acid (pH 5.03).

BE -- 26 to 33 cm; light olive brown (2.5Y 5/6) fine sandy loam; weak medium subangular blocky structure; friable; about 1 percent, by volume, ironstone; few fine roots; very strongly acid (pH 4.99).

Btv1 -- 33 to 65 cm; light olive brown (2.5Y 5/6) fine sandy loam; weak medium subangular blocky structure; friable; few faint clay films on ped faces; about 5 percent, by volume, strong brown (7.5YR 4/6) and red (2.5YR 5/8) plinthite nodules; few medium distinct strong brown (7.5YR 4/6) masses of iron accumulations; very strongly acid (pH 4.66).

Btv2 -- 65 to 95 cm; brownish yellow (10YR 6/6) sandy clay loam; moderate medium subangular blocky structure; friable; common faint clay films on ped faces; about 15 percent, by volume, strong brown (7.5YR 4/6), yellowish red (5YR 4/6), and red (2.5YR 5/8) plinthite nodules; common medium distinct strong brown (7.5YR 4/6) and few medium prominent red (2.5YR 4/6) masses of iron accumulation; very strongly acid (pH 4.70).

Btv3 -- 95 to 110 cm; light yellowish brown (10YR 6/4) fine sandy loam; moderate medium subangular blocky structure; friable; common faint clay films on ped faces; about 10 percent, by volume, strong brown (7.5YR 4/6), yellowish red (5YR 4/6), and red (2.5YR 5/8) plinthite nodules; common medium distinct strong brown (7.5YR 4/6) and common medium prominent red (2.5YR 4/6) masses of iron accumulation; very strongly acid (pH 4.71).

Btv4 – 110 to 130 cm, light yellowish brown (10YR 6/4) fine sandy loam; weak medium subangular blocky structure; friable; few faint clay films on ped faces; about 25 percent, by volume, strong brown (7.5YR 4/6), yellowish red (5YR 4/6), and red (2.5YR 5/8) plinthite nodules; common medium distinct strong brown (7.5YR 4/6) and common medium prominent red (2.5YR 4/6) masses of iron accumulations; very strongly acid (pH 4.74).

BCv – 130 to 152+ cm, strong brown (7.5YR 5/8) fine sandy loam; weak medium subangular blocky structure; about 20 percent, by volume, strong brown (7.5YR 4/6), yellowish red (5YR 4/6), and red (2.5YR 5/8) plinthite nodules; common medium distinct strong brown (7.5YR 4/6) and common medium prominent red (2.5YR 4/6) masses of iron accumulations; few medium prominent light gray (10YR 7/2) areas of iron depletions; very strongly acid (pH 4.98).

Remarks: Soil Drainage Class 3, well drained. Soil color of chroma two or less begins at a depth of 130cm.

Table 30. Standard Characterization; S2009AL-069-1 (Site ID: PP2), Fine-loamy, kaolinitic, thermic Plinthic Kandiudult.

Horizon	Lower Depth	Particle Size Distribution			Sand Size Distribution					Coarse Fragments		pH
		Sand	Silt	Clay	2 - 1.0	1.0 -.5	0.5 -.25	0.25 -.1	0.1 -.05	Gravimetric	Volumetric†	H_2O
	(cm)	----------------------------% < 2mm of Whole Soil--------------------------								-% > 2mm of Whole Soil-		------1:1------
Ap	26	82.2	11.8	6.1	1.3	7.2	26.4	34.6	12.6	0.0	0.0	5.03
BE	33	77.9	10.8	11.3	0.6	6.7	24.8	33.3	12.4	0.2	0.1	4.99
Btv1	65	71.3	9.9	18.8	0.8	5.6	21.1	31.8	12.0	0.2	0.1	4.66
Btv2	95	70.2	9.7	20.1	0.9	6.3	21.4	30.4	11.3	0.0	0.0	4.70
Btv3	110	72.8	9.2	18.0	0.5	7.2	23.6	30.4	11.1	0.0	0.0	4.71
Btv4	130	73.2	8.9	17.9	0.9	6.6	23.1	31.2	11.4	0.1	0.0	4.74
BCv	152+	74.1	7.9	18.0	2.9	8.0	22.8	29.5	10.9	0.7	0.4	4.98

