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Long-term Effects of Alternative Residue Management Practices on Near-surface Soil Properties and Soybean Production in a Wheat-soybean, Double-crop System in Eastern Arkansas

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Long-term Effects of Alternative Residue Management Practices on Near-surface Soil Properties and Soybean Production in a Wheat-soybean, Double-crop System in Eastern Arkansas

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Crop, Soil, and Environmental Sciences

By

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Abstract

Adoption of management practices that maintain or increase soil organic matter (SOM), which contains 58% carbon (C) on average, may help to mitigate climate change by sequestering atmospheric C. Therefore, the main objective of this study was to determine the long-term trends in SOM, soil C and nitrogen (N), bulk density, various soil chemical properties (i.e., pH, electrical conductivity [EC], and Mehlich-3-extractable nutrients) in the top 10 cm, and soybean yield as affected by residue burning (burning and non-burning), tillage (conventional and no-tillage), irrigation (irrigated and non-irrigated), and N-fertilization/residue level (high and low) in a wheat (*Triticum aestivum* L.)-soybean [*Glycine max* (L.) Merr.], double-crop system in eastern Arkansas. The secondary objective was to determine the relationship between soil water potential (-MPa) and soil water content (g g^{-1}) in the top 7.5 cm as affected by residue treatments. The field site has been consistently managed for 13 years at the University of Arkansas Lon Mann Cotton Research Station near Marianna, Arkansas on a Calloway silt loam (fine silty, mixed, active, thermic Glossaquic Fraglossudalf). Averaged across all other factors, SOM did not differ over time ($P > 0.05$) under irrigation, while SOM content increased over time ($P < 0.05$) until approximately nine years after initial conversion when SOM decreased thereafter under dryland production. Results indicated that irrigation management caused many of the largest differences in near-surface soil property trends over time, namely SOM and C, compared to the other field treatments. The relationship between the natural logarithm of soil water potential and the gravimetric soil water content was only affected ($P < 0.05$) by the N-fertilization/residue level treatment. Averaged across tillage, burning, and irrigation, soil water contents under high residue treatment exceeded those water contents under low residue treatment at the same water potential. The increased soil water retention under high residue treatment may

be related to increased biomass inputs, SOM accumulation, and soil aggregation at the < 2mm level compared with low residue treatment. Understanding the long-term effects of growing-season weather patterns as well as irrigation, burning, tillage, and fertilization management on near-surface soil properties is critical to developing sustainable agricultural practices in the mid-South.

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Support from the Arkansas Soybean Promotion board has enabled me to conduct my studies and research for the last two years, and I am very grateful. Thank you for enabling me to pursue my passion.

Dedication

To Wendell Berry, whose writing first kindled my interest in agriculture; to Mark Cain, who was my first teacher in the field; to my son, Jasper, whose face I see when I consider the sustainability of feeding the next generation; and to my wife, Shannon, who I love very much, and who shares my reverence for plants, water, and soil.

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Chapter 1

Literature Review

Introduction

The sustainability of soil and water resources in agroecosystems depends upon long-term agricultural management decisions. Agriculture currently places high demand on water resources and generates 10 to 12% of total global anthropogenic emissions of greenhouse gases (IPCC, 2013) through the burning of fossil fuels and the oxidation of soil organic matter (SOM). However, the impact of agriculture on soil and water resources may vary according to management. Residue management practices such as tillage, burning, nitrogen (N) fertilization, and irrigation can strongly affect the fate of soil OM, carbon (C), N, water content, and several other soil physical and chemical properties that are relevant to crop yield and sustainability.

Soil OM accumulation and oxidation over the long-term is determined by additions of biomass and the timeline of decomposition. Management practices such as tillage, burning, fertilization, and irrigation alter the soil physical and chemical environment, and therefore affect the activity of the microbes responsible for converting crop residues into stabilized fractions of SOM, as well as the activity of microbes responsible for attacking SOM. Management practices that promote the accumulation of SOM may also consequently increase plant available water (Nielson et al., 2002). Increases in SOM are often associated with changes in soil water retention characteristics, such as increased water infiltration, greater hydraulic conductivity, and increased water retention (Azooz and Arshad, 1996).

Previous research has indicated a relationship between varying management systems of tillage, burning, fertilization, and irrigation, and long-term effects on soil properties such as SOM and soil C. Conventional tillage mixes the plow layer and tends to increase decomposition, while no-tillage tends to increase SOM accumulation (Horowitz, 2011; Morgan et al., 2010; Padgitt et al., 2000; Verkler et al., 2009; Zanatta et al., 2007). Burning crop residues is a widespread practice in the mid-southern US (Frederick et al., 1998; Sanford, 1982), and is associated with increased pH and potassium (K) (Chan et al., 2005), decreased soil N, phosphorus (P), and sulfur (S) (Biederback et al., 1980), and decreased in SOM due to reduced biomass additions. N fertilization promotes wheat biomass and yield, which generally promotes SOM and soil C accumulation (Bowman and Halvorson, 1998; Halvorson et al., 1999), although some research has reported a decrease in soil C under increased N fertilization due to adverse effects on certain soil microorganism populations such as lignin decomposers (Lee and Jose, 2003). Irrigation promotes both increased additions of plant and microbial biomass as well as microbial decomposition of residues and SOM (Churchman and Tate, 1986; Six et al., 1999).Irrigation may have complex effects on soil properties over time, because many microbial processes are controlled by available moisture. Therefore, the effects of irrigation on SOM cycling can be difficult to predict.

An evaluation of the long-term effects of common residue and water management practice effects on soil properties and crop productivity in a double-crop, wheat (*Triticum aestivum* L.)-soybean [*Glycine max* (L.) Merr.] system might offer valuable insights for soybean producers that have long-term sustainability goals for their soil and water resources. Results from this study might be especially useful for determining best management practices in areas such as eastern Arkansas that have experienced large-scale decreases in SOM and may face potential water shortages in the future (Scott et al., 1998). Therefore, the main objective of this study was to determine the long-term trends of near-surface soil C and N, other near-surface soil physical (i.e., bulk density) and chemical (i.e., pH, electrical conductivity (EC), and Mehlich-3-extractable nutrients) properties, and soybean yield as affected by residue burning (burning and non-burning), tillage (conventional and no-tillage), irrigation (irrigated and dryland), and N-fertilization/wheat-residue level (high and low). A secondary objective of this study was to evaluate the long-term effects of residue burning, tillage, irrigation, and N-fertilization/wheat-residue level on the relationship between soil water potential and soil water content in the top 7.5 cm using a soil wetting-curve approach.

Literature Review

Soybean Production in the United States

As with many commodity crops in the United States, soybean [*Glycine max* (L.) Merr.] production has rapidly increased in the decades following World War II. Planted soybean area in the United States has doubled from approximately 14 million hectares in 1965 to about 34 million hectares in 2014, and is currently the second most widely grown crop in the United States in terms of hectares planted and harvested (USDA-NASS, 2015). Productivity has also increased from an average of 1.6 Mg ha^{-1} in 1965 to 3 Mg ha^{-1} in 2014 (USDA-NASS, 2015). New technologies are largely responsible for these rapid increases in scale and productivity. Genetically modified (GM) cropping systems have reduced weed pressure and increased yield, and glyphosate-resistant GM soybean now occupy 93% of the soybean area in the United States (USDA-NASS, 2013). Innovations in farm equipment, pesticides, and fertilizer have transformed agricultural labor efficiency, so that the average 11.1 hectares per worker in 1890 had increased to 300 hectares per worker by 1990 (Hunt, 2001).

However, new obstacles to soybean production have emerged in recent decades as well. Natural resources in many soybean-growing regions have become overtaxed by the accumulated demands of years of cultivated agriculture, as evidenced by topsoil erosion in the Midwest (Dickey et al., 1985) and dwindling water tables in eastern Arkansas (Scott, 1998). Certain weeds have evolved resistance to glyphosate, rendering GM-soybean cropping systems less effective. This is especially true in Arkansas, where over 98% of soybean cropland is planted to glyphosate-resistant seed (Scott and Smith, 2011) and six species of glyphosate-resistant weeds have been confirmed, most notably palmer amaranth (*Amaranthus palmeri*) (Nandula, 2010).

Another recent development that may compromise soybean production is climate change.

Changing weather patterns have implications for season length, precipitation, temperature, and other critical factors of crop production. Climate change has been partly generated by agriculture, due to fossil fuel use and oxidation of soil carbon (C; IPCC, 2013; Lal, 2004; Smith, 2008). Given that many of today's obstacles in soybean production are a cumulative result of past agricultural management, it is imperative to adopt management systems that balance production concerns with conserving natural resources, thereby preserving the ability of future generations to produce crops. Because soybean is such a prevalent crop in the USA, soybean residue management practices, tillage systems, and fertilization practices carry far-reaching ecological and economic consequences.

Arkansas Soybean Production

Overview

In 2014, Arkansas ranked 11th in planted soybean area nationwide (USDA-NASS, 2015). The average soybean yield in Arkansas in 2014 was 3.4 Mg ha^{-1}, which was slightly greater than the national average of 3.2 Mg $ha\text{-}^{1}$. Arkansas soybean production is primarily concentrated in the Southern Mississippi Alluvium [Major Land Resource Area (MLRA) 131A], especially in Mississippi, Poinsett, Clay, and Craighead Counties (Fig. 1). While Mississippi County surpassed other counties in area planted (120,596 ha) and harvested (120,151 ha) in 2013, Clay County led the state in productivity with a mean yield of 3.3 Mg ha^{-1} (USDA-NASS, 2015).

Soils and Climate of Eastern Arkansas

The viability of agriculture in eastern Arkansas is founded upon the region's soils, relatively flat topography, and warm, wet climate. Eastern Arkansas soils formed fairly recently in the late Holocene epoch, in rich alluvial deposits from the Ohio, Mississippi, and Arkansas Rivers (Foti, 1974). Coarser-textured soil particles settle out of suspension more rapidly than finer-textured soil particles (Allen, 1965), so the textural classes vary greatly depending on the site of alluvial deposition. In eastern Arkansas, sandy and loamy sediments settled out of suspension rapidly to form low ridges and natural levees near water channels (NRCS, 2006). Many soils in this area are situated in low landscape positions, where clays and finer silts have settled out of suspension more slowly and formed fine-textured soils (Scott, 1998). This abundance of flat, low-lying bottomland is ideal for operating large-scale tractors and irrigating over long distances. The topography tends to be level to depressional to very gently undulating plains (NRCS, 2006), and local relief varies by less than 5 m in most areas in eastern Arkansas (NRCS, 2006).

In addition to fine-textured soils and relatively flat topography, soybean production in eastern Arkansas is aided by a generally warm, wet climate. The dominant soil temperature regime is thermic (NRCS, 2006). In Stuttgart, (a city which approximates the middle of the Arkansas portion of MLRA 131-A) the mean maximum daily temperature exceeds 32°C in July, and the mean minimum daily temperature drops below 1°C in January. The normal daily range of temperature is approximately 6.7°C throughout the year, which is indicative of relatively high humidity conditions (Scott, 1998). Average annual rainfall ranges from 118 cm yr^{-1} at Saint Francis in the north to 134 cm yr^{-1} at Monticello in the south, with most weather stations scattered throughout the region reporting approximately 125 cm yr^{-1} (Scott, 1998). The annual distribution of rainfall tends to proceed along the following pattern: maximum rainfall occurs in March, April, and May; monthly precipitation significantly decreases in June, July, and August when the average cumulative water deficit is ~ 22 cm; and monthly precipitation greatly increases again in September. Because a substantial portion of the growing season for commodity crops in the region occurs during the driest months, irrigation is often utilized to maximize plant productivity.

Unfortunately, the same climatic factors that aid soybean production also make the soil organic matter (SOM) more susceptible to oxidation and decomposition under cultivated agricultural management (Reicosky et al., 1997; Brye et al., 2004). Several studies have examined the role of agricultural management practices in the depletion of SOM and oxidation of soil organic C in eastern Arkansas (Amuri et al., 2008; Brye et al., 2006; Verkler et al., 2009). When eastern Arkansas was covered by forested wetlands, the soils accumulated large concentrations of OM and C (Stanturf et al., 2000). Years of cultivated agriculture, however, have reduced SOM and C concentrations in the top 12 cm of cropland soil to 0.021% and 0.011 %, respectively (DeLong et al., 2003), compared to 4.6 to 6.5 % SOM and 2.26 to 3.18 % C in undisturbed prairie soils in eastern Arkansas (Brye and Pirani, 2005). Adopting agricultural management practices which slow or even reverse losses of SOM and soil C is imperative for the sustainability of agriculture in Arkansas.

Double-cropped Soybean

Of the 1.4 million hectares in Arkansas planted to soybean in 2014, 11% were double-cropped (USDA-NASS, 2015), or planted following a second crop. A common pairing with double-cropped soybean in Arkansas is winter wheat (*Triticum aestivum* L.) (ASPB, 1999). In a wheat -soybean, double-crop system, Arkansas growers plant soybean soon after a wheat harvest, generally between May 25 and June 20. Some producers will burn and/or till the field between wheat harvest and soybean planting. Soybean are then generally harvested between

October 15 and November 9 (UACES, 2000) and plant the field to wheat again after soybean harvest.

The main disadvantage of a wheat-soybean double-crop system is that wheat must mature to a harvestable stage before planting soybean, thus shortening the soybean growing season and may consequently decrease soybean biomass and harvestable yield (MacKown et al., 2007). There are some instances, however, when the difference between early planting in a full-season soybean system and later planting in a wheat-soybean, double-crop system is inconsequential. In a wheat-soybean experiment conducted on Maury silt-loam soil (Typic Paleudalf) in Kentucky, Coale and Grove (1990) observed that early season drought negatively affected soybean seed germination and stand establishment in full-season soybean, thus decreasing plant root growth, biomass, and plant population compared to double-cropped soybean. Full-season soybean and double-cropped soybean may also produce similar soybean yields when wheat is grown solely as a cover crop and removed earlier in the season. Harvesting wheat for hay instead of grain can advance the soybean planting date by up to six weeks, as well as leave more soil water for the soybean crop (MacKown et al., 2007).

One advantage of double-crop systems is the additional revenue from a second harvested crop. A wheat-soybean, double-crop study conducted on a clay loam (Chromic Hapluderts) in Stoneville, MO showed that, despite a 10 to 40% greater yield from full-season soybean, the double-crop trials were more profitable due to additional revenue from the wheat crop. In fact, the revenue from winter wheat generated over 60% of the combined net returns (Kyei-Boahen et al., 2006). A three-year experiment in the eastern Great Plains similarly concluded that the net economic returns per area were greater in double-cropped systems, despite greater yields from single-crop systems (Kelley, 2003).

In addition to economic advantages, double-cropping has the ecological advantages of reducing nutrient leaching and providing soil cover (Scott, 1998). Water-soluble nitrogen (N) fertilizers, such as nitrate-N (NO_3-N), can be easily transported into nearby aquatic ecosystems if not taken up by plants, resulting in financial losses for the producer and pollutants in the watershed (Scott, 1998; Dabney et al., 2001). Winter cover crops scavenge more excess N than volunteer vegetation, thereby reducing nutrient leaching (Dabney et al., 2001). Cover crops also prevent soil erosion by intercepting rain drops, thereby decreasing the likelihood of soil particle detachment, and increasing infiltration (Dabney et al., 2001).

Importance of Soil Organic Matter

Soil OM concentration strongly affects many soil properties that are relevant to crop production, such as soil fertility and water content, and is a determining factor in soil C sequestration (Follet et al., 2001). An increase in SOM content often decreases the need for fertilizer and irrigation inputs (Magdoff and Weil, 2004). An increase in SOM also represents an increase in soil C due to the composition of humus, a main component of SOM. Humus is approximately 58% C, 3 to 6% N, and has a C:N ratio of 10 to 20:1 (Luo and Zhou, 2010). Considering SOM is typically composed of organic residues of plants, animals, microbes, and stabilized organic compounds, the long-term balance of SOM is determined by how much plant biomass is added to the system and the timeline of decomposition. Soil OM tends to decompose at an average rate of 5% or less per year (Luo and Zhou, 2010), but can decompose more quickly or more slowly depending on environmental conditions. Soil OM accumulates more readily in fine-textured soils (Luo and Zhou, 2010), soils with cool temperatures, and in wet-soil conditions (Lal 2004). Soil OM content rapidly decreases, however, under certain kinds of agricultural management due to removal of residue or to oxidation of soil C by tillage (Follet et al., 2001; Lal 2004; Morgan et al., 2010). Burning residue and conventional tillage (CT) are long-standing, widespread practices in eastern Arkansas, where soils have consequently decreased in SOM since the introduction of cultivated agriculture (DeLong et al., 2003).

Soil Carbon Sequestration

The largest terrestrial reserve of C exists in SOM in the form of soil organic carbon (SOC) (Follet et al., 2001; Lal, 2004). Estimations of global SOC range from 700 Pg C (Bolin 1970) to 3150 Pg C, with the latter estimate including deeper soil layers as well as permanently frozen soils (Sabine et al., 2004). Even at the lower range of estimates, the SOC pool exceeds the amount of C in the atmosphere several times over (Brady and Weil, 2008), and SOM alone is estimated to contain three to four times the C content of the atmosphere (Stevenson, 1986). Atmospheric C initially enters the soil through the decaying tissue of photosynthetic organisms, primarily plants. Plants take in atmospheric C during photosynthesis and convert that C into simple plant sugars, ultimately depositing their residue in or on the soil.

The resulting residue, or particulate organic matter (POM), undergoes several physical and chemical transformations in the soil as it is fed upon by microorganisms in a process generally referred to as decomposition (Paustian et al., 2000). The estimated C content of the total litter pool, or the global amount of POM existing at any given time, ranges from 42 Pg C (Bonan et al., 2003) to 382 Pg C (Esser et al., 1982). Decomposition of POM involves the leaching, fragmentation, and chemical alteration of dead tissue. Decomposition produces heterotrophic respiration of CO_2, mineralizes nutrients such as inorganic N and C, and generates organic compounds that are incorporated into SOM (Luo and Zhou, 2010).

The amount of C in POM that becomes sequestered in the soil versus the amount of C that is respired depends on the activity of microorganisms. Microorganisms preferentially feed on easily decomposable carbohydrates in fresh residues, and in the process produce polysaccharides that bind the residue and soil particles into macroaggregates. The more recalcitrant intra-aggregate POM (iPOM) are less accessible to soil microorganisms, and consequently sequester C for longer periods of time. The iPOM bound and protected in soil aggregates decomposes more slowly than non-aggregate-bound POM, indicating that iPOM and aggregate stability are directly linked to a soil's ability to store and retain C (Paustian et al., 2000). For decomposing plant residues, approximately 70% of C is respired as CO_2, while 30% is retained in the SOC pool at the end of the growing season (Stevenson, 1986).

By manipulating soil conditions affecting SOM decomposition, agriculture can either extend or shorten the residence time of SOC. The global, cumulative effects of agriculture throughout history have tended to decrease the residence time of SOC, releasing approximately 78 Pg C to the atmosphere through land-use change and tillage (Lal, 2004).

Conversely, agricultural soils are also capable of acting as C sinks. Management practices that maintain or increase SOM concentrations will also increase the amount of C sequestered in a soil. Morgan et al. (2010) estimated that improved cropland management can increase SOC sequestration rates by 0.1 to 1 Mg C $ha^{-1}yr^{-1}$, a rate which would necessarily level off after reaching a new equilibrium of maximized sequestration potential. Under improved cropland management, the global potential of SOC sequestration is 0.9 ± 0.3 Pg C yr^{-1}, with a cumulative potential of 30 to 60 Pg within 25 to 50 years (Lal, 2004). Lal et al. (1999) suggested conservation tillage and residue management have great potential to increase SOC accumulation.

Focusing efforts on increasing SOC in agricultural soils through land management is an important step in mitigating climate change and promoting long-term sustainability.

Observable differentiations in near-surface SOC between residue treatments require sufficient time for POM at the soil surface to decompose and enter the profile, which is an obstacle when comparing the carbon sequestration potential of management systems. The length of time required for observable differences is difficult to precisely determine, due to varying local conditions, but decades of management are likely to produce greater differences than just a few growing seasons. A wheat-soybean double-crop study conducted on a Norge silt-loam near El Reno, OK that only lasted three years reported little difference in soil C and N between treatments at the 0 to 15 cm and 15 to 30 cm depths (MacKown et Al., 2007). Likewise, Amuri et al. (2008) observed no significant change in OM, N, and total C between residue treatments after five years of consistent management. Amuri et al. (2008) did, however, report increasing total C (TC) over the first six years following conversion from a monocrop soybean to a wheat-soybean, double-crop system, Six et al. (1999) observed small, insignificant differences in near-surface C between tillage treatments at a site managed for nine years, but noticed large, significant differences at sites managed for 24 to 33 years.

Some of the environmental and management factors that play critical roles in soil C sequestration include crop rotation, tillage system, and climate. On a Dewitt silt loam in eastern Arkansas, Motschenbacher et al. (2014) reported no difference in SOC between NT and CT treatments in the top 10 cm after 11 years of consistent management. However, Motschenbacher et al. (2014) did report 15 to 28% greater SOC contents in high-residue (i.e., winter wheat) containing rotations, compared to low-residue containing rotations. In a comparison study of various silt-loam soils in the Ozark Highlands and Grand Prairie Regions in Arkansas, Brye et al.

(2004) reported significantly greater total C, C:N ratios, and SOM concentrations in the upper 10 cm in the Ozark Highlands region. The increased SOC and SOM accumulation in the Ozark Highlands region was attributed to climatic factors, rather than parent material. C sequestration increases as precipitation increases, and decreases as temperature increases. Brye et al. (2004) suggests that as some regions become warmer and wetter during the course of climate change, the potential of these soils to sequester C will decrease.

Typical Crop Management Effects

Effects of Burning Crop Residue

The burning of wheat residue in wheat-soybean production systems is a widespread practice in mid-southern USA (Frederick et al., 1998; Sanford, 1982). In wheat-soybean double-crop systems, producers will typically burn wheat residue immediately before planting soybean as a means to control weed populations and prepare a proper seedbed. The burned residue creates what is sometimes called the ash-bed effect (Chan et al., 2005). As documented in a wheat-fallow study conducted on a clay-loam Luvisol and a sandy-loam Alfisol in New South Wales, Australia, the ash-bed effect is associated with increased pH and K (Chan et al., 2005). Chan et al. (2005) also reported decreased weed and disease pressure, improved seed germination, and increased yields in burned compared to non-burned treatments.

In contrast, residue burning can negatively impact SOM. Foremost, burning represents a lost opportunity to add organic matter to the soil. Secondly, burning destroys certain beneficial soil microorganisms. Depending on wind speed and amount of crop residue present on the soil surface as fuel, fires can reach temperatures that kill significant amounts of the soil bacteria, fungi, and macro-fauna populations (Biederbeck, 1980), all of which play critical roles in soil aggregate formation, generation of SOM, and the sequestration of C. In a winter wheat-summer fallow experiment on a Walla Walla silt-loam (Haploxeroll) soil near Pendleton, OR, Wuest et al. (2005) linked residue burning to a significant decrease in glomalin, basidiomycetes populations, and earthworm counts in the top 15 cm, each of which are also all agents of soil aggregation. Burning has also been shown to decrease surface infiltration rates (Rasmussen et al., 1980) and hydraulic conductivity (Biederback, 1980), which may be related to burning's deleterious effects on aggregate stability and SOM.

In addition to potentially negatively affecting aggregate stability and SOM, burning leads to a gradual decrease in plant available nutrients. Burning quickly releases plant-available, inorganic forms of N and phosphorus (P); however, these benefits are temporary in nature (Biederback et al., 1980). In an oat (*Avena sativa* L.) stubble experiment on a silty-clay Black Chernozem, a heavy clay Black Chernozem, and a Wood Mountain loam (Brown Chernozem) in Saskatchewan, Canada, Biederback et al. (1980) determined that burning increased yield in both fertilized and unfertilized control treatments, but had a cumulative effect of decreasing yield in the unamended control over 17 years. Biederback et al. (1980) concluded that long-term burning inflicted a slowly cumulative loss of N, P, sulphur (S), and boron (B) in the top 15 cm. Findings are consistent with an Indian study of a double-crop wheat and rice (*Oryza sativa* L.) system on a sandy-clay-loam Fluent, in which the residue-incorporated treatment showed increased rice and wheat yields, and organic C, available P, and available K concentration in the top 20 cm compared with burned treatment (Prasad et al., 1999). The yield results from Prasad et al. (1999) suggest that wheat can be planted immediately after the incorporation of rice residue and still produce yields that match or exceed those of wheat planted to a burned rice field.

Some studies have reported that burning also significantly decreases soil C in the upper

15 cm (Biederback, 1980), while others have observed little to no change in total soil C (Brye et al., 2006; Chan et al., 2005; Rasmussen et al., 1980; Wuest et al., 2005). Wuest et al. (2005) suggested that because burning primarily affects elements at or above the soil surface, the effects of multiple growing seasons of repeated annual burning would need to accumulate in order to manifest into measurable changes in soil C. This is consistent with a 4-yr wheat-soybean study conducted on a Brooksville silty-clay (Aquic Chomudert) that reported increased SOM content in a non-burned/no-tillage (NT) compared with a burned/CT treatment combination (Sanford, 1982). Conversely, another wheat-soybean study conducted on a Calhoun silt-loam (Typic Glossaqualf) and a Calloway silt-loam (Glossaquic Fragiudalf) that burning had no observable effect on loss of C as CO_2 from the soil. However, OM and total C increased under NT compared to CT (Brye et al., 2006). Smith et al. (2014) also reported that soil C respiration was more strongly correlated with tillage treatment than burning, in an 11-yr wheat-soybean study conducted on a Calloway silt-loam (Glossaquic Fragiudalf). Others have speculated that 20 to 30 years of residue burning would be needed in order for researchers to ascertain the full extent of the negative impact on SOM and yield (Rasmussen and Parton, 1994).

Effects of No-Tillage Compared to Conventional Tillage

Tillage systems can be classified into four categories: CT, which disturbs all of the soil surface and leaves less than 15% residue cover; reduced-tillage, which disturbs all of the soil surface and leaves 15 to 30% of the residue cover; conservation tillage, which implies any tillage or planting system that leaves 30% or more of the residue cover; and NT where the soil is left undisturbed after harvest, and is only minimally disturbed for planting (CTIC, 2014). Conventional-tillage systems in eastern Arkansas, and the Mississippi Delta in general, usually involve disking the field followed by harrowing, with the goal of creating a fine seedbed that contains less than 15% residue on the surface to facilitate soybean planting (Padgitt et al., 2000). Conventional-tillage systems may vary in frequency and depth of tillage. For instance, tillage systems using a moldboard plow incorporate 75% of crop residues at a depth below 15 cm, and can penetrate the soil profile up to 30 cm. Other CT systems may use a chisel plow or disk, which rarely penetrate deeper than 15 cm and incorporate residue at depths shallower than 10 cm (Staricka et al., 1991).

Compared to NT, CT offers tangible, immediate advantages by preparing finer seedbeds, reducing need for herbicides, and improving seedling germination (Chan et al., 2005). However, NT offers long-term benefits by increasing SOM accumulation, reducing the number of field passes with equipment, which is an economic and fuel savings, reducing soil erosion, and reducing greenhouse gas emissions (Horowitz, 2011; Morgan et al., 2010; Padgitt et al., 2000; Verkler et al., 2009; Zanatta et al., 2007). Weighing the immediate benefits to a crop against the long-term benefits to an agricultural soil is key to selecting the most appropriate tillage system.

The primary purposes of tillage are seedbed preparation, destruction of germinating weed populations, and aeration of the plow layer. In each of these cases, CT imparts immediate, short-term benefits to a crop, while simultaneously imparting long-term negative effects. Fine seedbed structure benefits a soybean crop because good seed-soil contact increases water penetration into seeds and improves germination and emergence (Guerif et al., 2001). However, over the long-term, CT often creates soil compaction below the plow layer, impeding root elongation and encouraging soil crusting at the soil surface, thereby inhibiting seedling emergence (Guerif et al., 2001). In contrast, NT systems generate neither the short-term benefits of fine seedbed structure nor the long-term drawbacks of soil compaction. However, surface residue may interfere with crop establishment by obstructing seedling emergence, releasing growth-inhibiting allopathic compounds, decreasing soil temperature, and decreasing the efficacy of herbicides (Amuri et al., 2008; Brye et al., 2006; Chan et al., 2005; Kaspar et al., 1990). It is difficult to model and predict the effects of tillage systems on seedling germination and emergence, given the large variation in local conditions (Guerif et al., 2001), but the benefits of crop establishment seem to trend towards CT. However, results from a soybean study in Wisconsin showed equivalent stand establishment could be achieved in NT compared to CT by increasing the seeding rate by 15 to 32% (Oplinger and Philbrook, 1992).

In CT, mechanical soil manipulation destroys weed seedlings that happen to be emerging at the time of cultivation, but can actually contribute to an overall increase in weed germination and emergence over time (Amuri et al., 2010; Botto et al., 1998; Mohler and Galford, 1997; Shrestha et al., 2002). Light stimulus during soil cultivation can trigger weed seed germination (Botto et al., 1998), and the vertical redistribution of weed seeds from deeper in the profile can position weed seeds at a more conducive depth for germination and emergence (Mohler and Galfor 2008). In a wheat-soybean double-crop system on a Calloway silt loam in eastern Arkansas, Amuri et al. (2010) observed greater total weed density under CT (513 plants m^{-2}) than NT (340 plants m^{-2}) in the early part of the 2006 growing season, although later in the season this trend reversed. Results imply late season weed density may increase under NT compared with CT because of reduced glyphosate (i.e., the Round-Up herbicide) efficacy in NT.

With regards to soil aeration, CT has a positive effect on soil aeration in the short-term and, but may negatively affect soil aeration over the long term. A New Zealand study examining oxygen diffusion rate (ODR) in various tillage systems on a Moutoa silty-clay (Typic Haplaquoll) observed that CT increased aeration at the 5-, 10-, and 15 cm depths (Sojka et al., 1997). A similar study conducted on a lateritic sandy-loam (Typic Acrorthox) in the coastal belt of eastern India also reported that CT increased aeration and soil temperature in the plow layer, i.e., the top 15 cm (Khan, 1996). The increased ODRs were only temporary, however, due to soil reconsolidation (Khan, 1996). In some cases, ODR levels in a CT system may drop below pre-tillage ODR levels within the same growing season (Khan, 1996; Sojka et al., 1997).

Soil properties are strongly affected by tillage management. Conventional tillage exposes soil to increased wet-dry and freeze-thaw cycles, but NT offers a protective soil cover in the form of vegetation or residue, thereby increasing the opportunity for soil aggregation, fostering worm population growth, increasing fungal hyphae colonization, increasing humification of residue, and increasing sequestration of C (Amuri et al., 2008; Halvorson et al., 1999; Six et al., 1999). Many of the specific benefits associated with NT are directly correlated to an increase in SOM.

Numerous studies have documented increased SOM in NT soils (Balesdent et al., 2000; Dolan et al., 2006; Six et al., 1999). In a study conducted on four soils (i.e., a Haplustoll, Fragiudalf, Hapludalf, and Paleudalf) at various locations around the United States, Six et al. (1999) observed a greater loss of 53 to 250 µm sized iPOM in the top 5 cm under CT than under NT. Intra-aggregate POM is a labile fraction of SOM that is particularly biologically and chemically active (NRCS, 2011), and therefore a loss of iPOM has negative implications for plant growth. Similarly, Balesdent et al. (2000) concluded that the decomposition rate of SOM under CT occurred at more than double the decomposition rate under NT, largely due to the fact that SOM is more protected under NT and becomes more rapidly exposed under CT.

The difference in SOM accumulations between tillage treatments is generally correlated with a difference in SOC accumulations as well. Paustian et al. (2000) analyzed the SOM and

SOC stocks in soils under different management systems, drawing data from various sources (Angers et al., 1993; Cambardella and Elliott, 1993; Beare et al., 1994; Franzluebbers and Arshad, 1996). Paustian et al. (2000) reported that the mean residence time of SOM and SOC stocks was approximately 73 yr in NT versus 44 yr in CT systems. Even though CT incorporates surface residue, thereby accelerating the process of soil aggregation, tillage has the stronger counter-effect of disrupting existing aggregates and increasing SOM decomposition, resulting in more rapid loss of soil C than in NT (Paustian et al., 2000). Similarly, a meta-analysis of 67 long-term agricultural experiments across the globe reported that a change from CT to NT can sequester 57 ± 14 g C m^2 yr^{-1} (West and Post, 2002).

An experiment conducted by Six et al. (1999) also confirms the increased loss of C under CT. On various loamy soils in corn (*Zea mays* L.), soybean, and wheat production, NT soils contained 9 to 16% greater concentrations of C in the top 20 cm than CT soils, with the greatest differences occurring at the 0- to 5-cm depth (Six et al., 1999). Similarly, in a 23-yr study with a soybean-containing rotation on a Waukegan silt loam (Typic Hapludoll), SOC and N increased more under NT compared to CT in the top 20 cm (Dolan et al., 2006).

Several long-term studies have also observed lower C:N ratios in tilled soils compared with undisturbed soils. In a 17-yr study on an Acrisol sandy clay loam (Paludult) in Brazil, NT cropland and grasslands contained larger C:N ratios in the top 2.5 cm than CT (Diekow et al., 2005). As depth increased, however, the C:N ratios of differentially managed agroecosystems became increasingly similar. Similarly, in an 18-yr Ohio study conducted on a Wooster silt loam (Typic Fragiudalf) and a Hoytville silty clay loam (Mollic Ochraqualf), Dick (1983) observed greater near-surface C:N ratios in NT than CT, but observed no significant differences in C:N ratio between tillage treatments when averaged across the 0 to 30 cm depth. Tillage appears to significantly affect the C:N ratio in near-surface soil depths and less significantly in the subsoil below a depth of 20 cm, which may be explained by the fact that under NT plant residues accumulate at the surface.

Other comparative studies of tillage treatments have reported no significant differences in total C, N, SOM, or C:N ratios. MacKown et al. (2007) conducted a 3-yr, double-cropped, wheat-soybean experiment on a Norge silt loam (Udic Paleustoll) in the southern Great Plains, and observed no significant difference in soil C and N levels between CT and NT. Similarly, Amuri et al. (2008) reported no significant variation in total C, N, OM, or C:N ratio between tillage treatments after five years of consistent management. In both cases, however, the similarity of soil properties between tillage treatments may be due to the relatively short durations of the studies.

In addition to management effects on soybean plant growth and soil properties, there are financial aspects to consider when comparing tillage systems. The majority of growers are already invested in CT infrastructure, and a conversion to NT might require phasing out current equipment and/or making new purchases. A 2003 survey submitted to Arkansas growers reported that one of the most commonly cited reason for refusing to convert from CT to NT was the expense of purchasing NT equipment (Hill et al., 2003). After the initial expenses associated with conversion however, NT can be equally productive to CT in economic terms. No-tillage requires fewer inputs and fewer passes with a tractor, thus can reduce production expenses in the long run (Verkler et al., 2009).

Effects of Irrigation Compared to Dryland Management

Most soybean producers in Arkansas irrigate during the growing season for the purpose of increasing yield. Between 1972 and 2003, the mean yield of irrigated soybean in Arkansas was estimated to be 2.5 Mg ha^{-1} compared to the dryland average yield of 1.5 Mg ha^{-1} (Egli, 2008). While irrigation can increase soybean yield, irrigation can also increase production expenses and sometimes be less profitable than non-irrigated soybean (Parsch et al., 2001). Finer-textured soils may require less irrigation for optimal soybean yield, and certain management practices, such as NT, may decrease irrigation needs (Verkler et al., 2009). Verkler et al. (2008) reported that soil dried down more slowly under non-burn and NT management than under burned and CT management. Moreover, water is an increasingly precious resource in eastern Arkansas. According to Scott et al. (1998), available water in the Alluvial Aquifer will be exhausted by 2050, due to years of crop irrigation withdrawals that have exceeded the recharge rate.

Irrigation strongly affects the activity of plants and soil microorganisms, leading to changes in SOM formation and decomposition. Lal and Bruce (1999) estimated that irrigated cropland sequesters between 50 to 150 kg ha^{-1} more C than non-irrigated cropland; however, Lal and Bruce (1999) also suggested that the effects of irrigation on SOC are complex and can be difficult to predict. Increased soil moisture promotes development of plant and microbial biomass, which can increase SOM and SOC (Blanco-Canqui et al., 2010). However, increased soil moisture also promotes microbial decomposition of SOM (Churchman and Tate, 1986) and slaking of unstable aggregates (Six et al., 2000b) resulting in a possible decrease of SOC. In a continuous corn and wheat-fallow study conducted on several silt-loam, loam, and clay-loam soils across the eastern United States, Linn and Doran (1984) reported that soil moisture tended to increase soil microbial activity and, consequently, soil respiration, up to 60% water-filled pore space, beyond which microbial activity and respiration decrease in the upper 7.5 cm.

Soil OM increases water infiltration rate, hydraulic conductivity, and water-holding capacity. Therefore, any management practice that increases SOM, such as NT, may decrease irrigation needs (Verkler et al., 2009). An 8-yr wheat study on a Bethany (Pachic Paleustoll) and a Renfrow (Udertic Paleustoll) silt loam near El Reno, OK reported significantly larger volumetric water contents in the 0- to 1.2-m depth of NT soils compared with CT soils (Dao 1993). In the same study, CT decreased water infiltration and negatively affected precipitation storage (Dao, 1993). Allowing wheat residue to decompose on the surface, such as in a NT/non-burn combination, will likely improve soil moisture storage capability (Amuri and Brye, 2008). Soil moisture retention is a critical factor of soybean production in eastern Arkansas, where hot, dry early summers often pose a threat to germination and stand establishment (Cordell et al., 2007).

Soybean plant growth response is strongly affected by irrigation timing. Ashley et al. (1978) reported that irrigating prior to soybean flowering increases vegetative biomass, pod count, and weight, whereas waiting to irrigate until the start of soybean flowering produced no increase in vegetative biomass, but increased pod count and weight.

Effects of Nitrogen-Fertilized Cover Crops

Unlike soybean, which can fix N and require little to no added N-fertilizer, wheat derives N entirely from the soil. Nitrogen fertilization tends to promote wheat biomass and yield, and split-application of N is particularly effective. Split-application reduces the loss of N through leaching and denitrification, thereby increasing plant uptake of N and increasing wheat yield (Sripada and Weisz, 2009). While a positive correlation exists between N-fertilization and wheat biomass, the effects of N-fertilization on SOM, SOC, and other soil chemical properties are more complex, due to the various implications of increased N on residue decomposition and microbial activity (Banger et al., 2010; Hogberg et al., 2007; Lee and Jose, 2003).

One potentially negative impact of increased N-fertilization is soil acidification. While few N-fertilizers are acidic, N-fertilizers encourage acid-forming reactions, such as the microbial oxidation of ammoniacal fertilizer (Barak et al., 1997). In a 3-yr, NT, wheat-corn-fallow rotation study conducted on a Platner loam (Aridic Paleustoll) in the Great Plains, Bowman and Halvorson (1998) reported a significant correlation between increased N-fertilization and a reduction in soil pH (6.5 to 5.1) in the top5 cm (Bowman and Halvorson, 1998).

Another commonly observed effect of increased N-fertilization is increased SOM and SOC, due to the increased plant biomass resulting from N-fertilization. Bowman and Halvorson (1998) reported 40% increase in SOC in the top 5 cm under increased N-fertilization management. Likewise, after 10 years of consistent management of a Weld silt-loam (Aridic Agiustoll) in the Great Plains in a rotation that included winter wheat, SOC increased more in a high-N-rate (134 kg N ha^{-1} yr^{-1}) than in low-N-rate treatments (Halvorson et al., 1999).

While it might be expected for N-fertilization to increase C sequestration due to increased plant biomass and subsequent SOM, some studies have observed the opposite trend. In a cottonwood (*Populus deltoides* Marsh.) and loblolly pine (*Pinus taeda* L.) study conducted on a Redbay sandy loam (Rhodic Paleudlt) in Florida, an application of 50 kg N ha^{-1} yr^{-1} for eight consecutive years was correlated with observable, but statistically insignificant, decreases in SOC (Lee and Jose, 2003). Microbial biomass decreased by over 20%, which suggests that N fertilizer may have adverse effects on some soil microorganisms (Lee and Jose, 2003). Banger et al. (2010) suggested that N-fertilizer may preferentially stimulate activity of certain microbes, while inhibiting development of others, such as lignin decomposers.

Treatment Effects on Water-Retention Characteristics

While soil water-retention characteristics are seasonally variable due to wet-dry and freeze-thaw cycles (Unger, 1991), long-term changes in water-retention characteristics may also be affected in the long-term by agricultural management practices. In a comparison study of water-retention characteristics between cultivated agriculture and native prairie soils on a Dewitt silt-loam in eastern Arkansas, Brye (2003) reported that land use significantly affected the slope of the soil moisture release curve in the top 10 cm. Results indicated that as both the native prairie and cultivated agricultural soils reached the same water potential, the native prairie soil would have a higher water content. Conversely, as soils of both land uses reached permanent wilting point (i.e., -1.5 MPa), water content would be similar.

Other studies have similarly concluded that repeated years of cultivation can negatively affect soil water-retention characteristics. In a continuous-corn study conducted on a Canisteo clay-loam (Typic Haplaquoll) and a Nicollet loam (Aquic Hapludolls), soils managed with reduced tillage systems retained more plant-available water and maintained greater unsaturaSted hydraulic conductivities than soils under CT at the 5- to 7.5-cm and 10- to 12.5-cm depth. (Hill et al., 1985). Similarly, on a Donnelly silt-loam (Gray Luvisol) managed consistently for 14 yr and a Donnelly sandy-loam (Gray Luvisol) managed consistently for 5 yr in Alberta, Canada, Azooz and Arshad (1996) reported that soils under NT maintained pore structure, which resulted in greater hydraulic conductivity and infiltration rates in NT than in CT.

Justification

An understanding of how different agricultural management practices impact SOM and SOC is essential for determining sustainable practices of food production. Mounting evidence implicates agriculture as a major source of greenhouse gas emissions. The Intergovernmental Panel on Climate Change (IPCC) concluded that agriculture generates 10 to 12% of total global anthropogenic emissions of greenhouse gases, including 60% of the nitrous oxide (N_2O) and 50% of the methane (CH_4) emissions (IPCC, 2013) through the burning of fossil fuels and the oxidation of SOM. Certain practices, such as NT, may increase accumulation of C in the soil, while simultaneously decreasing C emissions from cultural operations.

Soybean production must be economically viable as well as ecologically responsible, which requires an understanding of which management practices produce adequate yields. A long-term, consistently managed wheat-soybean study evaluating common residue and water management practice effects on SOM, carbon sequestration, and soybean yield might offer insight into how soybean production might become more sustainable, while maintaining productivity, in the future.

Objectives

The main objective of this study is to determine the long-term trends of near-surface soil C and N, other near-surface soil physical (i.e., bulk density) and chemical (i.e., pH, electrical conductivity (EC), and Mehlich-3-extractable nutrients) properties, and soybean yield as affected by residue burning (burning and non-burning), tillage (conventional and no-tillage), irrigation (irrigated and dryland), and N-fertilization/wheat-residue level (high and low). A secondary objective of this study is to evaluate the long-term effects of residue burning, tillage, irrigation, and N-fertilization/wheat-residue level on the relationship between soil water potential and soil water content in the top 7.5 cm using a soil wetting-curve approach.