Horizon	Organic Matter	Exchangeable Cations					Cation Exchange Capacity					Base Saturation
		Ca‡	Mg	K	Al	Na	ECEC	CEC-7	CEC-8.2	ECEC	CEC-7	NH_4OAc (pH7)
	(%)	--------------------------------cmol$_c$ kg soil^{-1}------------------------------------								-----cmol$_c$ kg clay^{-1}-----		-------%-------
Ap	1.7	0.69	0.08	0.03	0.61	0.07	1.49	2.90	4.07	24.49	47.75	30
BE	0.5	0.89	0.18	0.02	0.30	0.04	1.42	2.07	3.15	12.55	18.29	54
Btv1	0.3	0.96	0.08	0.02	0.70	0.05	1.81	3.50	4.44	9.64	18.63	32
Btv2	0.3	0.52	0.02	0.02	0.91	0.06	1.53	2.74	4.14	7.62	13.65	23
Btv3	0.2	0.36	0.01	0.02	0.82	0.06	1.26	2.18	3.57	6.99	12.08	20
Btv4	0.2	0.43	0.04	0.01	0.71	0.08	1.27	2.10	3.51	7.14	11.73	27
BCv	0.1	0.26	0.00	0.01	0.33	0.10	0.71	1.70	3.23	3.93	9.45	22

† Volumetric coarse fragment content estimated via NRCS rock/pararock fragment mass to volume conversion spreadsheet (Soil Survey Staff, 2010).

‡ Ca, Mg, K, and Na = NH_4OAc, pH 7.0 extractable calcium, magnesium, potassium, and sodium; Al = KCl extractable aluminum; ECEC = effective cation exchange capacity; CEC-7 = cation exchange capacity, NH_4OAc, pH 7.0; CEC-8.2 = cation exchange capacity, Sum of Cations (estimated after Hajek et al., 1972); Base Saturation = NH_4OAc, pH 7.0 base saturation.

Soil Description 13; S2009AL-061-2 (Site ID: PP3), Fine-loamy, kaolinitic, thermic Plinthic Kandiudult. Geneva County, Alabama, July 15, 2009.

Ap -- 0 to 28 centimeters; brown (10YR 4/3) loamy fine sand; weak fine granular structure; very friable; about 3 percent, by volume, ironstone; common fine and few coarse roots; strongly acid (pH 5.25).

Bt -- 28 to 52 cm; yellowish brown (10YR 5/6) sandy clay loam; weak medium subangular blocky structure; friable; about 2 percent, by volume, ironstone; few fine roots; few faint clay films on ped faces; very strongly acid (pH 4.85).

Btv1 -- 52 to 80 cm; yellowish brown (10YR 5/6) sandy clay loam; moderate medium subangular blocky structure; friable; about 2 percent, by volume, ironstone; common faint clay films on ped faces; about 4 percent, by volume, strong brown (7.5YR 5/6) plinthite nodules; very strongly acid (pH 4.78).

Btv2 -- 80 to 109 cm; yellowish brown (10YR 5/6) sandy clay loam; moderate medium subangular blocky structure; friable; common faint clay films on ped faces; about 7 percent, by volume, strong brown (7.5YR 4/6) plinthite nodules; few medium distinct strong brown (7.5YR 4/6) masses of iron accumulation; very strongly acid (pH 4.75).

Btv3 -- 109 to 128 cm; brownish yellow (10YR 6/6) sandy clay loam; moderate medium subangular blocky structure; friable; common faint clay films on ped faces; about 7 percent, by volume, strong brown (7.5YR 4/6) and red (2.5YR 4/6) plinthite nodules; common medium distinct strong brown (7.5YR 4/6) and few medium prominent red (2.5YR 4/6) masses of iron accumulations; very strongly acid (pH 4.60).

BC – 128 to 144 cm, mixed light yellowish brown (10YR 6/4), strong brown (7.5YR 4/6), and yellowish red (5YR 5/6) sandy clay; moderate medium subangular blocky structure; friable; about 2 percent, by volume, ironstone; common faint clay films on ped faces; about 10 percent, by volume, strong brown (7.5YR 4/6) and red (2.5YR 4/6) plinthite nodules; common medium distinct strong brown (7.5YR 4/6) masses of iron accumulations; common medium prominent pale brown (10YR 6/3) areas of iron depletions; very strongly acid (pH 4.67).