Hypotheses

Non-burning is expected to increase SOM, SOC, and plant available nutrients, compared to burning. No-tillage is expected to increase SOM, SOC, and soil fertility compared to CT. Irrigation is expected to increase SOM and soybean yield compared to non-irrigation. High N-fertilization/wheat-residue level is expected to produce more wheat residue biomass, thereby increasing SOM and SOC compared to low N-fertilization/wheat-residue level. The treatment combination of high N-fertilization/wheat-residue level, NT, non-burning, and irrigation is expected to increase SOM and SOC. Tillage is expected to strongly affect the relationship between soil water potential and soil water content in the top 7.5 cm, such that when soil water potential of CT and NT is equal, the NT soil water content will be greater compared to CT.

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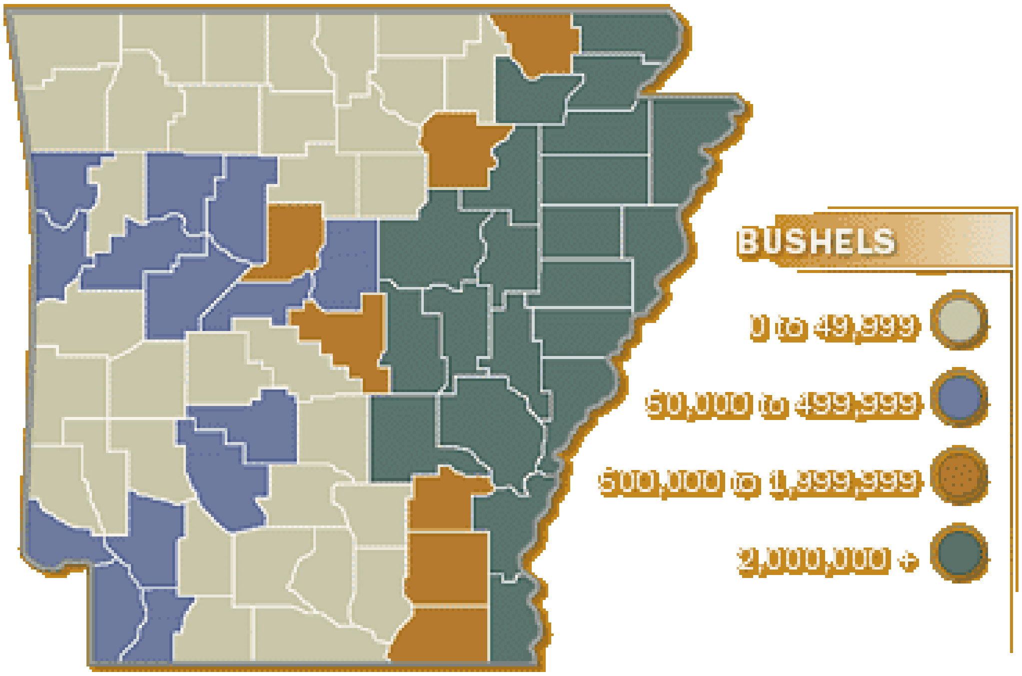

Fig. 1. County map of Arkansas soybean production, in bushels. Data reported from 1999. To convert bushels to Mg, multiply by 0.028. Adapted from ASPB (2014).

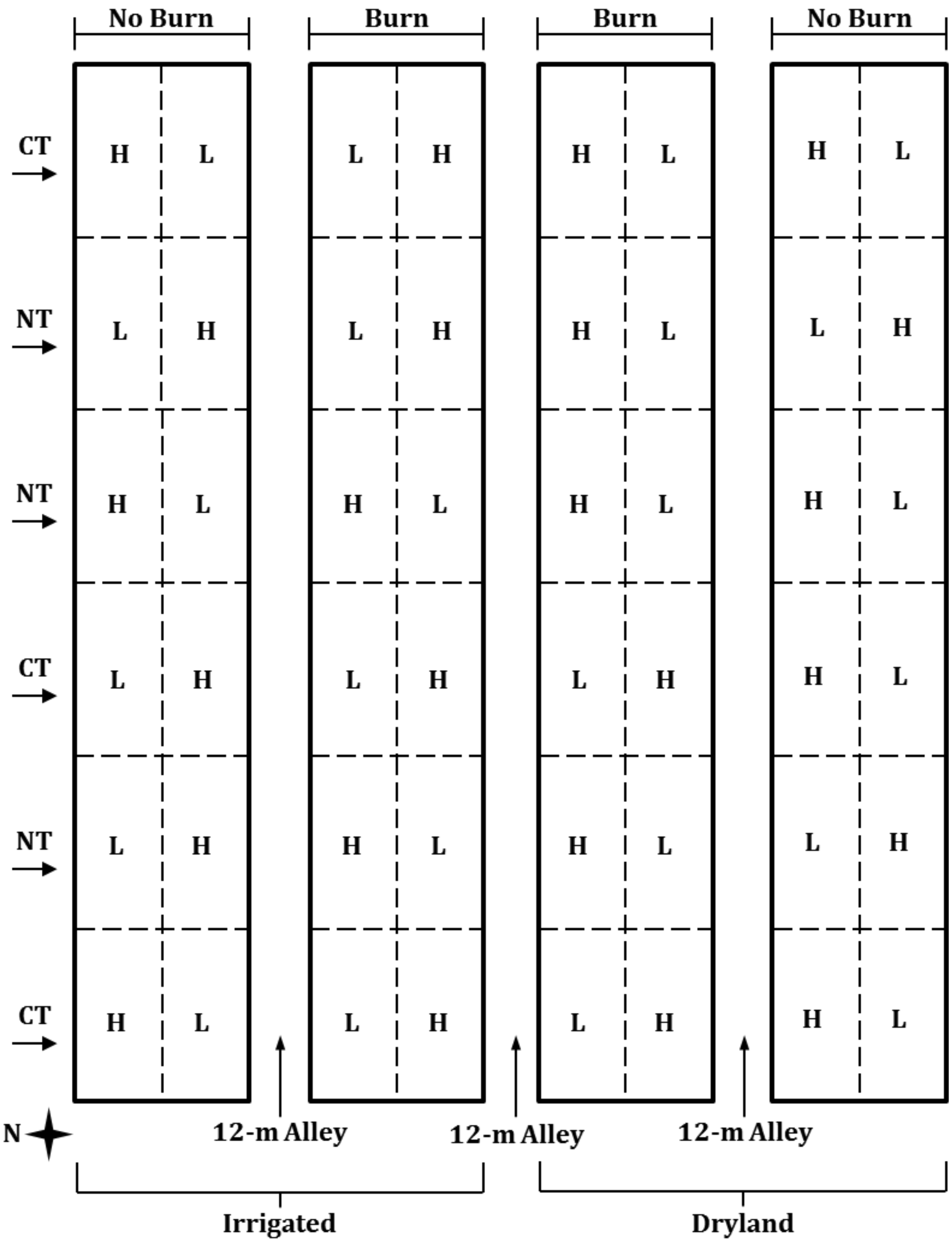

Fig. 2. Experimental layout at the Lon Mann Cotton Branch Experiment Station in eastern Arkansas depicting residue-level [high (H) and low (L)], burn, tillage [conventional tillage (CT) and no-tillage (NT)], and irrigation treatments.

Chapter 2

Long-term Residue Management Effects on Soil Properties and Yields in a Wheat-soybean, Double-crop System in Eastern Arkansas

Abstract

Adoption of management practices that maintain or increase soil organic matter (SOM), which contains 58% carbon (C) on average, may help to mitigate climate change by sequestering atmospheric C. Therefore, the main objective of this study was to determine the long-term trends in SOM, soil C and nitrogen (N), bulk density, various soil chemical properties (i.e., pH, electrical conductivity [EC], and Mehlich-3-extractable nutrients) in the top 10 cm, and soybean yield as affected by residue burning (burning and non-burning), tillage (conventional and no-tillage), irrigation (irrigated and non-irrigated), and N-fertilization/residue level (high and low) in a wheat (*Triticum aestivum* L.)-soybean [*Glycine max* (L.) Merr.], double-crop system in eastern Arkansas. The field site has been consistently managed for 13 years at the University of Arkansas Lon Mann Cotton Research Station near Marianna, Arkansas on a Calloway silt-loam (fine silty, mixed, active, thermic Glossaquic Fraglossudalf). Averaged across all other factors, SOM did not differ over time ($P > 0.05$) under irrigation, while SOM content increased over time ($P < 0.05$) until approximately nine years after initial conversion when SOM decreased thereafter under dryland production. Soil OM content also decreased over time ($P < 0.05$) under residue burning, but increased over time under non-burning. The results of this study indicated that irrigation management was responsible for many of the largest differences in near-surface soil property trends over time, namely SOM and C, compared to the other field management practices evaluated. Understanding the long-term effects of growing-season weather patterns as well as irrigation, burning, tillage, and fertilization management on near-surface soil properties is critical to developing sustainable agricultural practices in the mid-South.

Introduction

An understanding of how different agricultural management practices impact soil organic matter (SOM), soil carbon (C), other various soil properties, and crop yield is essential for determining sustainable practices of food production. The Intergovernmental Panel on Climate Change concluded that agriculture generates 10 to 12% of total global anthropogenic emissions of greenhouse gases (IPCC, 2013) through the burning of fossil fuels and the oxidation of SOM. Management of crop residues can strongly affect the fate of SOM in agricultural soils, as well as a host of other soil physical and chemical properties, which has implications for crop production in the short-term as well as sustainability in the long-term.

The long-term balance of SOM is determined by how much biomass is added to the system and the timeline of decomposition. Biomass inputs primarily consist of plant residue, as well as animal and microbial tissues. Management factors such as tillage, burning, fertilization, and irrigation may influence the rate at which microbes convert organic residues into stabilized fractions of SOM, as well as the rate at which microbes decompose SOM by altering the physical and chemical soil environment.

Tillage homogenizes the plow layer and alters the near-surface soil environment, which can have cumulative effects on various soil physical and chemical properties. Conventional tillage (CT) disturbs all of the soil surface and leaves less than 15% residue cover, while no-tillage (NT) leaves the soil undisturbed after harvest, and causes minimal disturbance for planting (CTIC, 2014). Conventional-tillage systems in eastern Arkansas, and the lower Mississippi River Delta region in general, usually involve disking the field followed by harrowing, with the goal of creating a fine seedbed that contains less than 15% residue on the surface to facilitate soybean planting (Padgitt et al., 2000).

Compared to NT, CT offers tangible, immediate advantages by preparing finer seedbeds, reducing need for herbicides, and improving seedling germination (Chan et al., 2005). However, NT offers long-term benefits by increasing SOM accumulation, reducing the number of field passes with equipment, which is an economic and fuel savings, reducing soil erosion, and reducing greenhouse gas emissions (Horowitz, 2011; Morgan et al., 2010; Padgitt et al., 2000; Verkler et al., 2009; Zanatta et al., 2007). Weighing the immediate benefits to a crop against the long-term benefits to soil resource used for agricultural production is key to selecting the most appropriate residue management and tillage system.

Burning crop residues is an alternative residue management with tillage and can also have cumulative effects on various soil properties. Burning wheat residue in wheat (*Triticum aestivum* L.)-soybean [*Glycine max* (L.) Merr.] production systems is a widespread practice in the mid-southern US (Frederick et al., 1998; Sanford, 1982). In wheat-soybean double-crop systems, producers will typically burn wheat residue immediately before planting soybean as a means to control weed populations and prepare a proper seedbed. The burned residue creates what is sometimes called the ash-bed effect (Chan et al., 2005). As documented in a wheat-fallow study conducted on a clay-loam Luvisol and a sandy-loam Alfisol in New South Wales, Australia, the ash-bed effect is associated with increased pH and potassium (K) (Chan et al., 2005). However, residue burning can negatively impact SOM because of the lost opportunity to add organic matter to the soil. Moreover, burning can lead to a gradual decrease in plant available nutrients. Burning quickly releases plant-available, inorganic nutrients such as nitrogen (N) and phosphorus (P), but may inflict a slowly cumulative loss of N, P, and sulfur (S) over time (Biederback et al., 1980).

In addition to tillage and residue burning, N fertilization is a common management practice that promotes wheat biomass and yield. Split application of N is particularly effective because the loss of N through leaching and denitrification is reduced and therefore plant uptake of N is increased (Sripada and Weisz, 2009). While a positive correlation exists between N fertilization and wheat biomass, the effects of N fertilization on SOM, soil C, and other soil chemical properties are more complex, due to the various implications of increased N on residue decomposition and microbial activity (Banger et al., 2010; Hogberg et al., 2007; Lee and Jose, 2003). Bowman and Halvorson (1998) reported 40% increase in soil C in the top 5 cm under increased N-fertilization management. Likewise, after 10 years of consistent management of a Weld silt-loam (Aridic Agiustoll) in the Great Plains in a rotation that included winter wheat, SOC increased more in a high- (134 kg N ha^{-1} yr^{-1}) than in low-N-rate treatments (Halvorson et al., 1999). In contrast, a cottonwood (*Populus deltoides* Marsh.) and loblolly pine (*Pinus taeda* L.) study conducted on a Redbay sandy loam (Rhodic Paleudlt) in Florida reported a decrease in SOC in correlation with an application of 50 kg N ha^{-1} yr^{-1} for eight consecutive years (Lee and Jose, 2003). Microbial biomass decreased by over 20%, which suggested that N fertilizer may have adverse effects on some soil microorganisms (Lee and Jose, 2003). Banger et al. (2010) suggested that N-fertilizer may preferentially stimulate activity of certain microbes, while inhibiting development of others, such as lignin decomposers.

Another potential effect of increased N fertilization is soil acidification. While few N fertilizers are themselves acidic, many N fertilizers encourage acid-forming reactions (i.e., nitrification; Barak et al., 1997). In a 3-yr, NT, wheat-corn (*Zea mays* L.)-fallow rotation study on a Platner loam (Aridic Paleustoll) in the Great Plains, Bowman and Halvorson (1998) reported a significant correlation between increased N fertilization and a reduction in soil pH (6.5 to 5.1) in the top 5 cm.

Similar to N fertilization, properly applied irrigation can greatly increase crop yield. Between 1972 and 2003, the mean yield of irrigated soybean in Arkansas was estimated to be 2.5 Mg ha^{-1} compared to the dryland average yield of 1.5 Mg ha^{-1} (Egli, 2008). Consequently, the majority of soybean producers in Arkansas choose to irrigate during the growing season. However, irrigation also incurs added costs and can sometimes be less profitable than non-irrigated production (Parsch et al., 2001; Verkler et al., 2009). Moreover, water is an increasingly precious resource in eastern Arkansas, and irrigation may become cost prohibitive in the near future. According to Scott et al. (1998), available water in the Alluvial Aquifer will be exhausted by 2050, due to years of crop irrigation withdrawals that have exceeded the recharge rate.

Irrigation alters the soil moisture environment, thereby affecting the activity of plants and soil microorganisms and the cycling of SOM. Increased soil moisture promotes development of plant and microbial biomass, which can contribute to an overall increase in SOM. However, increased soil moisture also promotes the microbial decomposition of SOM and slaking of unstable aggregates (Churchman and Tate, 1986; Six et al., 1999), which can contribute to overall decrease in SOM. Therefore, the effects of irrigation on SOM cycling can be difficult to predict.

Irrigation influences the accumulation and decomposition of SOM, and SOM likewise influences soil water. Soil OM increases water infiltration rate, hydraulic conductivity, and water-holding capacity. Therefore, any management practice that increases SOM, such as NT, may decrease irrigation needs (Verkler et al., 2009). An 8-yr wheat study on a Bethany (Pachic Paleustoll) and a Renfrow (Udertic Paleustoll) silt loam near El Reno, OK reported significantly larger volumetric water contents in the 0- to 1.2-m depth of NT soils compared with CT soils (Dao 1993). In the same study, CT decreased water infiltration and negatively affected precipitation storage (Dao, 1993). Soil moisture retention is a critical factor orf soybean production in eastern Arkansas, where hot, dry early summers often pose a threat to germination and stand establishment (Cordell et al., 2007).

The effects of residue management on SOM and soil C have been previously studied in the lower Mississippi River Delta region of eastern Arkansas. On a Dewitt silt loam in eastern Arkansas, Motschenbacher et al. (2014) reported no difference in soil C between NT and CT treatments in the top 10 cm after 11 years of consistent management. However, Motschenbacher et al. (2014) reported 15 to 28% greater soil C content in high-residue (i.e., winter wheat) containing rotations compared to low-residue-containing rotations. In a comparison study of various silt-loam soils in the Ozark Highlands and Grand Prairie regions in Arkansas, Brye et al. (2004) reported significantly greater total C, C:N ratios, and SOM concentrations in the upper 10 cm in the Ozark Highlands region. The increased soil C and SOM accumulation in the Ozark Highlands region was attributed to climatic factors, rather than parent material. Carbon sequestration tends to increase as precipitation increases, and tends to decrease as temperature increases. Brye et al. (2004) suggested that as some regions become warmer and wetter during the course of climate change, the potential of these soils to sequester C will decrease.

When eastern Arkansas was covered by forested wetlands, the soils accumulated large concentrations of OM and C (Stanturf et al., 2000). Years of cultivated agriculture, however, have reduced SOM and C concentrations in the top 12 cm of cropland soil to 2.1% and 1.1 %, respectively (DeLong et al., 2003), compared to 4.6 to 6.5 % SOM and 2.3 to 3.2 % C in undisturbed prairie soils in eastern Arkansas (Brye and Pirani, 2005). Adopting agricultural management practices which slow or even reverse losses of SOM and soil C are imperative for the sustainability of agriculture, particularly in Arkansas.

An understanding of how different agricultural management practices impact SOM and soil C is essential for determining sustainable practices of food production. A long-term, consistently managed wheat-soybean study evaluating common residue and water management practice effects on soil properties and crop productivity might offer insight into how soybean production might become more sustainable, while maintaining productivity, in the future. Therefore, the objective of this study was to determine the long-term trends of near-surface SOM, C and N, bulk density, and other soil chemical properties (i.e., pH, electrical conductivity [EC], and Mehlich-3-extractable nutrients), and soybean yield as affected by residue burning (burning and non-burning), tillage (conventional and no-tillage), irrigation (irrigated and dryland), and N-fertilization/wheat-residue level (high and low) in a wheat-soybean, double-crop production system in eastern Arkansas. It was hypothesized that SOM, SOC, and plant available nutrients, would increase under non-burning compared to burning. Soil OM, soil C, and plant available nutrients were hypothesized to increase under NT compared to CT. SOM and soybean yield were hypothesized to increase under irrigation compared to dryland management. The high N-fertilization/wheat-residue level treatment was hypothesized to produce more wheat residue biomass, thereby increasing SOM and soil C compared to low N-fertilization/wheat-residue level. Soil OM and C were hypothesized to increase under the high N-fertilization/wheat-residue level, NT, non-burning, and irrigation treatment combinations.

Materials and Methods

Site Description

An on-going field study was initiated in Fall 2001 at the University of Arkansas Lon Mann Cotton Research Station (N34°, 44’, 2.26”; W90°, 45’ 51.56”, Cordell, 2007) in the Southern Mississippi Alluvium [Major Land Resource Area (MLRA) 131A]. Major Land Resource Area 131A extends along the Mississippi River alluvial plain, south of the confluence of the Ohio and Mississippi Rivers. Maximum local relief is approximately 5 m, however, the relief in most of the region is less than 5 m (USDA, 2006). The topography tends to be level to depressional to gently undulating plains (USDA, 2006). The warm and wet climate, the relatively flat topography, and the fertile alluvial sediments of MLRA 131A make for a highly agriculturally productive region. The site of this field study is on a Calloway silt loam (fine silty, mixed, active, thermic Glossaquic Fraglossudalf; Gray, 1977; NRCS, 2015) which has 16% sand, 73% silt, and 11% clay in the top 10 cm (Brye et al., 2006). The 30-yr mean annual temperature of the region is 15.6°C and the 30-yr mean annual precipitation is 128 cm (NOAA, 2002). The 30-yr mean maximum and minimum air temperatures of the region are 32.8°C in July and 2.4°C in January (NOAA, 2002).

Experimental Design

The original study used a three-factor, split-strip-plot, randomized complete block experimental design with six replications of each of eight treatment combinations (Cordell et al., 2007). The three factors were i) residue level [high residue (H), achieved with a split application of N fertilizer, or low residue (L), achieved with minimal to no N additions]; ii) burning of residue [burning (B) or non-burning (NB)]; and iii) tillage (CT or NT) (Cordell et al., 2007). In

2005, an irrigation factor was introduced when the original study area was divided into two irrigated (I) and two non-irrigated (NI; i.e., dryland) blocks (Verkler et al., 2009). Consequently, since 2005, the experimental area has consisted of 48, 3- x 6-m plots with six replications for every tillage-burning-residue-level combination and three replications for every tillage-irrigation-burning-residue level combination (Fig. 1; Amuri et al., 2008).

Field Management

Prior to the initiation of the study in Fall 2001, the site was managed as a continuous, mono-cropped soybean system using CT (Cordell et al., 2007). The first field preparations in Fall 2001 involved disking twice followed by broadcast applications of N, P, K, and pelletized limestone at rates of 20, 22.5, 56, and 1120 kg ha^{-1}, respectively, prior to wheat planting. Wheat was drill seeded with a 19-cm row spacing each Fall. In early March 2002 through 2004, all plots were manually broadcast fertilized with urea (46% N) at the rate of 101 kg N ha^{-1}. To produce different levels of wheat residue, high-residue plots (n = 24) were manually broadcast fertilized in late March at approximately the late-jointing stage with an additional 101 kg N ha^{-1}. No N fertilizer was applied in Spring 2005 because the wheat stand failed to establish due to prolonged wet soil conditions in Fall 2004. Since 2006, the high-residue plots received an initial broadcast application of 56 kg N ha^{-1} as urea in approximately late February, followed by a split application of an additional 56 kg N ha^{-1} at the late-jointing stage in approximately late March, roughly one month later. The low-residue plots have not received any N fertilization since 2006 in order to achieve the desired residue-level difference.

In approximately early June each year, wheat was harvested using a plot combine. Immediately following wheat harvest, wheat residue was uniformly spread by hand over each plot. The remaining wheat stubble was mowed with a rotary mower to a maximum height of 3 cm from the soil surface in order to achieve a uniform residue-covered surface for soybean planting. After mowing, the burning treatment was imposed on half of the plots by propane flaming. In 2005, 2007, and 2012 the residue-burning treatment was not able to be imposed because of the absence of a wheat stand in Spring 2005, prolonged wet soil conditions in Spring 2007, and overly weedy conditions in 2012. Imposition of the burning treatment was followed by imposing the tillage treatment each year. The CT plots were disked at least twice with a tandem disk to a depth of approximately 10 cm followed by seedbed smoothing with at least three passes of a soil conditioner, which is representative of widely used pre-soybean-planting tillage operation in the region.

In approximately mid-June each year, a glyphosate-resistant soybean cultivar, maturity group 5.3 or 5.4, was drill-seeded with 19-cm row spacing at a rate of approximately 47 kg seed ha^{-1}. Potassium fertilizer was applied according to recommended rates (UACES, 2000) when the previous year's soil test indicated K was needed. In 2002 through 2004, all plots were furrow-irrigated as needed, three to four times each soybean-growing season. Since 2005, a levee was created to exclude furrow-irrigation water from the dryland treatment, which received only natural rainfall, while furrow-irrigation continued annually as needed in the irrigated treatment. Weeds and insects were managed annually the same throughout the entire study area as necessary based on University of Arkansas Cooperative Extension Service recommendations, which generally consisted of herbicide and insecticide applications during both the wheat and soybean growing seasons (UACES, 2000). In late October to early November, soybean were harvested with a plot combine. Soybean residue was left in place, into which the subsequent wheat crop was sown to begin the next cropping cycle.

Soil Sample Collection and Processing

Between 2002 and 2008, after wheat harvest and prior to residue burning, 10 soil cores from the top 10 cm were collected from each plot and combined into a single composite sample per plot. After 2008, a single soil sample was collected from the top 10 cm using a 4.8-cm-diameter stainless steel core chamber between wheat maturity and residue burning. Soil samples were oven-dried for 48 hr at 70^{o}C and ground to pass through a 2-mm mesh screen (Verkler et al., 2009) for soil chemical analyses (Brye et al., 2006). Soil pH and EC were determined potentiometrically using an electrode in a 1:2 (w/v) soil-to-water solution. Soil OM was determined by weight-loss-on-ignition after 2 hr at 360^{o}C (Schulte and Hopkins, 1996). Total soil C and N were determined by high-temperature combustion with a LECO CN-2000 analyzer (LECO Corp., St. Joseph, MI) or an Elementar VarioMAX Total C and N Analyzer (Elementar Americas Inc., Mt. Laurel, NJ). All soil C was assumed to be organic C because the soil of the upper solum does not effervesce upon treatment with dilute hydrochloric acid (HCl) (Brye et al., 2006). The soil C:N ratio was calculated from measured C and N concentrations. Soil was also extracted with Mehlich-3 extractant solution in a 1:10 (w/v) soil-to-extractant solution ratio (Tucker, 1992) and analyzed for extractable nutrients [i.e., P, K, calcium (Ca), magnesium (Mg), S, iron (Fe), sodium (Na), manganese (Mn), and copper (Cu)] by inductively coupled, argon-plasma spectrophotometry (ICAPS;CIROS CCD model, Spectro Analytical Instruments, MA). All measured soil elemental concentrations (mg kg^{-1}) were converted to contents (kg ha^{-1}) using the measured bulk density and 10-cm sample depth interval.

Soil samples were also collected between approximately 8 and 10 weeks after soybean planting by extracting a single 4.8-cm-diameter soil core from the top 10 cm using the methods outlined by Brye et al. (2006). Mid-season soil cores were oven-dried at 70°C for 48 hr and weighed for bulk density determinations.

Plant Sample Collection and Processing

Each year, all wheat grain harvested from the middle 1.5-m of each plot was collected. After grain harvest each year, the standing wheat stubble was mowed with a rotary mower to a height of approximately 10 cm. A sample of aboveground residue was then collected from within a 0.25-m^2 metal frame, oven-dried for 3 to 7 days at 55°C, and weighed to obtain an estimate of aboveground residue mass. All soybean grain harvested from the middle 1.5-m of each plot was also collected. Wheat and soybean grain were air-dried for approximately three weeks and weighed. Wheat and soybean yields were determined by oven-drying air-dried grain subsamples for 48 hr at 70°C, re-weighing, and adjusting to 13% moisture content for yield reporting (Smith, 2014).

Statistical Analyses

An analysis of covariance (ANCOVA) was conducted using SAS (version 9.3, SAS Institute, Inc., Cary, NC) to determine the effects of residue level, tillage, burning, and irrigation on the relationship between annual soil chemical properties, bulk density, and wheat and soybean yields (dependent variable) over time (i.e., 2007 through 2014; independent variable). Though the actual experimental design in the field was a strip-split-plot, randomized complete block, to facilitate the ANCOVA, the experimental designed was assumed to be completely random with three replications of each of 16 treatment combinations. The full ANCOVA model was reduced using a hierarchical principle to remove non-significant terms, except when non-significant terms participated in higher-order, complex treatment combinations. An analysis of variance was also conducted using SAS, separately by year, to evaluate the effect of N-fertilization/residue level on aboveground residue mass. When appropriate, means were separated by least significant difference (LSD) at the 0.05 level.

Results and Discussion

The linear and quadratic slopes of regressions were evaluated in the statistical analysis for each variable. The intercepts of regressions, i.e., the values of measured soil properties at year 0, have been analyzed in previous studies (Brye et al., 2006; Amuri et al., 2008). Intercepts of regressions were uniform in the top 10 cm across field treatment factors, with a few exceptions. Soil Mg and P were greater for the burn than the no-burn treatment, and pH was greater for the no-burn than the burn treatment (Amuri et al., 2008). Due to the fact that intercepts of regressions have been analyzed in previous publications, and that the primary objective of this study was to analyze the trend over time rather than differences at any specific point in time, the intercepts of regressions were not evaluated in the final statistical analysis.

The high-N-fertilization rate achieved a numerically greater residue than the low-N-fertilization treatment in seven of the eight years (i.e., 2008 to 2014), but did not achieve a numerically greater aboveground residue level in year 6 (i.e., 2007). The high-N-fertilization rate achieved a significantly greater ($P < 0.05$) residue level compared with the low-N-fertilization rate in six out of the eight years (i.e., years 7, 8, 10, 11, 12, and 13 or 2008, 2009, 2011, 2012, 2013, and 2014, respectively), but did not achieve a significantly greater residue level in year 6 and year 9 (i.e., 2007 and 2010; data not shown).

Bulk Density

Over the course of seven complete wheat-soybean cropping cycles (i.e., 2007 to 2014), after six complete cropping cycles (i.e., 2001 to 2007) following conversion to alternative management practices in treatment combinations managed consistently for 13 consecutive years (i.e., 2002 to 2014), the trend in bulk density in the top 10 cm over time was affected ($P < 0.05$; Appendix A - Table 1) by all field treatment factors evaluated. Near-surface bulk density in all treatment combinations increased until approximately nine years after initial conversion then decreased thereafter (Fig. 2). Though there were many subtle differences among treatment combinations, the largest and most obvious differences occurred between tillage, residue level, and irrigation treatments, based on an interpretation of the LSDs between slope parameter estimates for the appropriate specific treatment combinations (Appendix B - Table 1). Clear differences existed between CT and NT treatments under high-residue, non-irrigated production. Averaged across burning, bulk density increased ($P < 0.001$) over time under the NT-H-NI at approximately three times the rate of increase under the CT-H-NI treatment combination (Appendix B - Table 1). Approximately nine years after initial conversion, bulk density began to decrease ($P < 0.001$) over time under the NT-H-NI at a greater rate than under the CT-H-NI treatment combination (Appendix B - Table 1). Results suggest that the effects of soil compaction under the weight of equipment for routine field operations exceeded the effects of improved soil structure (i.e., decrease in bulk density) associated with NT management. These results are consistent with an 11 yr corn study in Central Canada that reported 10% higher bulk density values in NT than in CT in the top 10 cm (Dam et al., 2005). However, these results are in contrast with an 8 yr winter wheat study near El Reno, OK that reported decreased near-surface bulk density under NT compared CT (Dao, 1993).

The measured bulk density values from each spring were used as part of the calculation to convert measured elemental concentrations (mg kg^{-1}) of soil chemical properties (i.e., SOM, C, N, Fe, Na, S, P, Cu, Ca, Mg, Mn, K, and Zn) into contents (kg m^{-2}). Therefore, the effects of field treatments on bulk density are embedded in all following soil content trends over time.

Another important contextual point for understanding the results of this study, which considers trends over time from years 6 to year 13 (i.e., 2007 to 2014) following conversion to new management practices, is the study many of similar properties after the first 6 years of consistent management. Trends over time in soil bulk density and soil C were affected by residue management. However, the majority of measured soil and plant properties (i.e., SOM and N contents, wheat and soybean yields, and most measured extractable nutrients) were unaffected over time by any of the imposed field treatments after the first 6 years following conversion to new management, likely due to an insufficient length of time for cumulative effects to have a measurable impact on soil and plant properties (Amuri et al., 2008). In contrast, many differences were observed in this study in the trends over time among soil and plant properties as affected by alternative residue management practices after 13 years following conversion to new management.

Soil OM, C, and N

Over the course of seven complete wheat-soybean cropping cycles (i.e., 2007 to 2014), after six complete cropping cycles (i.e., 2001 to 2007) following conversion to alternative management practices in treatment combinations managed consistently for 13 consecutive years (i.e., 2002 to 2014), the trends in SOM, C, and N contents (kg m^{-2}) in the top 10 cm over time were affected ($P < 0.05$; Appendix A - Table 2) by all field treatment factors evaluated, and most clearly affected by the irrigation treatment in particular.

The trend in SOM content (kg m^{-2}) in the top 10 cm over time was affected ($P < 0.05$; Appendix A - Table 2) by all field treatment factors evaluated. These results are in contrast to results analyzed from the first 6 years following conversion to new management practices, where SOM in the top 10 cm was unaffected by tillage, burning, and residue level but increased across all treatments at an average rate of 0.097 kg m^{-2} yr^{-1}, likely due to the conversion from a monoculture to a more diverse crop rotation.

Though there were many subtle differences among treatment combinations, the largest and most obvious differences between the trends over time in SOM content occurred between irrigated and non-irrigated treatments. Averaged across tillage, burning, and residue level, SOM content increased at a rate of 0.56 kg m^{-2} yr^{-1} ($P < 0.001$) over time under dryland production until approximately nine years after initial conversion, then decreased at a rate of 0.03 kg m^{-2} yr^{-1} thereafter (Appendix B - Table 2; Fig. 3). In contrast, there was no change ($P > 0.05$; Appendix B - Table 2) in SOM content over time under irrigation. Consequently, the original hypothesis that SOM content would increase over time under irrigated conditions was rejected.

Irrigation strongly affects the activity of plants and soil microorganisms, leading to changes in SOM formation and decomposition. While increased soil moisture can increase SOM and soil C by promoting development of plant and microbial biomass, increased soil moisture also promotes microbial decomposition of SOM and respiration losses of C (Churchman and Tate, 1986). For example, Linn and Doran (1984) reported increases in soil respiration associated with increases in soil moisture, up to 60% water-filled pore space, beyond which microbial activity and respiration decrease in the upper 7.5 cm in a continuous corn and wheat-fallow study conducted on several silt-loam, loam, and clay-loam soils across the eastern United States.

Similarly, the results of this study suggest that microbial decomposition of SOM under dryland production was reduced by the lack of irrigation and human-induced wetting and drying cycles and that irrigation management, more than any other treatment factor, was responsible for the greatest differences in SOM and C trends over time.

The maximum point in the SOM content trend over time under dryland production between years 9 and 10 (i.e., 2010 and 2011; Fig. 3) may have been influenced by changes in growing-season weather patterns. During the year 9 (i.e., 2010) growing season (i.e., June through October), total rainfall was 58% lower and daily mean air temperature was 5% greater than the 30-yr cumulative rainfall and mean air temperature, respectively, during the same time period (NOAA, 2002). The year 9 and year 10 (i.e., 2011 and 2012) growing seasons also had 15 and 22% lower rainfall, respectively, compared to the 30-yr mean rainfall for the growing season (i.e., June through October; NOAA, 2002; Table 1; Appendix G). Furthermore, soybean yield sharply decreased under dryland production approximately year 9 (i.e., 2010), indicating a reduction in additions of plant biomass under dryland production. The hot, dry growing conditions occurring in year 9 (i.e., 2010) likely caused a reduction in crop biomass, microbial activity, and residue decomposition.

Burning also significantly affected ($P = 0.015$) the trend in SOM content over time (Appendix A - Table 2; Fig. 3). Averaged across residue level, tillage, and irrigation, and similar to that hypothesized, SOM content decreased at a rate of -0.02 kg m^{-2} yr^{-1} over time under residue burning, but increased at a rate of 0.02 kg m^{-2} yr^{-1} over time under non-burning (Fig. 3). Clearly, burning crop residues reduces the amount of plant material returned to the soil for potential microbial decomposition and eventual conversion to SOM. This is consistent with a 4-yr wheat-soybean study conducted on a Brooksville silty clay (Aquic Chromudert) in Mississippi that reported increased SOM content under no-burn, NT treatment combinations compared with a burn, CT treatment combinations (Sanford, 1982). These results are in contrast with results analyzed after the first 6 years following conversion to alternative management practices, in which burning had no effect on changes in SOM over time (Amuri et al., 2008), likely due to an insufficient length of time for measurable differences to appear.

As fractions of SOM, it would stand to reason that soil C and N contents would behave like SOM content trends over time. Similar to SOM, the trend in C content (kg m^{-2}) in the top 10 cm over time was affected ($P < 0.05$; Appendix A - Table 2) by all field treatment factors evaluated. Also similar to SOM, the largest and most obvious differences occurred between irrigated and non-irrigated treatments ($P < 0.05$). Averaged across tillage, burning, and residue level, C content increased at a rate of 0.16 kg m^{-2} yr^{-1} ($P < 0.05$) over time under dryland production until approximately nine years after initial conversion, then slightly decreased at a rate of 0.01 kg m^{-2} yr^{-1} ($P < 0.05$) thereafter (Appendix B - Table 3). In contrast, C content decreased at a rate of 0.16 kg m^{-2} yr^{-1} ($P < 0.05$) over time under irrigation until approximately nine years after initial conversion, then slightly increased at a rate of 0.01 kg m^{-2} yr^{-1} thereafter (Appendix B - Table 3; Fig. 4). This result somewhat negates the original hypothesis that C content would increase over time under irrigation. 94% of the measured C content values in the entire seven year study fell within a range of 1 to 1.6 kg C m^{-2} (data not shown). To put this range of C contents in context, 0.2 kg C m^{-2} extrapolated across 1 ha would equal 2000 kg C ha^{-1}. Considering the 34 million ha planted to soybean in the United States in 2014 (USDA-NASS, 2015), these observed differences in C content trends may have large-scale, real-world significance in the industry as a whole.

These results are somewhat similar to what was reported after the first 6 years following conversion to new management practices, in which soil C content increased at a greater rate under irrigation (0.11 kg C m^{-2} yr^{-1}) than under dryland production (0.044 kg C ha^{-1} yr^{-1}; Amuri et al., 2008). Similarly, Lal and Bruce (1999) suggested that soil C sequestration is strongly linked to irrigation practices, estimating that irrigated cropland sequesters between 50 to 150 kg ha^{-1} more C than non-irrigated cropland. Other studies have reported more significant effects on soil C as a result of tillage practices, i.e., greater soil C sequestration under CT than NT (Franzluebbers et al., 1998; Grandy et al., 2006) as a result of increased oxidation of SOM under CT management.

The maximum points in the C content trends over time under irrigated and non-irrigated soybean production (Fig. 4) occurred at approximately the same time as the maximum point in the SOM trend over time under non-irrigated production (Fig. 3), and therefore may have been similarly influenced by changes in the growing-season weather patterns. The increase in temperature and decrease in moisture may have caused a reduction in crop biomass, microbial activity, and residue decomposition, which may account for the shift from increasing decreasing C content under dryland production between years 9 and 10 (i.e., 2010 and 2011). In contrast, the growing conditions under irrigated conditions were hot and moist, which may have increased microbial decomposition of crop residue and increased the amount of plant biomass converted into stabilized, recalcitrant fractions of C. It is also important to note that, for unknown reasons, the maximum point in the C content trend over time under irrigation occurred slightly earlier than that under dryland production.

Furthermore, while soybean yield under irrigation began to slightly decrease approximately year 9 (i.e., 2010; $P < 0.001$; Appendix B - Table 8; Fig. 7), soybean yield under irrigation continued to exceed soybean yield under dryland production throughout the entire measured time period, indicating that the crop growth under dryland production was more strongly affected by the change in growing-season weather patterns. The continued, annual additions of relatively large amounts of biomass under irrigation compared to dryland production may have influenced the quadratic increase ($P < 0.05$; Appendix B - Table 3; Fig. 4) in soil C content under irrigation.

Also similar to SOM content, C content trends were affected ($P = 0.002$; Appendix A - Table 2) by burning in a manner consistent with the original hypothesis. Although the linear trend of soil C over time was unaffected ($P > 0.05$) by burning, the quadratic coefficient of soil C content was affected ($P = 0.002$) by burning (Appendix A - Table 2). Under residue burning, soil C content began to decrease over time beginning approximately year 9 (i.e., 2010; $P < 0.05$; Appendix B - Table 3). In contrast, under the no-burn treatment, soil C began to sharply increase over time beginning approximately year 8 (i.e., 2009; $P < 0.05$; Appendix B-Table 3). These results are somewhat similar to what was reported after the first 6 years following conversion to alternative management practices, in which the rate of increase in soil C was significantly ($P = 0.008$) greater under non-burning than under burning (Amuri et al., 2008).

The trend in the C fraction of SOM in the top 10 cm over time was affected ($P < 0.05$; Appendix A - Table 3) by all treatment factors evaluated. Though there were many subtle differences among treatment combinations, the largest and most obvious differences again occurred between irrigation treatments. Averaged across tillage, burning, and residue level, the C fraction of SOM slightly decreased ($P < 0.05$) over time under both irrigated and dryland production until approximately nine years after initial conversion, then increased ($P < 0.05$) thereafter (Appendix A - Table 3; Fig. 5). However, the C fraction of SOM under irrigation increased approximately three times faster than the rate under dryland production after year 9 (i.e., 2010; Appendix B - Table 4). The greater increase in C fraction of SOM over time under irrigation (Fig. 5) is consistent with the increase in C content over time under irrigation (Fig. 4) beginning approximately year 9 (i.e., 2010).

Trends in soil C and/or SOM are often accompanied by similar trends in soil N. The trend in soil N content (kg m^{-2}) in the top 10 cm over time was affected ($P < 0.001$) by irrigation, and unaffected ($P > 0.05$) by any other treatment factor evaluated (Appendix A - Table 2). Averaged across tillage, burning, and residue level, soil N content increased at a rate of 0.03 kg m^{-2} yr^{-1} over time under dryland production until approximately nine years after initial conversion, then slightly decreased at a rate of 0.002 kg m^{-2} yr^{-1} thereafter (Appendix B - Table 6; Fig. 6). These results are in contrast to results reported after the first 6 years following conversion to alternative management practices, in which the trend in soil N content over time was unaffected by any imposed field treatments. The maximum point approximately year 9 (i.e., 2010; Fig. 6) approximately corresponds to the maximum points in SOM content (Fig. 3), C content (Fig. 4), and C fraction of SOM (Fig. 5), and may have been similarly influenced by changes in growing-season weather patterns. In contrast, there was no change in soil N content over time under irrigation ($P > 0.05$; Appendix B - Table 6). The N fraction of SOM in the top 10 cm over time was affected by tillage, irrigation, and residue level treatments ($P < 0.023$; Appendix A - Table 3). However, trends in N fraction of SOM over time contained no significant slope or quadratic terms, i.e., all treatment combinations were statistically similar (Appendix B - Table 7).

Evaluated independently, soil C and N provide useful information, but evaluated together as the C:N ration can provide even more insight into the biogeochemical cycling of SOM. The trend in soil C:N ratio in the top 10 cm over time was affected ($P < 0.05$; Appendix A -Table 3) by all field treatments evaluated. Though there were many subtle differences among treatment combinations, the largest and most obvious differences occurred between high- and low-residue treatments. Averaged across tillage, burning, and irrigation, soil C:N ratio decreased ($P < 0.05$) over time until approximately nine years after initial conversion, then increased thereafter under both high- and low-residue treatments (Appendix B - Table 5; Fig. 5). However, soil C:N ratio decreased at a greater rate prior to year 9 and increased at a greater rate after year 9 (i.e., 2010) under the low- than the high-residue treatment (Appendix B - Table 5; Fig. 5). One possible explanation for this trend is the accumulation of soil N under the high-residue/high-fertilization treatment. Soil under the high-residue management received twice the amount of N fertilizer that soil under the low-residue management received, and therefore the slower rate of increasing C:N ratio under the high-residue management may have been influenced by the greater input of N fertilizer. This interpretation is consistent with a 50-yr wheat-fallow cropping study on a silt loam Typic Haploxeroll in Oregon, where unfertilized treatments had a greater C:N ratio than N-fertilized treatments in the top 30 cm (Rasmussen et al., 1980). It is also possible that soil microbes under the low-residue/low-fertilization treatment lacked sufficient soil N to consume SOM as rapidly as microbes under the high-residue/high-fertilization treatment, especially given the high C:N ratio of the wheat residue (C:N≈ 55). The reduced efficiency of microbial respiration may account for the greater accumulation of soil C compared to soil N under the low-residue/low-fertilization treatment. In contrast to this study, after the first 6 years following conversion to new management, no significant trends in C:N ratio over time were reported (Amuri et al., 2008). Another study similarly reported no significant effects on soil C and N dynamics as a result of high (134 kg N ha^{-1} yr^{-1}) and low-N-rate treatments after 10 years of consistent management of a Weld silt-loam (Aridic Agiustoll) in the Great Plains (Halvorson et al., 1999).