CB1 – 144 to 156 cm, mixed light yellowish brown (10YR 6/4), strong brown (7.5YR 4/6), and yellowish red (5YR 5/6) sandy clay; weak medium subangular blocky structure; friable; few faint clay films on ped faces; about 12 percent, by volume, strong brown (7.5YR 4/6) and red (2.5YR 4/6) plinthite nodules; common medium distinct strong brown (7.5YR 4/6) masses of iron accumulations; common medium prominent pale brown (10YR 6/3) and few to common, increasing with depth, light brownish gray (10YR 6/2) areas of iron depletions; very strongly acid (pH 4.67).

CB2 – 156 to 180+ cm, mixed strong brown (7.5YR 4/6), red (2.5YR 4/6), and light brownish gray (10YR 6/2) clay; weak medium subangular blocky structure; friable; few faint clay films on ped faces; about 12 percent, by volume, strong brown (7.5YR 4/6) and red (2.5YR 4/6) plinthite nodules; very strongly acid (pH 4.66).

Remarks: Soil Drainage Class 3, well drained. Soil color of chroma two or less begins at a depth of 144cm.

Table 31. Standard Characterization; S2009AL-061-2 (Site ID: PP3), Fine-loamy, kaolinitic, thermic Plinthic Kandiudult.

Horizon	Lower Depth	Particle Size Distribution			Sand Size Distribution					Coarse Fragments		pH
		Sand	Silt	Clay	2 - 1.0	1.0 -.5	0.5 -.25	0.25 -.1	0.1 -.05	Gravimetric	Volumetric†	H_2O
	(cm)	----------------------------% < 2mm of Whole Soil------------------------------								-% > 2mm of Whole Soil-		-------1:1------
Ap	28	82.8	11.6	5.6	2.6	10.4	25.6	31.2	13.1	6.3	3.9	5.25
Bt	52	66.4	12.8	20.9	4.4	11.5	21.4	21.0	8.0	1.4	0.9	4.85
Btv1	80	56.2	9.8	34.0	2.8	8.0	16.6	19.7	9.0	6.8	4.2	4.78
Btv2	109	58.4	8.1	33.5	4.6	10.0	17.7	18.5	7.5	1.9	1.2	4.75
Btv3	128	58.6	8.1	33.3	2.0	9.1	18.8	20.5	8.2	2.1	1.3	4.60
BC	144	56.2	8.2	35.6	2.8	11.5	17.6	17.1	7.2	0.3	0.2	4.67
CB1	156	51.9	7.9	40.2	2.2	9.3	15.1	17.3	8.0	0.2	0.1	4.67
CB2	180+	39.8	8.1	52.0	1.2	6.6	11.4	13.9	6.8	0.4	0.3	4.66

Horizon	Organic Matter	Exchangeable Cations					Cation Exchange Capacity					Base Saturation
		Ca‡	Mg	K	Al	Na	ECEC	CEC-7	CEC-8.2	ECEC	CEC-7	NH_4OAc (pH7)
	(%)	---------------------------------cmol$_c$ kg soil^{-1}---------------------------------------								-----cmol$_c$ kg clay^{-1}-----		-------%-------
Ap	1.1	1.32	0.64	0.13	0.13	0.01	2.23	2.21	3.79	39.67	39.40	95
Bt	0.6	1.06	0.26	0.05	0.51	0.20	2.08	3.57	4.97	9.98	17.12	44
Btv1	0.5	0.87	0.18	0.03	0.77	0.10	1.95	3.79	6.04	5.74	11.14	31
Btv2	0.4	0.83	0.32	0.03	0.76	0.11	2.05	3.53	5.90	6.10	10.54	36
Btv3	0.4	0.52	0.13	0.02	1.10	0.19	1.95	3.71	5.23	5.86	11.15	23
BC	0.3	0.32	0.15	0.03	1.60	0.16	2.25	3.66	8.87	6.34	10.28	18
CB1	0.2	0.45	0.31	0.02	2.63	0.21	3.62	5.42	11.38	9.00	13.50	18
CB2	0.1	0.56	0.55	0.03	3.62	0.14	4.90	7.52	10.00	9.43	14.44	17

† Volumetric coarse fragment content estimated via NRCS rock/pararock fragment mass to volume conversion spreadsheet (Soil Survey Staff, 2010).