Soybean and Wheat Yields

Over the course of seven complete wheat-soybean cropping cycles (i.e., 2007 to 2014), after six complete cropping cycles (i.e., 2001 to 2007) following conversion to alternative management practices in treatment combinations managed consistently for 13 consecutive years (i.e., 2002 to 2014), the trend in soybean yield (Mg ha^{-1}) over time was affected ($P < 0.05$) by only irrigation (Appendix A - Table 1). Soybean yield increased ($P = 0.01$) over time under irrigation until approximately nine years after initial conversion, then slightly decreased ($P < 0.001$) thereafter (Appendix B - Table 8; Fig. 7). In contrast, soybean yield sharply decreased ($P < 0.001$) over time under dryland production until approximately 11 years after initial conversion, then slightly increased ($P = 0.003$) thereafter (Appendix B - Table 8; Fig. 7). The drought conditions during years 9 and 11 (i.e., 2010 and 2012) may have caused a reduction in crop growth and yield, with the sharpest decrease occurring between years 10 and 11 (i.e., 2011 and 2012) under dryland production (Fig. 7). Soybean yields are strongly affected by water availability and air temperature (Andresen et al., 2001), which is a partially a function of climatic conditions and irrigation practices. In contrast to this study, soybean yields over time did not differ among field treatments in the first 6 years following conversion to alternative management practices (Amuri et al., 2008).

In contrast to soybean yield trends, the trend in wheat yield (Mg ha^{-1}) over time was affected ($P < 0.05$; Appendix A - Table 1) by all treatment factors evaluated. However, all treatment combinations decreased at the same rate over time ($P < 0.001$). Therefore, while all treatment factors significantly affected the trend in wheat yield over time, the differences over time between specific treatment combinations were statistically insignificant. Wheat yield increased at a similar rate under all treatment combinations until approximately year 9 (i.e., 2010), then slightly decreased thereafter (Appendix B - Table 9; Fig. 8). Irrigation was only provided during the soybean growing season, which may explain why irrigation clearly affected soybean yield trends (Fig. 7), but failed to directly affect wheat yield (Fig. 8). These results are similar the first 6 years following conversion to alternative management practices, during which wheat yields did not differ among field treatments (Amuri et al., 2008).

Soil Chemical Properties

Time Effects Only

The trends in EC (dS m^{-1}), and Fe, S, and N contents (kg ha^{-1}) over time were unaffected by any of the treatment factors evaluated. However, similar to wheat yield, all treatment combinations increased or decreased at a statistically similar rate over time in each of these measured variables. The trend in soil EC in the top 10 cm over time had a slight increasing linear ($P < 0.001$) trend, followed by a slight decreasing quadratic ($P < 0.001$) trend. However, the overall trend in soil EC appeared to decrease at approximately the same rate over time under all treatment combinations (Appendix B - Table 10; Fig. 9). The decrease in EC over time is consistent with the decreasing trend in sodium (Na) over time, indicating a lack of accumulation of salinity and soluble salts over time. These results are similar to what was reported following the first 6 years of consistent management, in which soil EC was unaffected by any field management practice in this study and decreased significantly over time (Amuri et al., 2008).

Similar to soil EC, the trends in Fe and S contents in the top 10 cm over time were also unaffected ($P > 0.05$; Appendix A - Table 4) by any of the field treatment evaluated. However, Fe and S contents varied in time ($P < 0.001$; Appendix B - Table 11 and Table 13, respectively). While the coefficient estimates indicated an increasing linear trend in Fe (Appendix B - Table 11) and S (Appendix B - Table 13) content, followed by a slight decreasing quadratic trend (Fig. 10; Appendix B -Table 11 and Table 13), the changes over time were minute from a production standpoint. Sulfur is rarely a limiting nutrient in soybean production, and no Fe deficiency for soybean has ever been diagnosed in Arkansas (Slaton et al., 2013). Therefore, the slight changes observed in the trends in Fe and S content trends over time were agronomically non-significant.

Similar to EC and Fe and S contents, the trend in Na content in the top 10 cm over time was unaffected ($P > 0.05$; Appendix A - Table 4) by any of the field treatments evaluated. However, unlike EC and Fe and S contents, soil Na content only varied linearly over time ($P < 0.001$; Appendix B - Table 12). Soil Na in all treatment combinations slightly decreased over time (Fig. 11). The lack of increasing salinity or EC over time, even under irrigation, may be partly explained by the low EC and Na and chloride (Cl) concentrations in the irrigation water used (Amuri et al., 2008). Furthermore, there may be enough ample moisture to remove Na from the top 10 cm so that the damaging effects of soil dispersion, possible crusting, and destruction of structure are likely to not be present.

Single Treatment Effects

In contrast to the lack of clear residue management effects on EC and Fe, S, and Na contents, the trends in several measured soil properties, namely soil pH and P and Cu contents, exhibited large and obvious differences due to the imposition of a single treatment factor. The trend in soil pH in the top 10 cm over time was statistically affected ($P < 0.05$; Appendix A - Table 5) by all field treatments evaluated, however, the largest and most obvious differences occurred between the high- and low-residue treatments (Appendix B – Table 14). Soil pH decreased over time under all treatment combinations until 10 years after conversion to new management, then slightly increased thereafter (Fig. 12). However, averaged across tillage, burning, and irrigation, soil pH decreased at a greater rate over time under the high- than under the low-residue treatment up to approximately year 10 (i.e., 2011; Appendix B – Table 14). Shortly after 10 years after conversion to new management, soil pH began to increase at a slightly greater rate over time under the high- than under the low-residue treatment (Fig. 12), with the exception of the NT-NB-H-I and CT-B-H-I treatment combinations (Appendix B - Table 14). Soil pH was not affected ($P = 0.058$) by any of the field treatments under the NT-NB-H-I treatment combination, and soil pH under the CT-B-H-I treatment decreased until 10 years after conversion to new management, then increased at a statistically similar rate to soil pH under low-residue treatment (Appendix B; Table 14).

In contrast to this study, soil pH was unaffected by residue level treatment, increased over time under irrigated treatment, and did not change over time under dryland production during the first 6 years following conversion to new management (Amuri et al., 2008). A possible explanation for the shift from irrigation-driven changes in pH during the first 6 years of management to residue level-driven changes in pH from year 6 to year 14 is that the lime applied at the initiation of the study in 2001 may have progressively dissolved at different rates under irrigated and non-irrigated management, thereby altering the soil pH most significantly according to irrigation treatment in earlier years and less significantly in later years.

All of the observed differences in soil pH trends over time occurred well-above the threshold of 6.0, below which soybean yield reductions can be expected on silt-loam soils (Slaton et al., 2013). Therefore, while the differences in soil pH trends over time may be statistically significant, they are agronomically non-significant with regards to soybean production on silt-loam soils in eastern Arkansas.

The trend in P content in the top 10 cm over time was affected by irrigation ($P = 0.019$) and residue level ($P < 0.001$) and was unaffected by tillage and burning ($P > 0.05$; Appendix A - Table 5). Similar to SOM, C, and N contents, the largest and most obvious differences in soil P trends occurred between irrigation treatments (Appendix B - Table 15). Averaged across tillage, burning, and residue level, soil P content increased ($P < 0.001$) over time under dryland production until approximately nine years after initial conversion, then decreased thereafter (Appendix B - Table 15; Fig. 13). In contrast, soil P content decreased quadratically over time under irrigation ($P = 0.02$; Appendix B - Table 15). In contrast to this study, no significant differences were reported in the trends in soil P content over time between irrigation treatments during the first 6 years following conversion to alternative management practices (Amuri et al., 2008). One possible explanation for why the trend in soil P content over time was most clearly affected by irrigation is that changes in soil P content are associated with changes in SOM (Rhoton, 2000), and the trend in SOM content over time was most clearly affected by the irrigation treatment. The trend in soil P content over time under dryland production (Fig. 13) approximately mirrors the trend in SOM content over time under dryland production (Fig. 3).

The differences between trends in soil P content under irrigated and non-irrigated management are not only statistically significant, but agronomically significant as well. Soil P contents ranged between very low (< 19.5 kg ha^{-1}) and medium (33.8 to 45.5 kg ha^{-1}) soil test P levels, based on a conversion of the part per million (ppm) soil test P levels provided by the

Arkansas Soybean Production handbook (Slaton et al., 2013) and using an assumed bulk density of 1300 kg m^{-3} in combination with the measured soil depth of 0.1 m. There is no evidence that P fertilization of soils with medium soil test P levels will produce a yield response, although fertilization may help maintain optimum P levels by replacing the portion of P expected to be removed by the harvested soybean grain (Slaton et al., 2013). The soil P content trend under dryland management occurred mostly within the medium soil test P level range (Fig. 13), indicating that P fertilization requirements for soybean on silt-loam soils in eastern Arkansas may possibly be reduced under dryland management compared to irrigation management. These results suggest that irrigation treatment effects may impact the necessity, amount, and/or frequency of P fertilization. However, it is important to note that P deficiency in soybean is much less common than other potential deficiencies, such as K (Slaton et al., 2013).

Similar to P content, the trend in soil Cu content in the top 10 cm over time was affected ($P = 0.009$) by irrigation and was unaffected ($P > 0.05$) by tillage, burning, or residue-level treatments (Appendix A - Table 5). Averaged across tillage, burning, and residue level, Cu content decreased ($P < 0.001$) over time under irrigation until approximately 10 years after initial conversion, then slightly increased thereafter (Appendix B - Table 16; Fig. 13). In contrast, there was no change in soil Cu content over time under dryland production ($P > 0.05$; Appendix B - Table 16). In contrast to this study, no significant differences were reported in the trends in soil Cu content over time between irrigation treatments during the first 6 years following conversion to alternative management practices (Amuri et al., 2008). All soil Cu trend values occurred well-above the threshold for low soil test Cu levels (< 1 kg ha^{-1}; Slaton et al., 2013). Therefore, the trends in soil Cu content over time under irrigation were also agronomically non-significant.

Burning and Irrigation Treatment Effects

While the largest and most obvious the trends in trends in pH and P and Cu contents over time were only affected by a single treatment factor, the trends in Ca, Mg, and Mn contents (kg ha^{-1}) over time were affected by irrigation and burning treatment combinations. The trend in Ca content in the top 10 cm over time was affected ($P < 0.05$) by all field treatment factors evaluated (Appendix A - Table 6). Tillage and residue-level participated in significant treatment combinations, but had no observable impacts on the trend in Ca content over time (Appendix B - Table 17). The largest and most obvious differences occurred between the irrigation and burning treatment combinations, based on an interpretation of the LSD between estimate parameters of specific treatment combinations (Appendix B - Table 17). Averaged across tillage and residue level, Ca content increased ($P < 0.05$) over time under most non-burned, non-irrigated treatment combinations until approximately nine years after initial conversion then decreased ($P < 0.05$) thereafter, with the exception of the CT-NB-L-NI treatment combination, exhibited no change over time ($P > 0.05$; Appendix B - Table 17; Fig. 14). In contrast, Ca content decreased ($P < 0.05$) over time under non-burned, irrigated production until approximately ten years after initial conversion then increased ($P < 0.05$) thereafter (Appendix B - Table 17; Fig. 14). While the statistical differences between Ca content trends over time under different treatment combinations may be of scientific interest, all of the measured Ca contents exceed plant growth requirements for most row crops in eastern Arkansas (Slaton et al., 2013).

Similar to Ca, the trend in soil Mg content in the top 10 cm over time was affected ($P < 0.05$) by all field treatments evaluated (Appendix A - Table 6). Also similar to Ca, the largest and most obvious differences occurred between irrigation and burning treatment combinations (Appendix B - Table 18). Averaged across tillage and residue level, soil Mg content decreased (P

< 0.05) over time under burned, irrigated combinations until approximately eight years after initial conversion, then increased thereafter (Appendix B - Table 18; Fig. 14). In contrast, soil Mg content decreased ($P < 0.001$) over time under non-burned, irrigated combinations at approximately four times the rate of the decrease under burned, irrigated management until approximately eight years after initial conversion, then increased ($P < 0.001$) thereafter at approximately three times the rate of the increase under burned, irrigated management (Appendix B - Table 18; Fig. 14). However, Mg deficiencies are rare for soybean production in eastern Arkansas given that Mg is prevalent in the groundwater (Slaton et al., 2013). Moreover, measured Mg contents consistently occurred above the threshold for low soil test Mg levels (< 45 kg ha^{-1}; Slaton et al., 2013), thus Mg differences were also likely agronomically non-significant. These results are in contrast to results reported after the first 6 years following conversion to new management, in which Ca and Mg contents increased at a greater rate over time under irrigation compared with dryland production, likely due to the gradual dissolution of the initial application of lime in 2001 (Amuri et al., 2008).

The trend in Mn content in the top 10 cm over time was affected ($P < 0.05$) by tillage, burning, and irrigation (Appendix A - Table 6). Tillage and residue level contributed to significant higher-order interactions, but neither had an observable impact on the trend in Mn content over time (Appendix B – Table 19). Similar to Ca and Mg, the largest and most obvious differences in soil Mn content trends occurred between irrigation and burning treatments (Appendix B - Table 19). Averaged across tillage and residue level, soil Mn content sharply increased ($P < 0.05$) over time under the non-burned, irrigated treatment combinations until approximately 10 years after initial conversion, then decreased thereafter (Appendix B - Table 19; Fig. 15). In contrast, soil Mn content increased ($P < 0.05$) over time under dryland production at less than half the rate of the increase under the non-burned, irrigated combination until approximately nine years after initial conversion, then slightly decreased thereafter (Appendix B - Table 19; Fig. 15). However, measured Mn contents were consistently well-above the threshold for low soil test Mn levels (< 13 kg ha^{-1}; Slaton et al., 2013), thus, like soil Ca and Mg, were also agronomically non-significant. These results are similar to results reported after the first six years following conversion to alternative residue management practices, in which the trend in Mn content over time was most significantly affected by irrigation. During the first six years following conversion to alternative residue management practices, the trend in Mn content increased under irrigation and did not change under dryland management.

Complex Treatment Effects

Compared to other observed trends in this study, the effects of residue management on soil K and Zn content trends over time were the most complex. The trend in soil K content in the top 10 cm over time was affected ($P < 0.05$) in some way by all field treatment factors evaluated (Appendix A - Table 7). There were many subtle differences in soil K content trends over time among treatment combinations. Based on LSDs among parameters estimates (Appendix B - Table 20), it appeared that burning and residue level had less of an impact on soil K content trends over time than did tillage and irrigation. Similar to Ca (Appendix B – Table 17), soil K content in the NT-B-H-NI, CT-NB-H-NI, and NT-NB-L-NI treatment combinations did not vary over time (Appendix B – Table 20). All other treatment combinations decreased ($P < 0.05$) over time until approximately 10 years after conversion to new management, then slightly increased thereafter (Appendix B – Table 20; Fig. 16). One statistically similar grouping of treatment combinations (Appendix B – Table 20) was the NT-NB-L-I, NT-NB-H-I, NT-B-L-I, and CT-B-

H-I treatment combinations, which sharply decreased ($P < 0.001$) over time until approximately 10 years after conversion to new management, then slightly increased thereafter (Appendix B – Table 20). In contrast, another statistically similar group of treatment combinations (i.e., CT-B-H-NI, NT-B-L-NI, CT-B-L-I, NT-B-H-I, CT-NB-L-I, CT-B-L-NI, CT-NB-L-NI, NT-NB-H-NI, and CT-NB-H-I) decreased more gradually ($P < 0.05$) over time until approximately 10 years after conversion to new management, then some combinations (i.e., CT-B-L-I, NT-B-H-I, CT-NB-L-I, CT-B-L-NI, CT-NB-L-NI, NT-NB-H-NI, and CT-NB-H-I) increased thereafter, while others (i.e., CT-B-H-NI, NT-B-L-NI) exhibited no quadratic trend (Appendix B – Table 20).

The differences in K content trends over time observed in this study were agronomically significant because K contents ranged between very low to optimum soil test K levels. Soil K contents at or below 78 kg ha^{-1} were in the very low range and those between 170 and 228 kg ha^{-1} were in the optimum soil test K range (Slaton et al., 2013). Between years 9 and 13 (i.e., 2010 and 2014), the trend in soil K content generally occurred within the very low range in the NT-NB-L-I, NT-NB-H-I, NT-B-L-I, and CT-B-H-I treatment combinations (Fig. 16). In contrast, within the same time period, the trend in soil K content generally occurred within the medium range (i.e., 118 to 169 kg P ha^{-1}) of soil test K in the CT-B-H-NI, NT-B-L-NI, CT-B-L-I, NT-B-H-I, CT-NB-L-I, CT-NB-L-NI, NT-NB-H-NI, and CT-NB-H-I treatment combinations. However, given the complexity of the treatment effects, it is challenging to translate the variations in soil K content over time into practical recommendations for improved field management of soil K aside from maintaining adequate levels with periodic fertilization.

In contrast to these results, the trends in soil K content over time differed between irrigation treatments during the first six years following conversion to alternative management practices. Soil K contents decreased linearly under irrigation, but increased under dryland management, indicating a possible leaching of soil K due to irrigation treatment during the first six years following conversion to new management practices, in addition to increased plant uptake of soil K under irrigated production.

Similar to K, the trend in soil Zn content in the top 10 cm over time was complex compared to other measured variables in the study, with many subtle differences between treatment combinations. While Zn content was affected ($P < 0.05$; Appendix A - Table 7) by all field treatments evaluated, the burn treatment appeared to have the most clearly discernible effects (Appendix B - Table 21). Soil Zn content increased ($P < 0.05$) over time in the NT-B-H-NI, NT-NB-L-I, NT-NB-L-NI, and CT-NB-H-I treatment combinations until approximately 10 years after conversion to new management, then decreased thereafter (Appendix B - Table 21; Fig. 17). In contrast, soil Zn content decreased ($P < 0.05$) over time in the NT-B-L-NI and CT-B-H-I treatment combinations until approximately 11 years after conversion to new management, then slightly increased thereafter (Appendix B - Table 21; Fig. 17). In contrast to these results, Zn content increased under dryland management and did not change over time under irrigation during the first six years following conversion to alternative residue management practices (Amuri et al., 2008).While differences in soil Zn content trends among the various treatment combinations were statistically significant, no Zn deficiency has ever been observed or diagnosed in an Arkansas soybean crop (Slaton et al., 2013), thus, similar to soil pH, Fe, S, Cu, Ca, and Mg, differences in soil Zn were agronomically non-significant in terms of Arkansas soybean production.

Summary and Conclusions

Over the course of seven complete wheat-soybean cropping cycles (i.e., 2007 to 2014), after six complete cropping cycles (i.e., 2001 to 2007) following conversion to alternative management practices in treatment combinations managed consistently for 13 consecutive years (i.e., 2002 to 2014), all field treatments evaluated in this study affected trends in one or more measured soil properties over time. Irrigation management was responsible for the greatest differences in trends in soybean yield, C fraction of SOM, and SOM, C, N, P, Cu contents over time. Burning also significantly affected the trend in SOM and C contents over time. Irrigation and burn treatment combinations were responsible for the greatest differences in trends in soil Ca, Mg, and Mn contents over time. Residue level was responsible for the greatest differences in trends in soil C:N ratio and pH over time. Trends in wheat yield, EC, and Fe, Na, and S contents were unaffected by any of the field treatments evaluated, but all varied significantly over time. Trends in bulk density, and K and Zn contents over time were affected by complex treatment combinations that included interactions among tillage, burning, and irrigation.

As originally hypothesized, SOM and C contents increased over time under non-burning and decreased over time under burning. Contrary to original hypotheses, tillage and residue treatments failed to cause clear and obvious differences in the trends in SOM, C, and extractable nutrient contents over time. In fact, differences between irrigation treatments appeared the have the clearest, most obvious effects on the trends in SOM, C, N, P, and Cu contents over time. Also contrary to that hypothesized, SOM and C contents did not decrease under dryland soybean production. Rather, SOM and C contents increased over time under dryland production until approximately year 9 (i.e., 2010), then decreased thereafter.

Overall, it can be inferred from this study that irrigation management plays a critical role in the long-term trends in SOM, C, and N contents and other soil physical and chemical properties over time. Moreover, the accumulation of SOM, C, and N appears to be greatly influenced by growing season weather patterns, especially under dryland production. Crop management that strikes a balance between increasing crop biomass and decreasing the rate of microbial turnover of SOM can maintain or increase SOM levels, and thereby work towards long-term soil improvement and soil C sequestration.

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Table 1. Summary of soybean growing-season rainfall and average temperature from Year 6 to Year 13 (i.e., 2007 through 2014).

	Precipitation (cm)								
Month	**30 yr Mean**	**Year 6 Mean**	**Year 7 Mean**	**Year 8 Mean**	**Year 9 Mean**	**Year 10 Mean**	**Year 11 Mean**	**Year 12 Mean**	**Year 13 Mean**
June	11.2	9.3	3.9	8.9	3.3	6.4	2.0	1.9	24.8
July	9.7	15.3	5.4	21.8	6.7	12.3	6.5	7.1	6.5
August	6.9	2.3	15.2	6.4	1.6	8.6	3.1	4.8	11.9
September	8.0	7.6	6.6	12.3	2.1	5.6	12.3	11.1	3.4
October	9.6	10.3	7.3	32.1	5.4	5.7	11.5	6.8	11.5
Season Total	45.4	44.8	38.4	81.5	19.1	38.6	35.4	31.7	58.1
	Temperature (°C)								
June	25	27	27	27	29	28	26	26	26
July	27	26	28	26	28	29	28	26	25
August	26	29	26	26	29	28	27	26	27
September	23	24	23	23	25	21	24	24	23
October	17	19	17	16	18	16	16	17	18
Season Mean	23.6	25	24.2	23.6	25.8	24.4	24.2	23.8	23.8

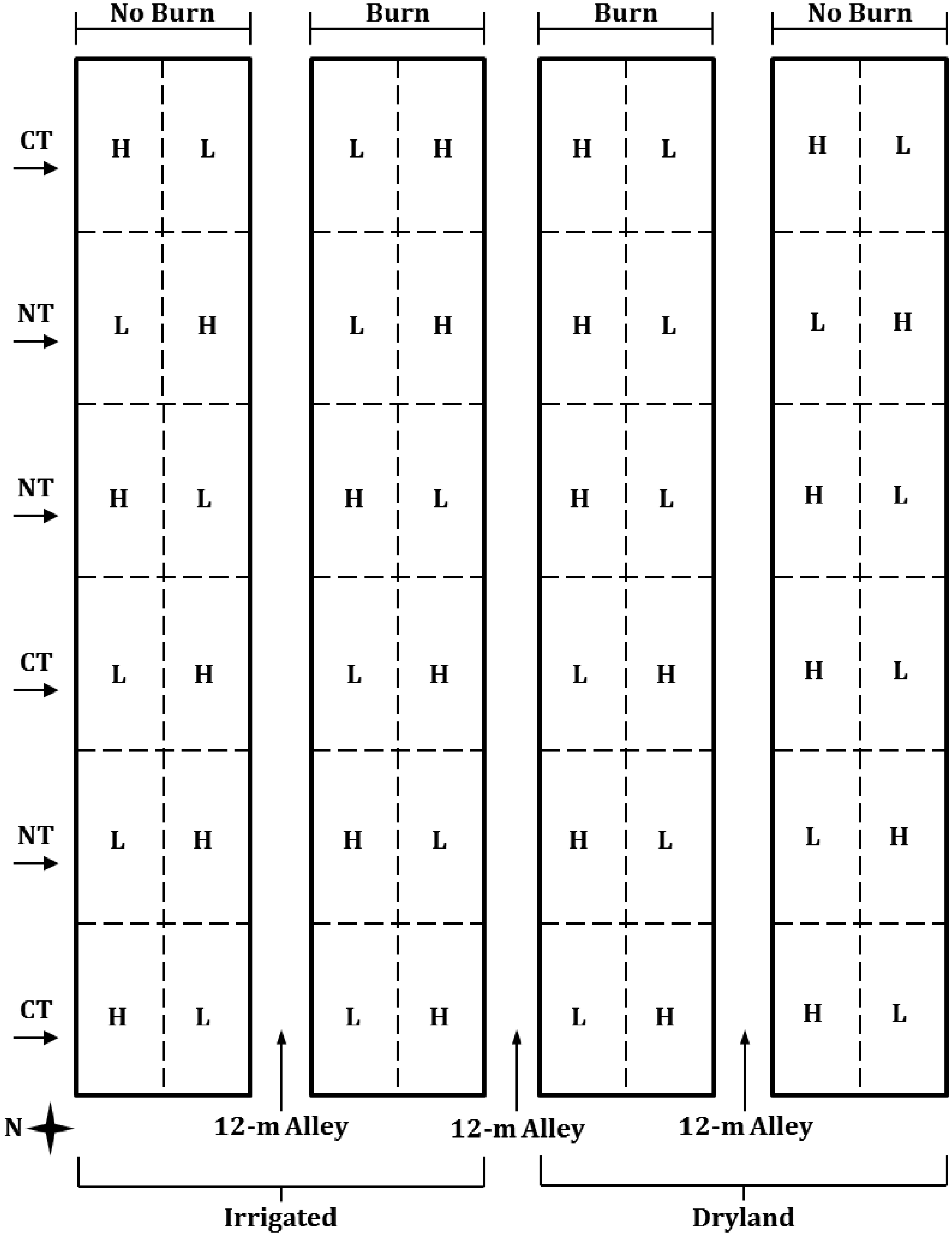

Fig. 1. Experimental layout at the Lon Mann Cotton Branch Experiment Station in eastern Arkansas depicting 48, 3- x 6-m plots subjected to residue-level [high (H) and low (L)], burn, tillage [conventional tillage (CT) and no-tillage (NT)], and irrigation treatments.

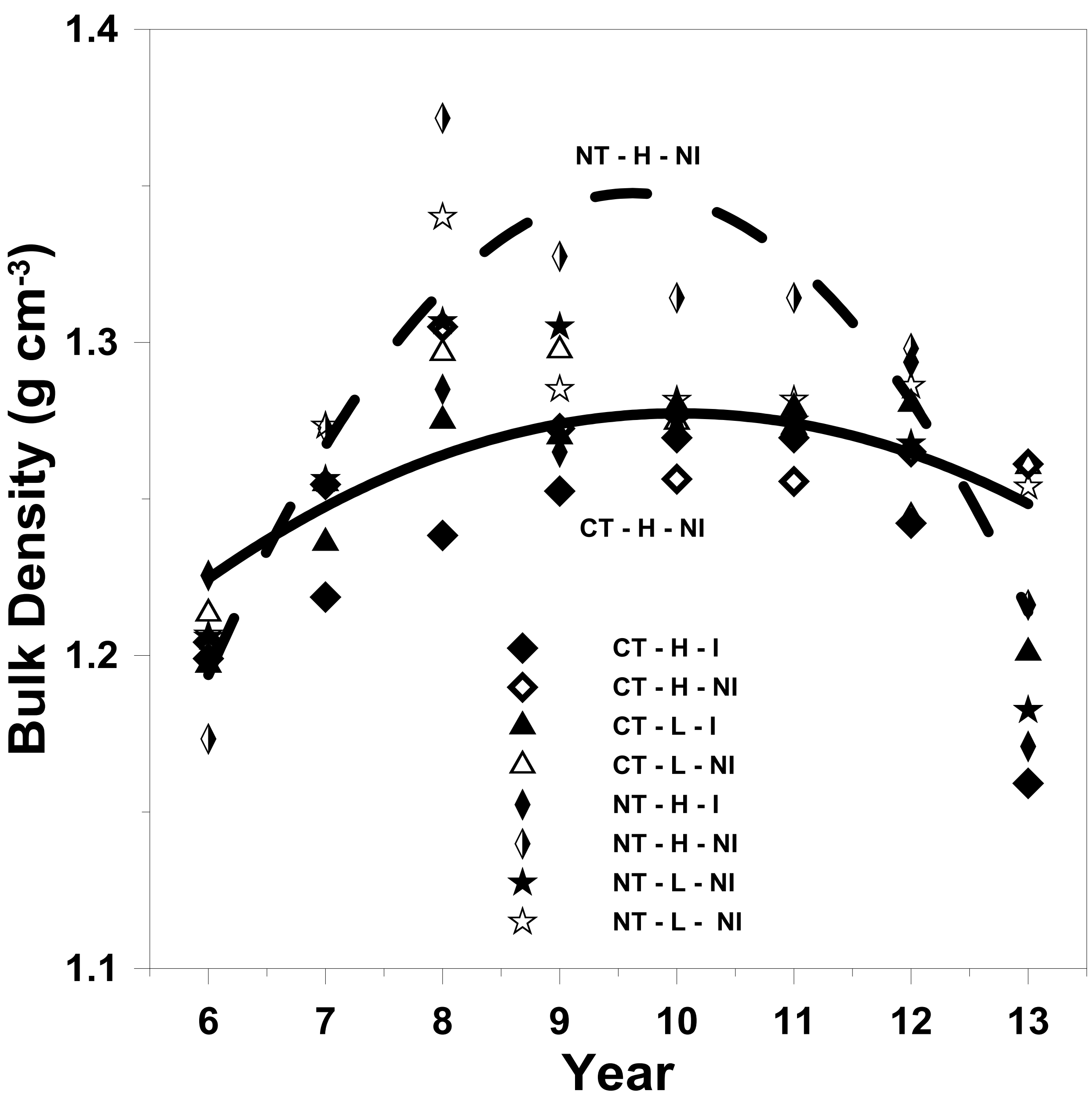

Fig. 2 Influence of tillage [conventional tillage (CT) and no-tillage (NT)], residue-level [high (H) and low (L)], and irrigation [irrigated (I) and non-irrigated (NI)] on the trend in bulk density in the top 10 cm over time after initial conversion to alternative management practices after initial conversion to alternative management practices in a wheat-soybean, double-crop system in eastern Arkansas.

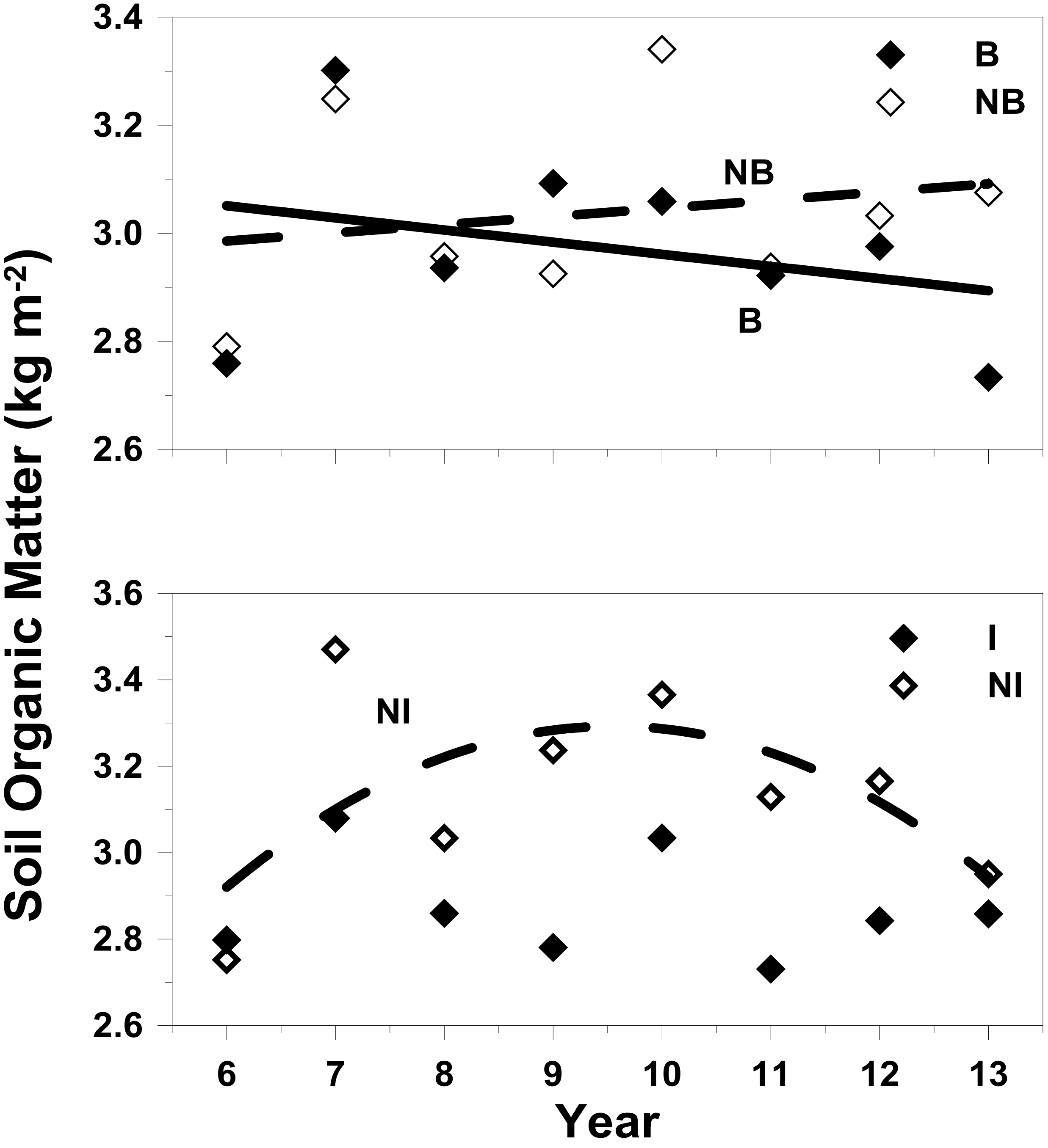

Fig. 3 Influence of burning [burn (B) and no-burn (NB)] and irrigation [irrigated (I) and non-irrigated (NI)] on the trend in soil organic matter (SOM) content in the top 10 cm over time after initial conversion to alternative management practices in a wheat-soybean, double-crop system in eastern Arkansas. Soil OM content under the irrigated treatment did not differ over time and averaged 2.87 kg m^{-2}.

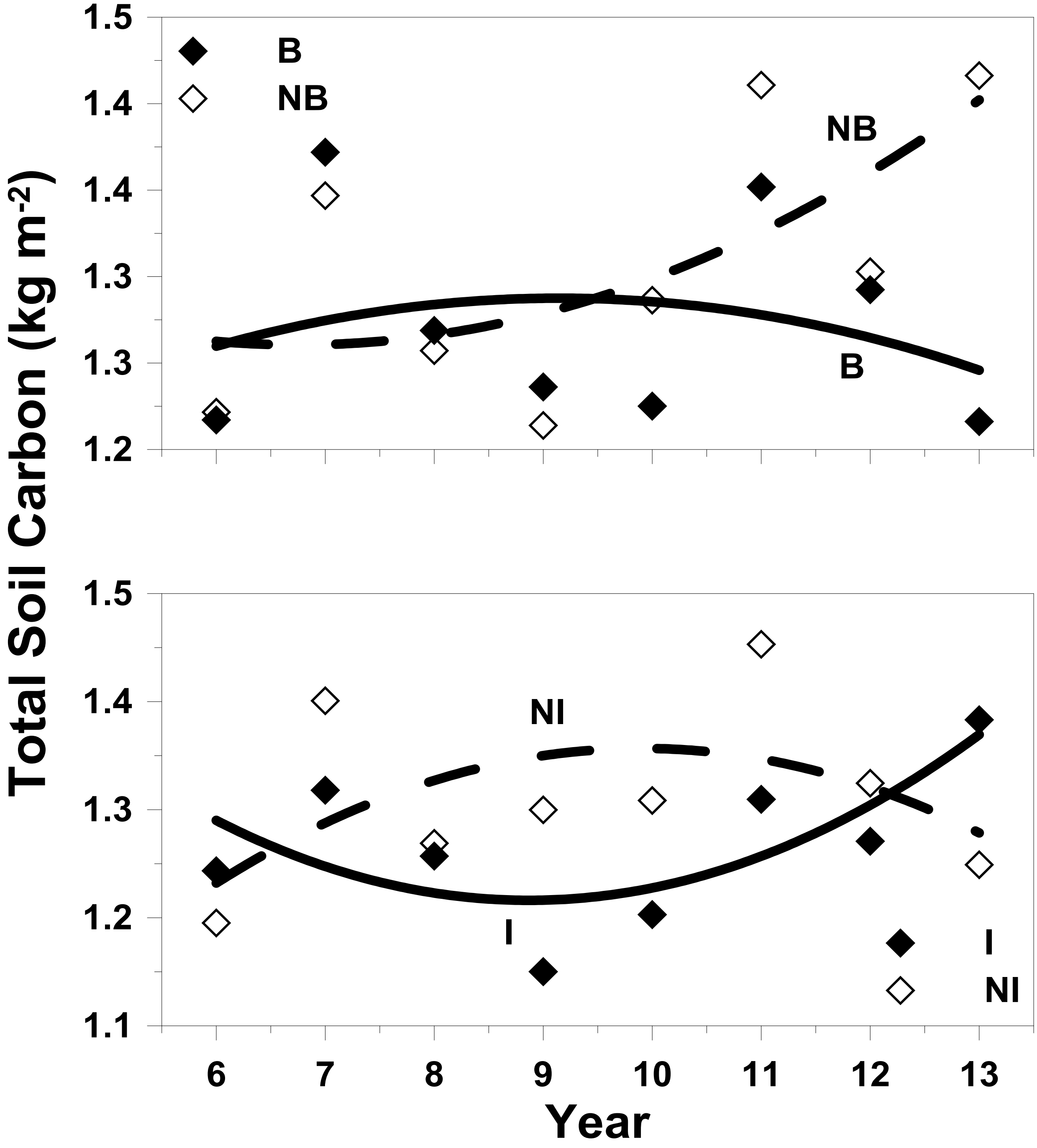

Fig. 4 Influence of burning [burn (B) and no-burn (NB)] and irrigation [irrigated (I) and non-irrigated (NI)] on the trend in soil carbon content in the top 10 cm over time after initial conversion to alternative management practices in a wheat-soybean, double-crop system in eastern Arkansas.

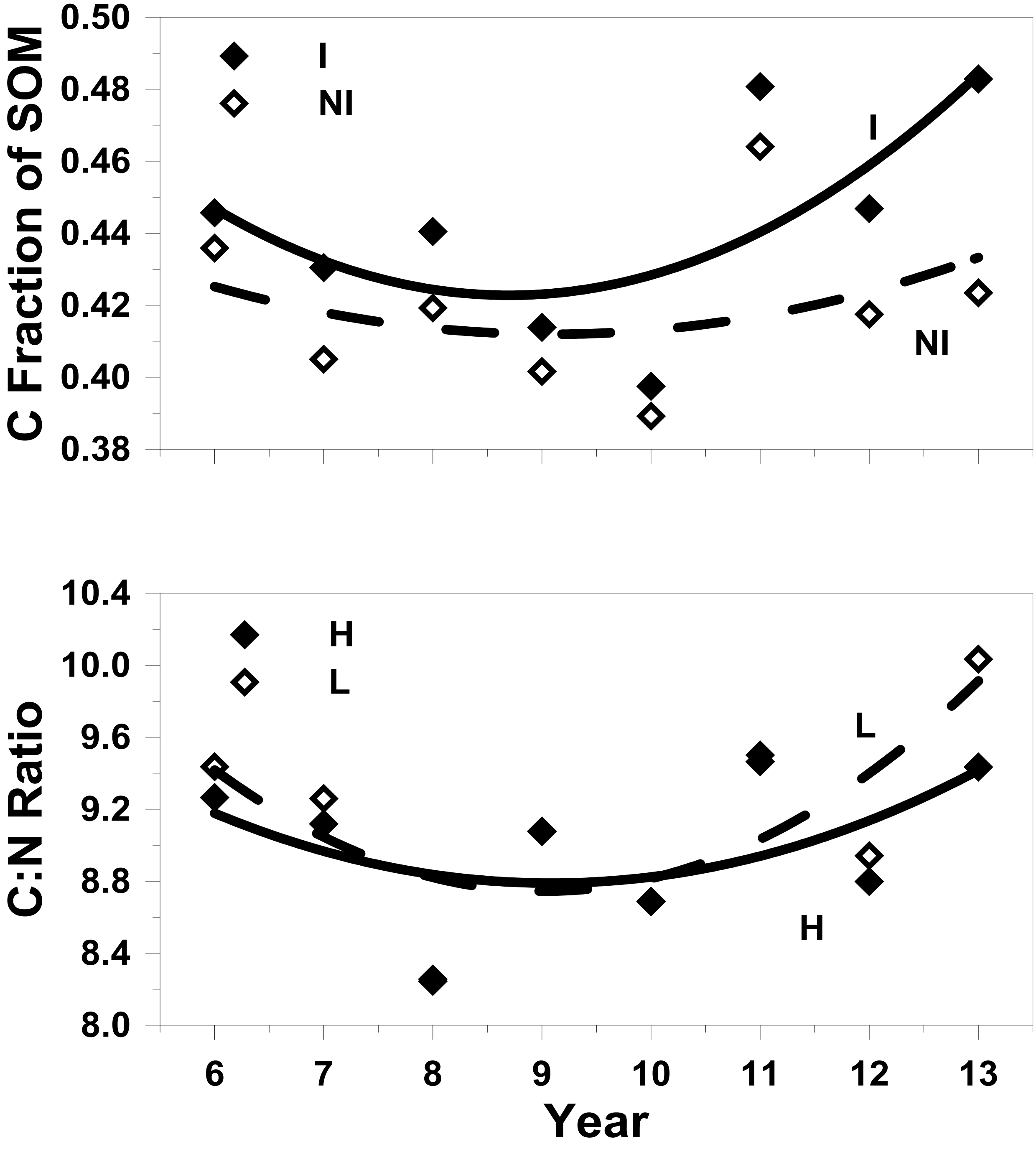

Fig. 5 Influence of residue-level [high (H) and low (L)], and irrigation [irrigated (I) and non-irrigated (NI)] on the trend in carbon (C) fraction of soil organic matter (SOM) and C:nitrogen (N) ratio in the top 10 cm over time after initial conversion to alternative management practices in a wheat-soybean, double-crop system in eastern Arkansas.