‡ Ca, Mg, K, and Na = NH_4OAc, pH 7.0 extractable calcium, magnesium, potassium, and sodium; Al = KCl extractable aluminum; ECEC = effective cation exchange capacity; CEC-7 = cation exchange capacity, NH_4OAc, pH 7.0; CEC-8.2 = cation exchange capacity, Sum of Cations (estimated after Hajek et al., 1972); Base Saturation = NH_4OAc, pH 7.0 base saturation.

Table 32. Coefficient of variation (CV) and degree of variability (after Wilding and Drees, 1983) of select use-invariant and management-dependent soil properties for thirteen repetitions (ten for active carbon, field capacity, wilting point, and available water holding capacity) of Dothan (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soils within long-term land use-managements in the Wiregrass Region of the Alabama Coastal Plain.

Low (CV < 15)		Moderate (15 < CV < 35)		High (CV > 35)	
Soil Property†	CV	Soil Property	CV	Soil Property	CV
Sand (%)	6	Silt (%)	17	Gibbsite (%)	38
CEC(cmol$_c$ kg clay^{-1})	15	Clay (%)	18	WDC (%)	43
Kaolinite (%)	11	ECEC(cmol$_c$ kg clay^{-1})	21	TON (gkg^{-1})	53
ρ_b (Mg m^{-3})	7	Fe_2O_3 (%)	25	POMN (g kg^{-1})	64
WSA (%) (0-5)	9	Depth to argillic/kandic (cm)	25	AC (mg kg^{-1})	43
WSA (%) (5-15)	7	Depth to plinthite (cm)	27	ECEC(cmol$_c$ kg soil^{-1})	47
		Depth to chroma ≤ 3 (cm)	21	P (mg kg^{-1})	189
		SS (kPa)	27	Fe (mg kg^{-1})	63
		CDR (%)	26	Ca (mg kg^{-1})	64
		TOC (g kg^{-1})	26	Mg (mg kg^{-1})	92
		POMC (g kg^{-1})	30	K (mg kg^{-1})	139
		CEC(cmol$_c$ kg soil^{-1})	25	$\Theta_{g,\ 10kPa}$ (kg kg^{-1}) (0-6 cm)	43
		Θg, 10kPa (kg kg-1) (5-21 cm)	20	$\Theta_{g,\ 1.5MPa}$ (kg kg^{-1}) (0-6 cm)	74
		Θg, 1.5MPa (kg kg-1) (5-21 cm)	33	$K_{sat,\ 15\ cm}$ (cm hr^{-1})	124
		AWHC (kg kg-1) (0-6 cm)	32	$K_{sat,\ 30\ cm}$ (cm hr^{-1})	164
		AWHC (kg kg-1) (15-21 cm)	17	$K_{sat,\ 50\ cm}$ (cm hr^{-1})	71

† Sand, Silt, and Clay = particle size separates (0.05 - 2.0, 0.002 - 0.05, <0.002 mm, respectively); CEC = cation exchange capacity (NH_4OAc, pH 7) ; ECEC = effective cation exchange capacity (NH_4OAc, pH 7); Gibbsite and Kaolinite = clay fraction (<0.002 mm) gibbsite and kaolinite; Fe_2O_3 = dithionite-citrate-bicarbonate extractable iron converted to iron oxide basis; Depth to argillic/kandic = depth from soil surface to argillic/kandic diagnostic subsurface horizon; Depth to plinthite = depth from soil surface to occurrence of ≥ 5% nodular plinthite; Depth to chroma ≤ 3 = depth from soil surface to occurrence of iron depletions with chroma ≤ 3; SS = soil strength; ρ_b = soil bulk density; WDC = water dispersible clay; CDR = clay dispersion ratio (calculated as total clay/WDC); WSA = water stable aggregates; TOC and TON = total soil organic carbon and nitrogen; POMC and POMN = particulate organic matter (>53 µm) associated carbon and nitrogen; AC = active carbon; P and Fe = Mehlich I extractable phosphorus and iron; Ca, Mg, and K = NH_4OAc, pH 7 extractable bases; $\Theta_{g,\ 10kPa}$ = gravimetric soil water content at field capacity; $\Theta_{g,\ 1.5MPa}$ = gravimetric soil water content at wilting point; AWHC = available water holding capacity (calculated as Θg, 10kPa - Θg, 1.5 MPa); K_{sat} = saturated hydraulic conductivity.

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