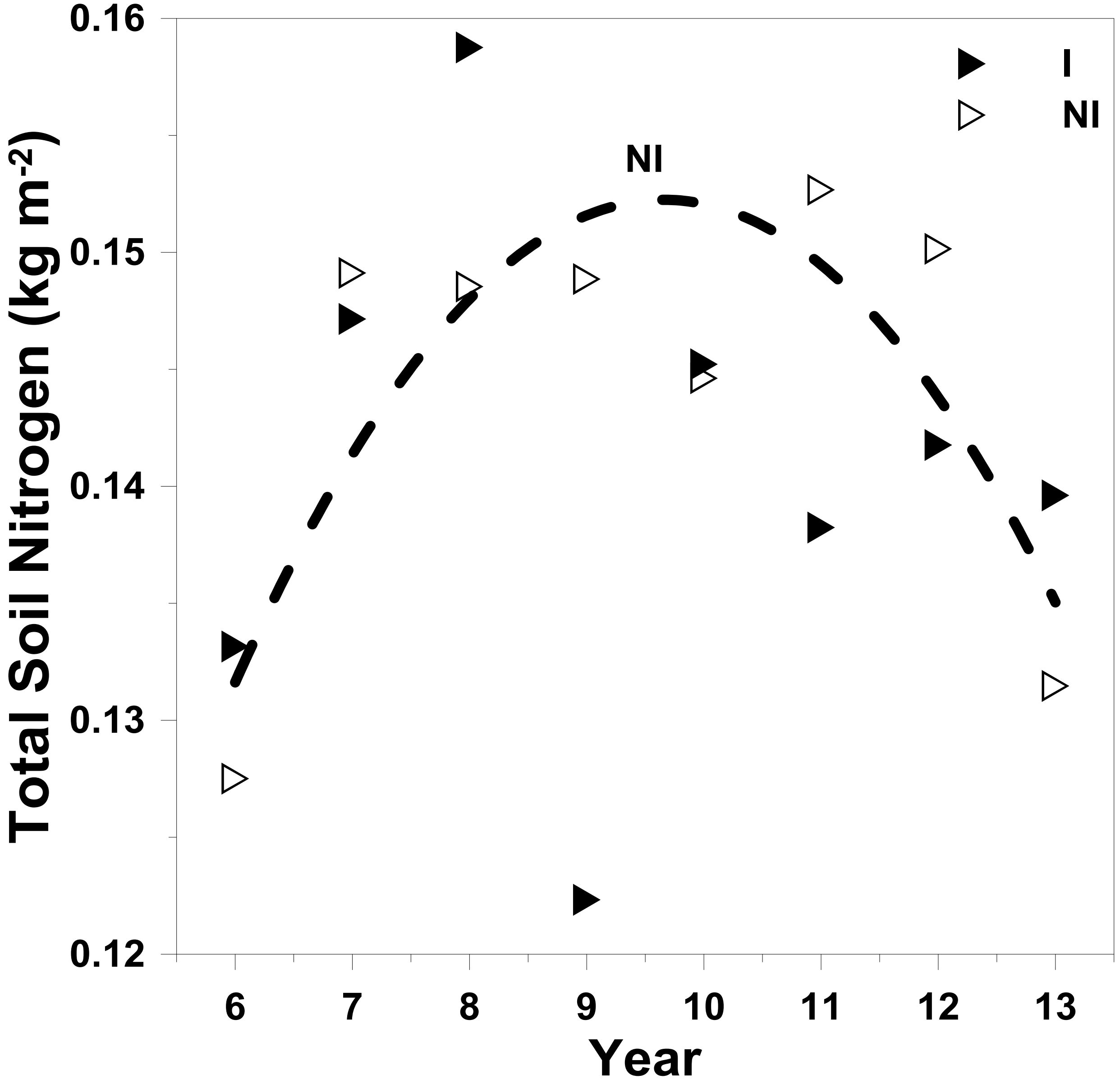

Fig. 6 Influence of irrigation [irrigated (I) and non-irrigated (NI)] on the trend in nitrogen (N) content in the top 10 cm over time after initial conversion to alternative management practices in a wheat-soybean, double-crop system in eastern Arkansas. Soil N content under the irrigated treatment did not differ over time and averaged 0.14 kg m^{-2}.

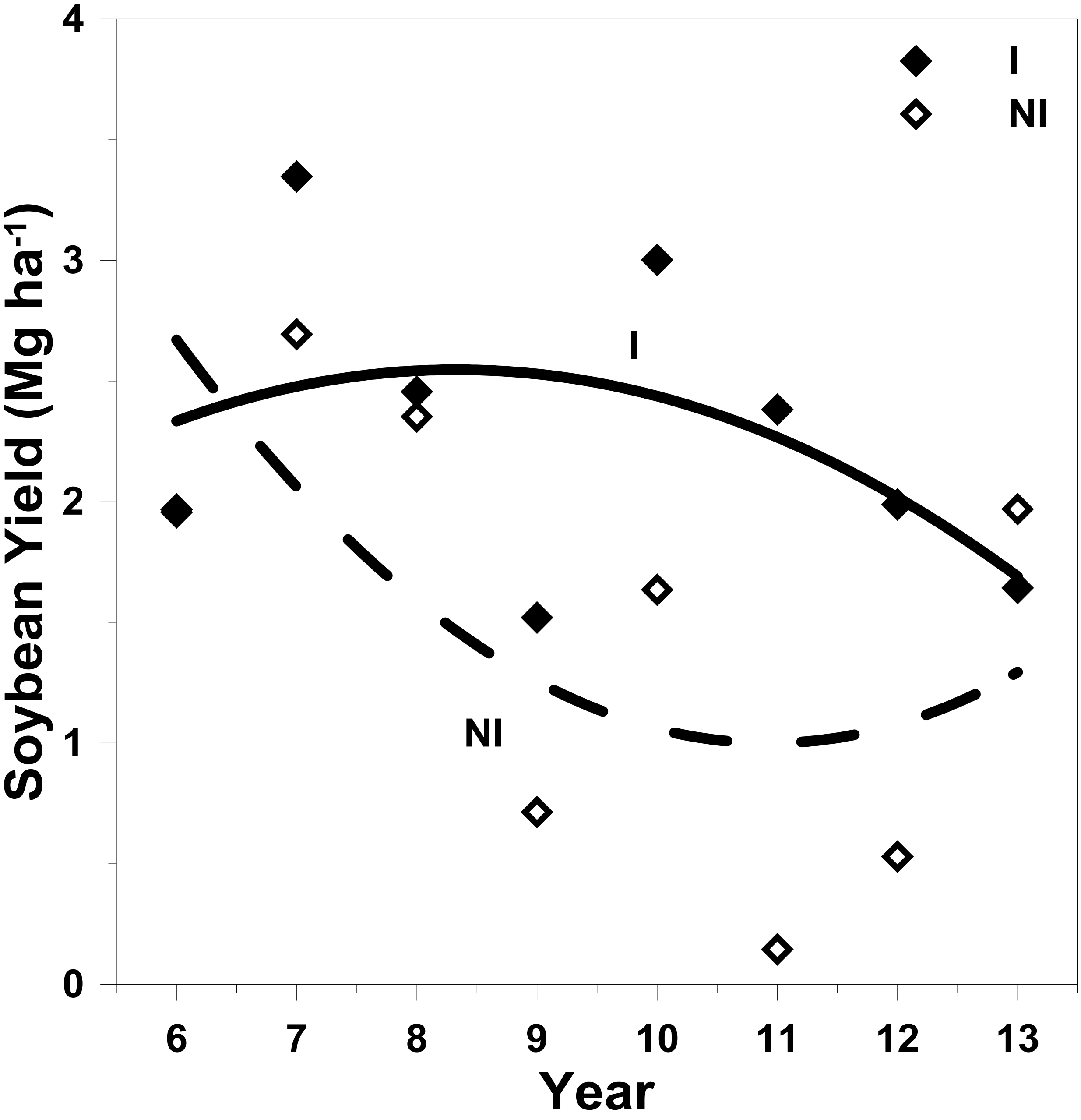

Fig. 7 Influence of irrigation [irrigated (I) and non-irrigated (NI)] on the trend in soybean yield over time after initial conversion to alternative management practices in a wheat-soybean, double-crop system in eastern Arkansas.

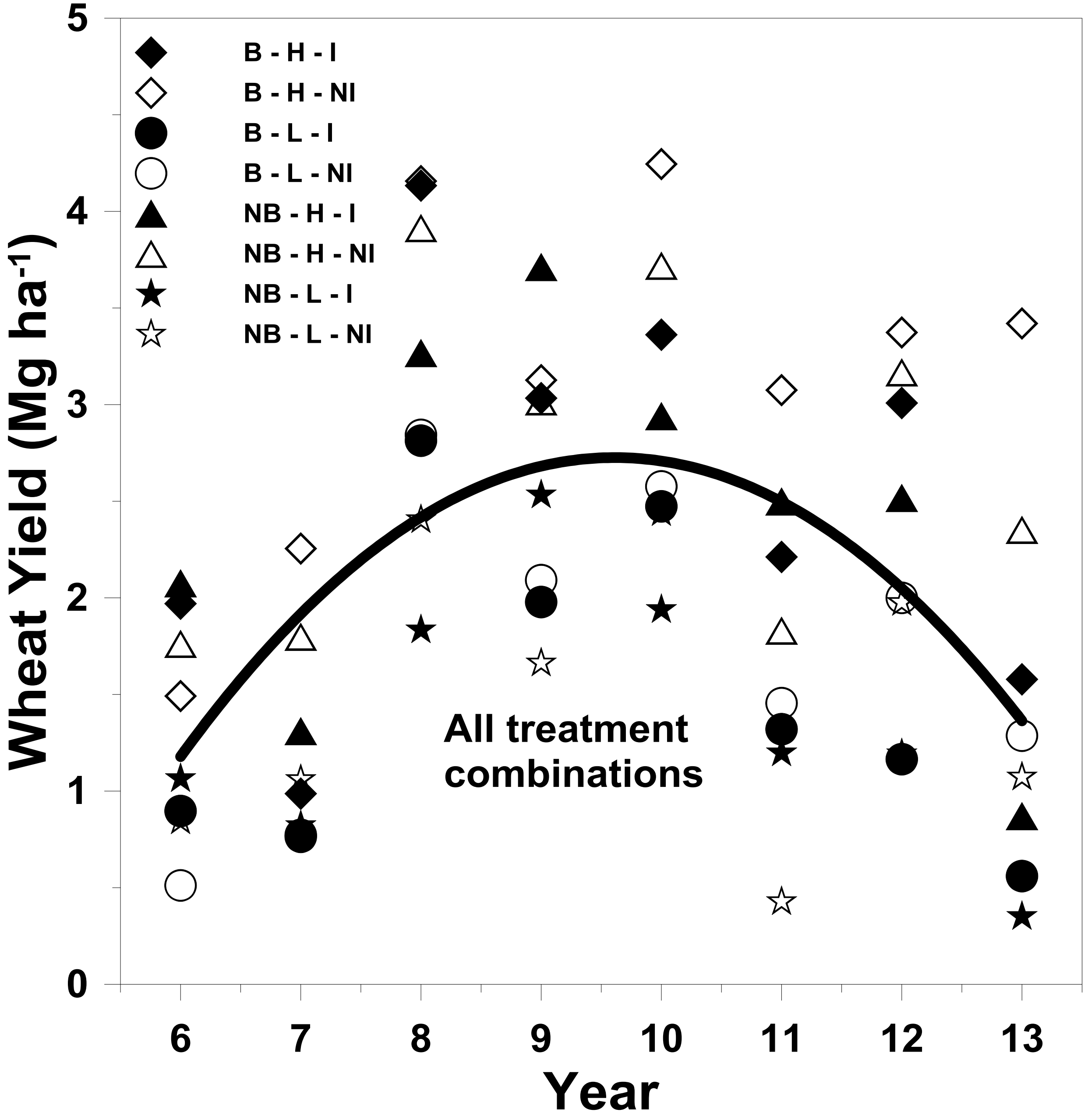

Fig. 8 Influence of burning [burn (B) and no-burn (NB)], residue-level [high (H) and low (L)], and irrigation [irrigated (I) and non-irrigated (NI)] on the trend in wheat yield over time after initial conversion to alternative management practices in a wheat-soybean, double-crop system in eastern Arkansas.

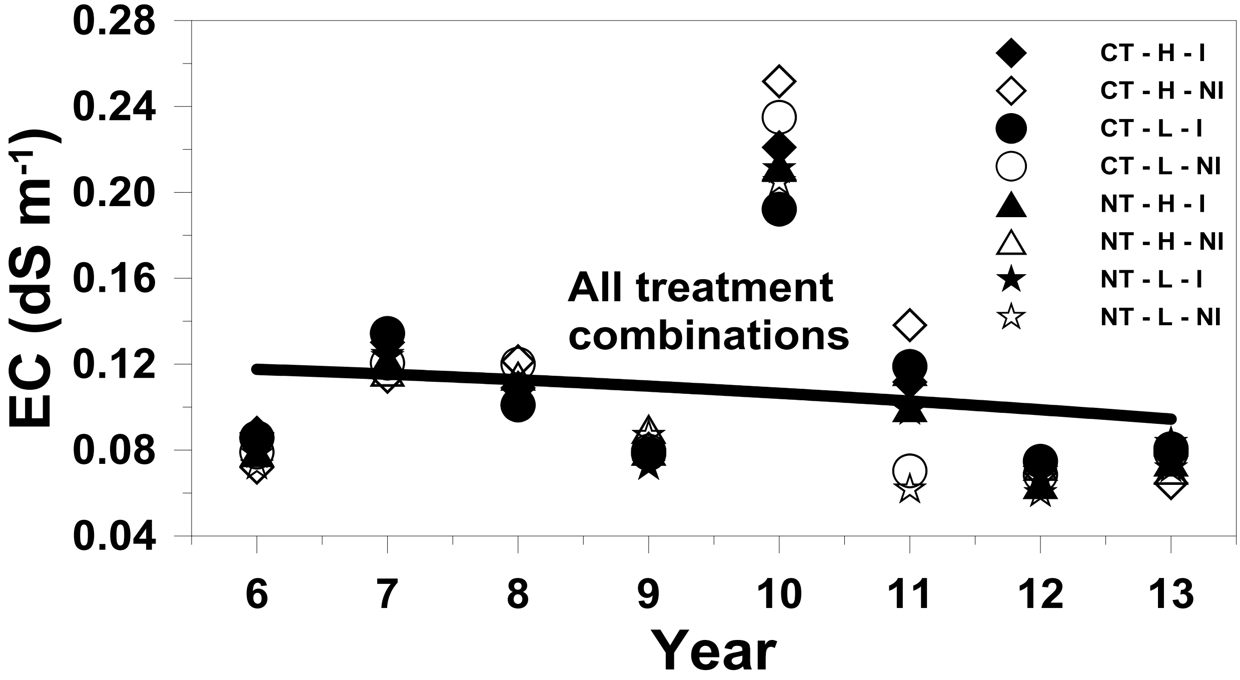

Fig. 9 Influence of tillage [conventional tillage (CT) and no-tillage (NT)], residue level [high (H) and low (L)], and irrigation [irrigated (I) and non-irrigated (NI)] on the trend in electrical conductivity (EC) in the top 10 cm over time after initial conversion to alternative management practices in a wheat-soybean, double-crop system in eastern Arkansas.

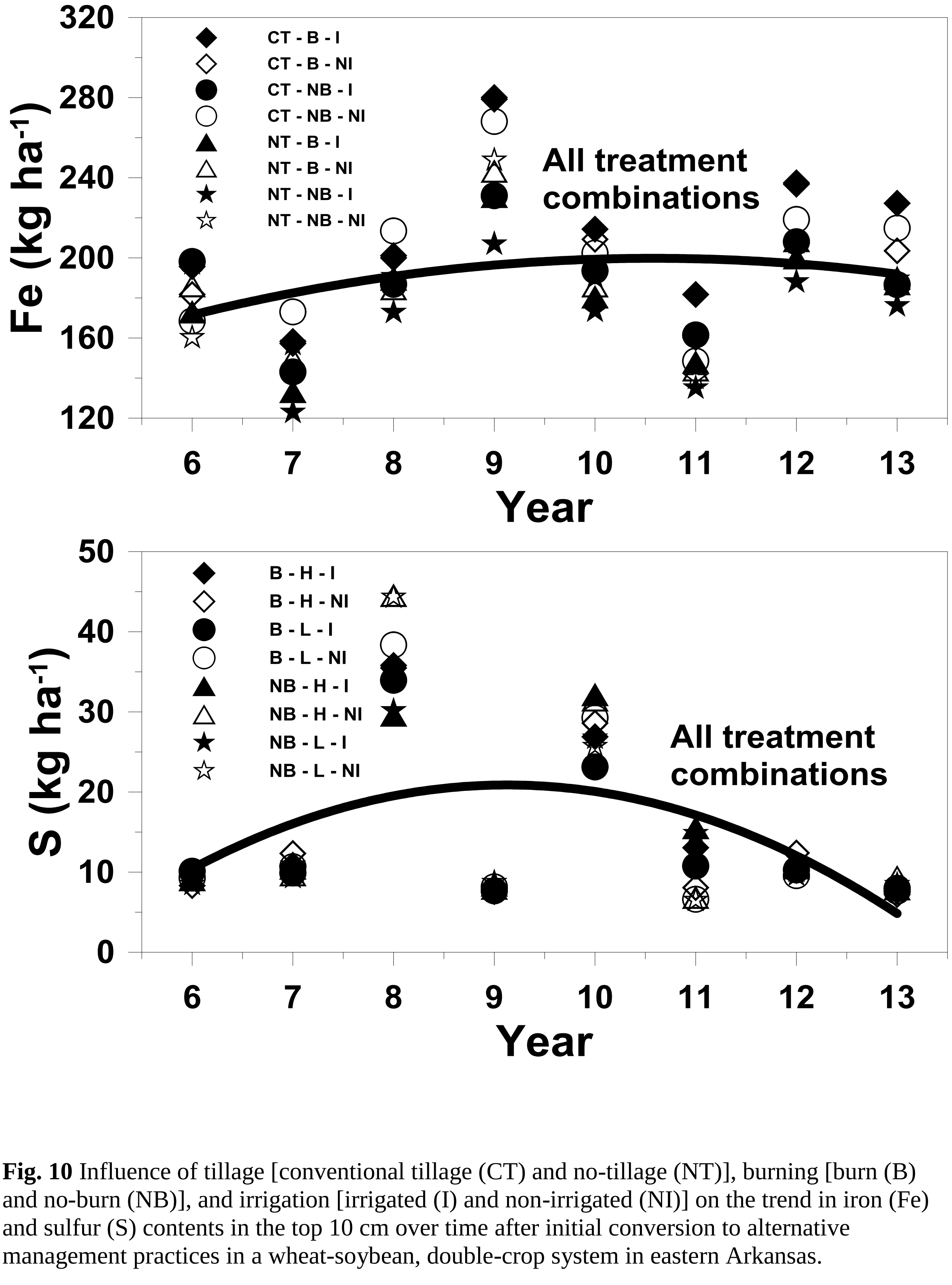

Fig. 10 Influence of tillage [conventional tillage (CT) and no-tillage (NT)], burning [burn (B) and no-burn (NB)], and irrigation [irrigated (I) and non-irrigated (NI)] on the trend in iron (Fe) and sulfur (S) contents in the top 10 cm over time after initial conversion to alternative management practices in a wheat-soybean, double-crop system in eastern Arkansas.

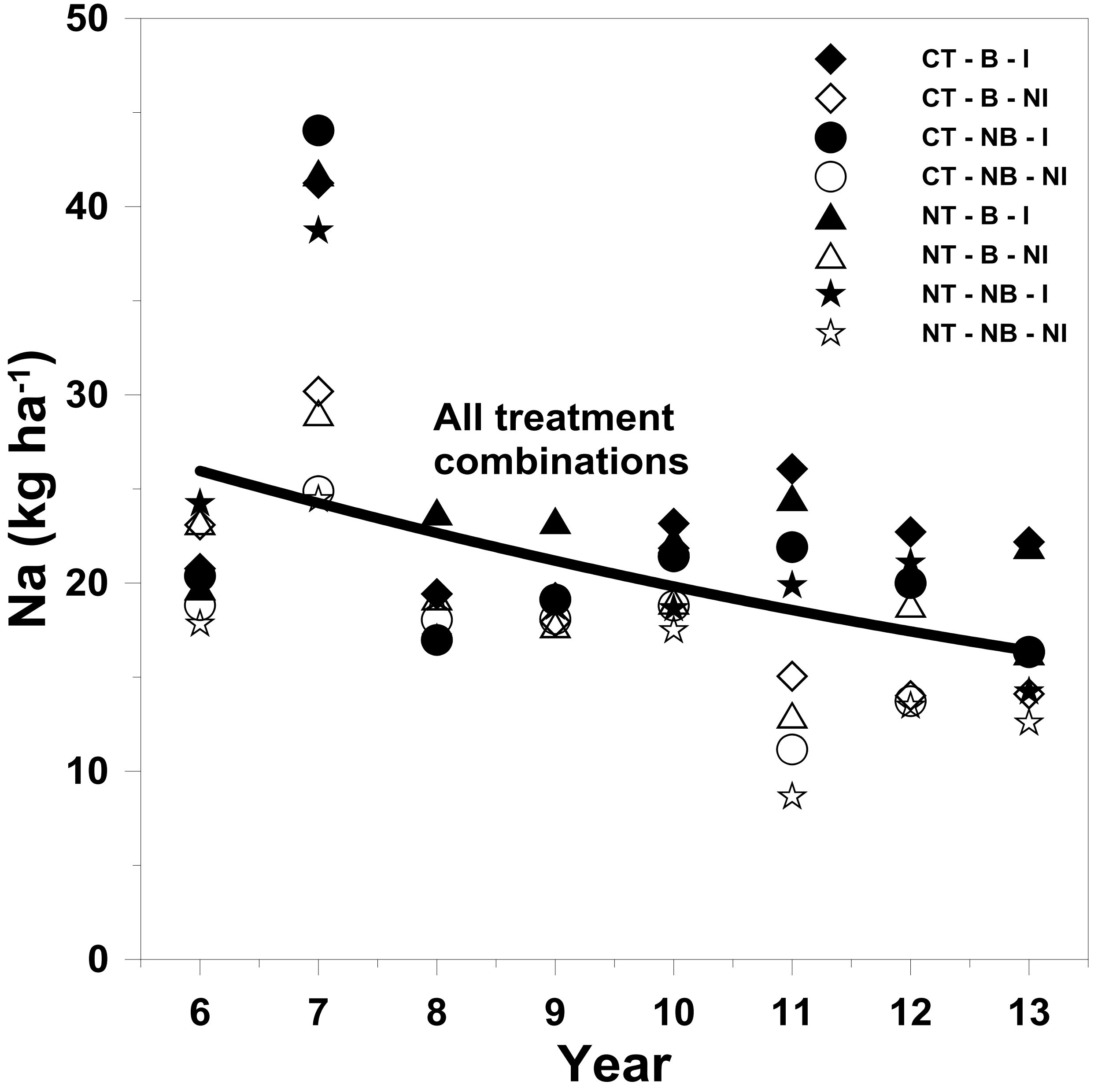

Fig. 11 Influence of tillage [conventional tillage (CT) and no-tillage (NT)], burning [burn (B) and no-burn (NB)], and irrigation [irrigated (I) and non-irrigated (NI)] on the trend in sodium (Na) content in the top 10 cm over time after initial conversion to alternative management practices in a wheat-soybean, double-crop system in eastern Arkansas.

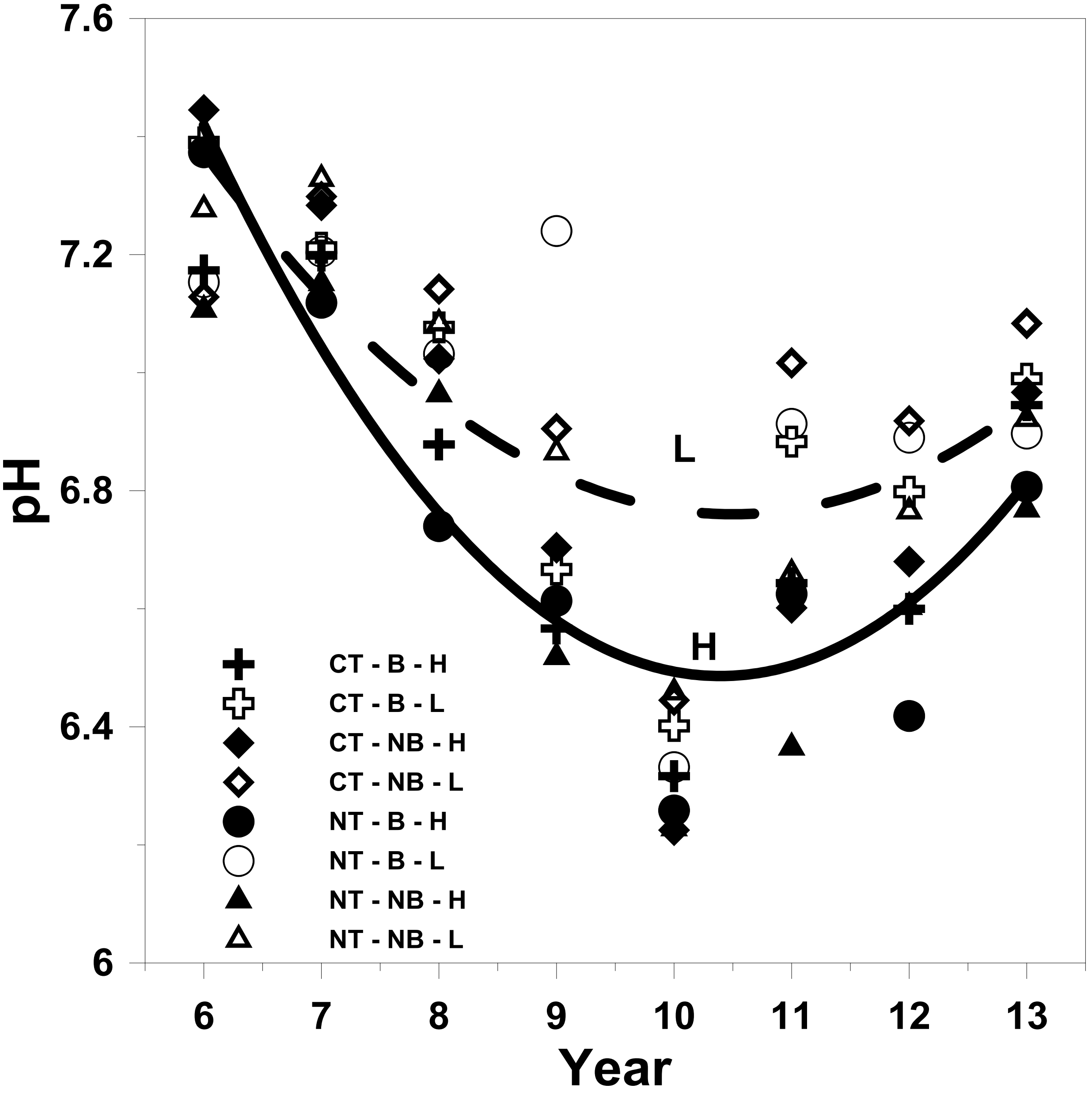

Fig. 12 Influence of tillage [conventional tillage (CT) and no-tillage (NT)], burning [burn (B) and no-burn (NB)], and residue level [high (H) and low (L)] on the trend in pH in the top 10 cm over time after initial conversion to alternative management practices in a wheat-soybean, double-crop system in eastern Arkansas.

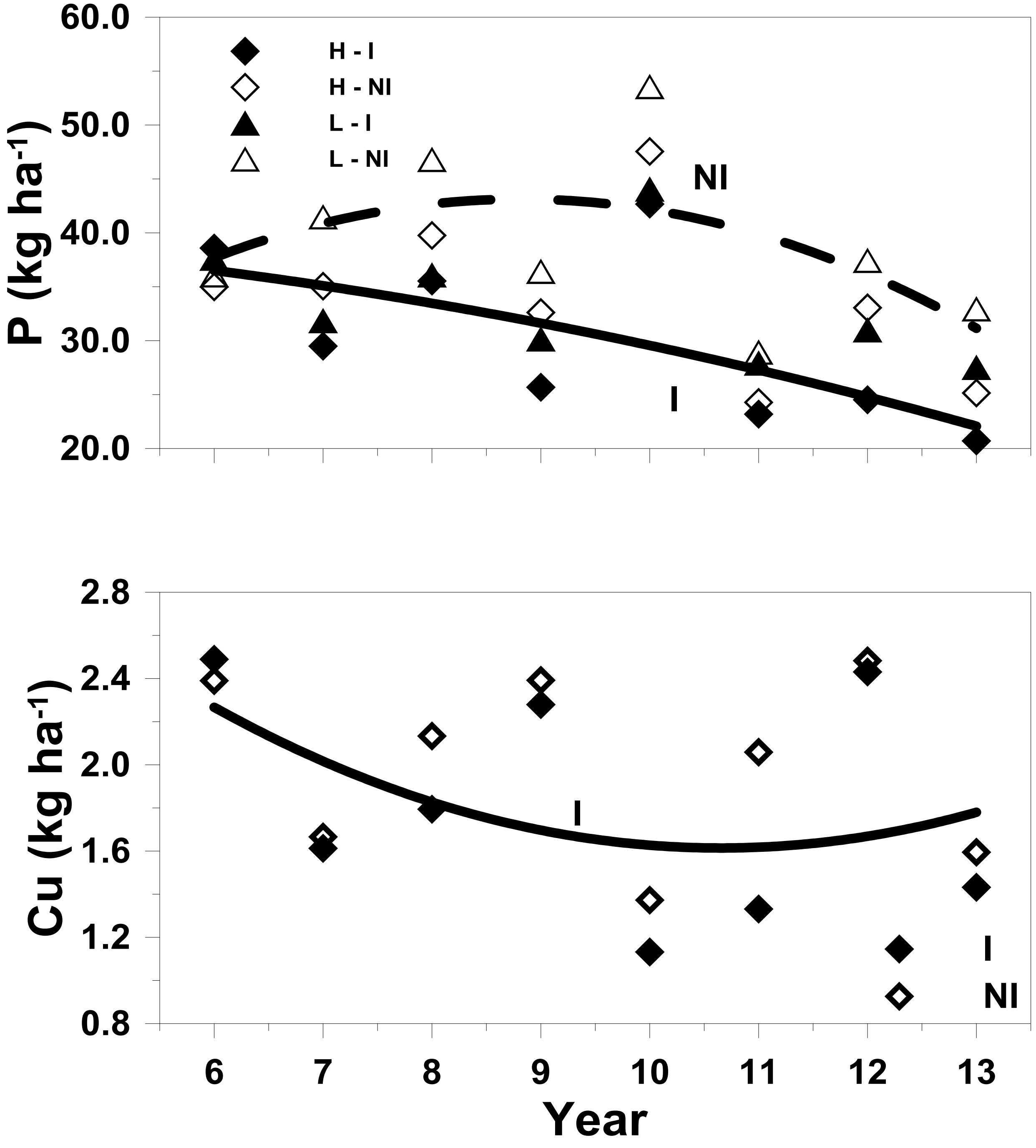

Fig. 13 Influence of residue level [high (H) and low (L)] and [and irrigation [irrigated (I) and non-irrigated (NI)] on the trend in phosphorus (P) and copper (Cu) contents over time after initial conversion to alternative management practices in a wheat-soybean, double-crop system in eastern Arkansas. Soil Cu content under the non-irrigated treatment did not differ over time and averaged 2.01 kg ha^{-1}.

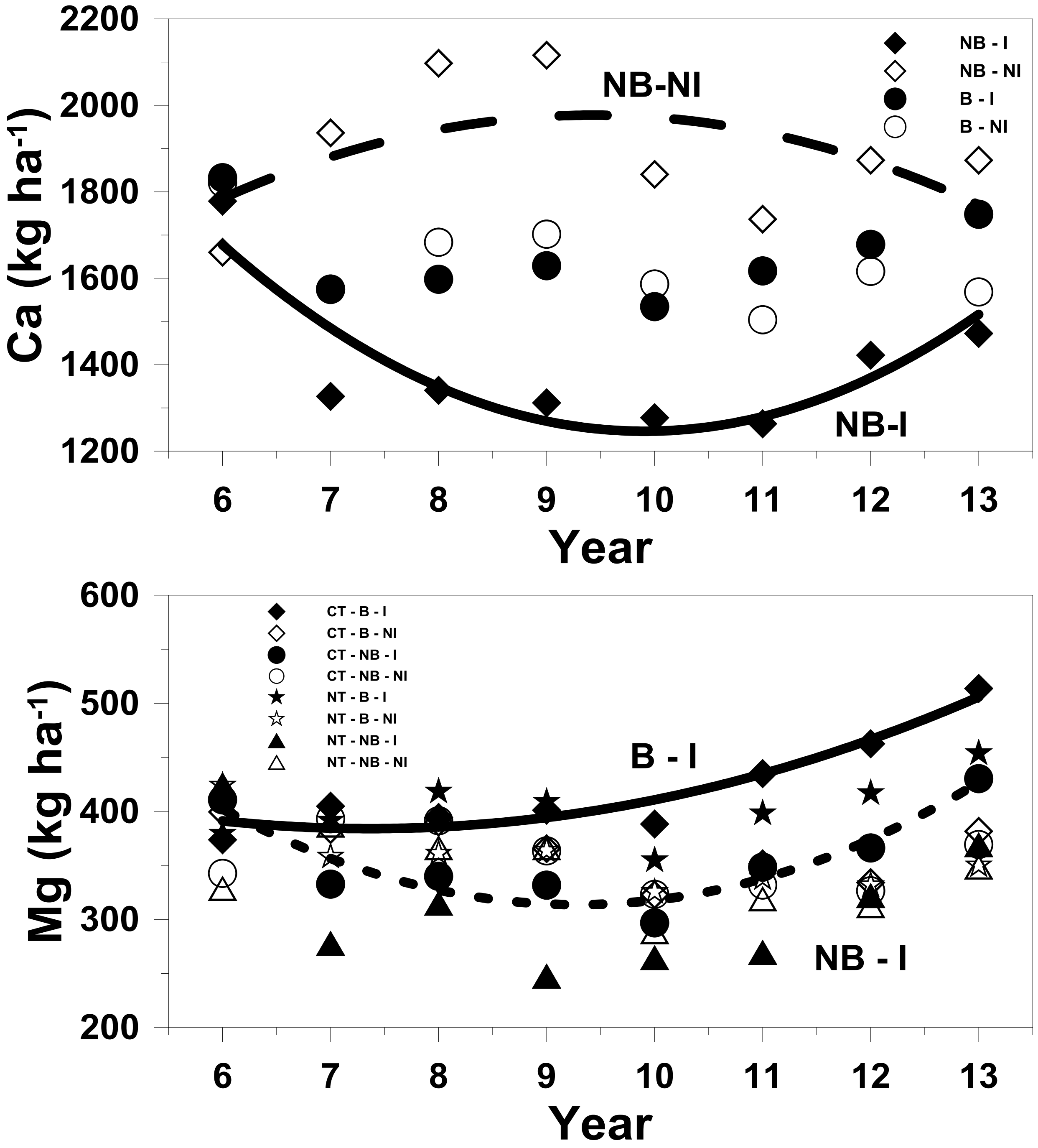

Fig. 14 Influence of burning [burn (B) and no-burn (NB)] and irrigation [irrigated (I) and non-irrigated (NI)] on the trend in calcium (Ca) and magnesium (Mg) contents in the top 10 cm over time after initial conversion to alternative management practices in a wheat-soybean, double-crop system in eastern Arkansas.

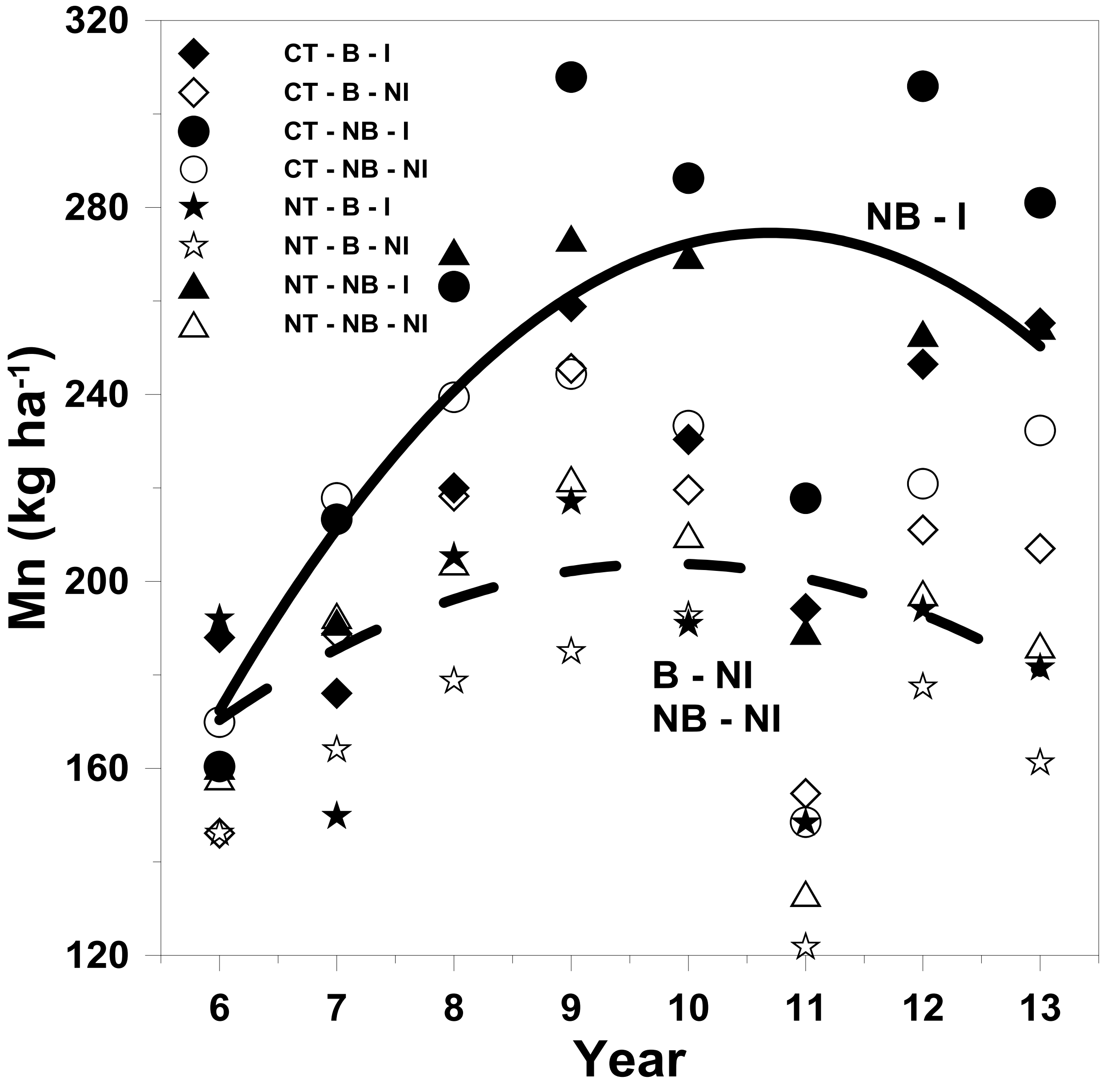

Fig. 15 Influence of tillage [conventional tillage (CT) and no-tillage (NT)], burning [burn (B) and no-burn (NB)], and irrigation [irrigated (I) and non-irrigated (NI)] on the trend in manganese (Mn) content in the top 10 cm over time after initial conversion to alternative management practices in a wheat-soybean, double-crop system in eastern Arkansas.

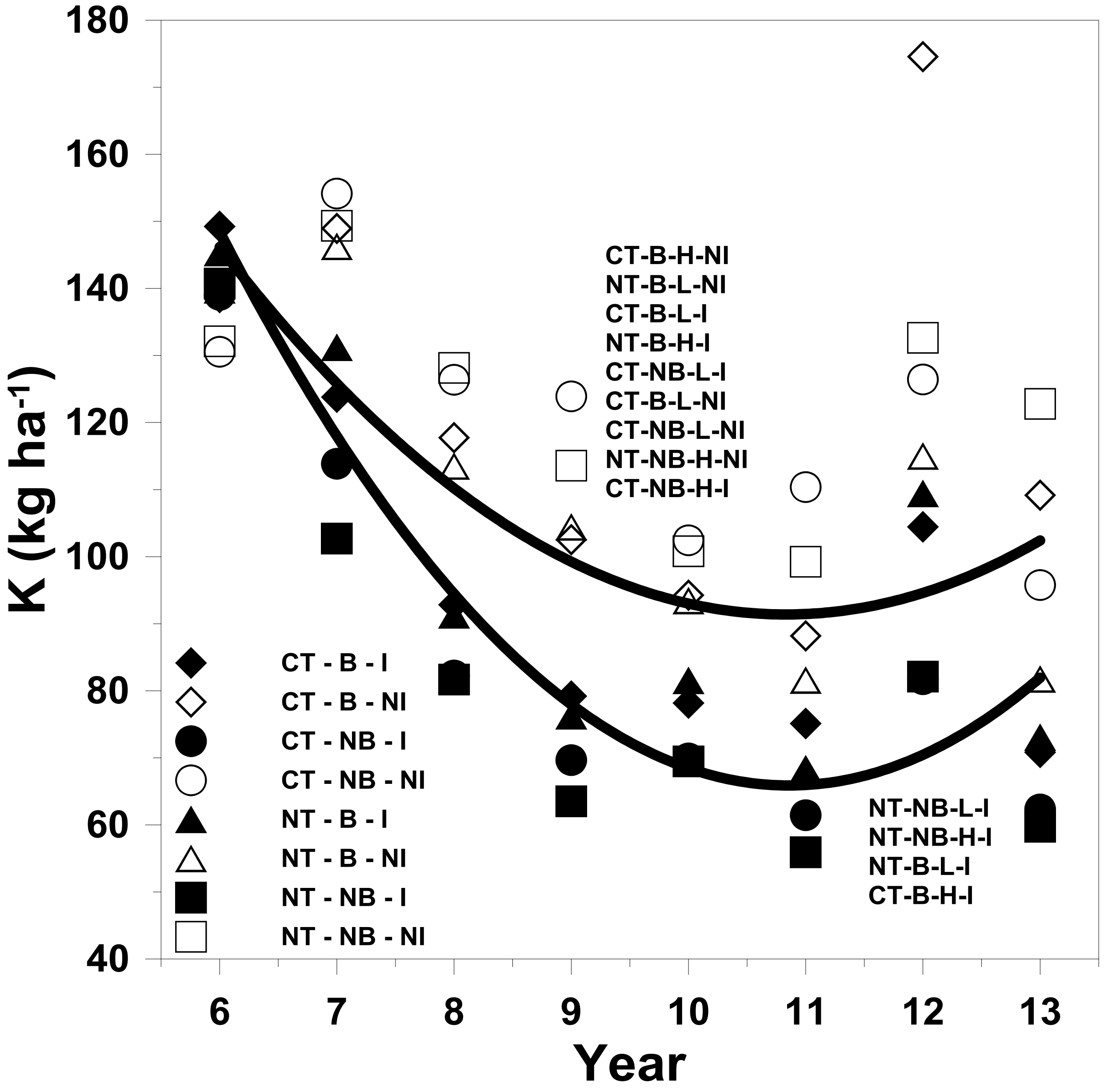

Fig. 16 Influence of tillage [conventional tillage (CT) and no-tillage (NT)], burning [burn (B) and no-burn (NB)], and irrigation [irrigated (I) and non-irrigated (NI)] on the trend in potassium

(K) in the top 10 cm over time after initial conversion to alternative management practices in a wheat-soybean, double-crop system in eastern Arkansas.

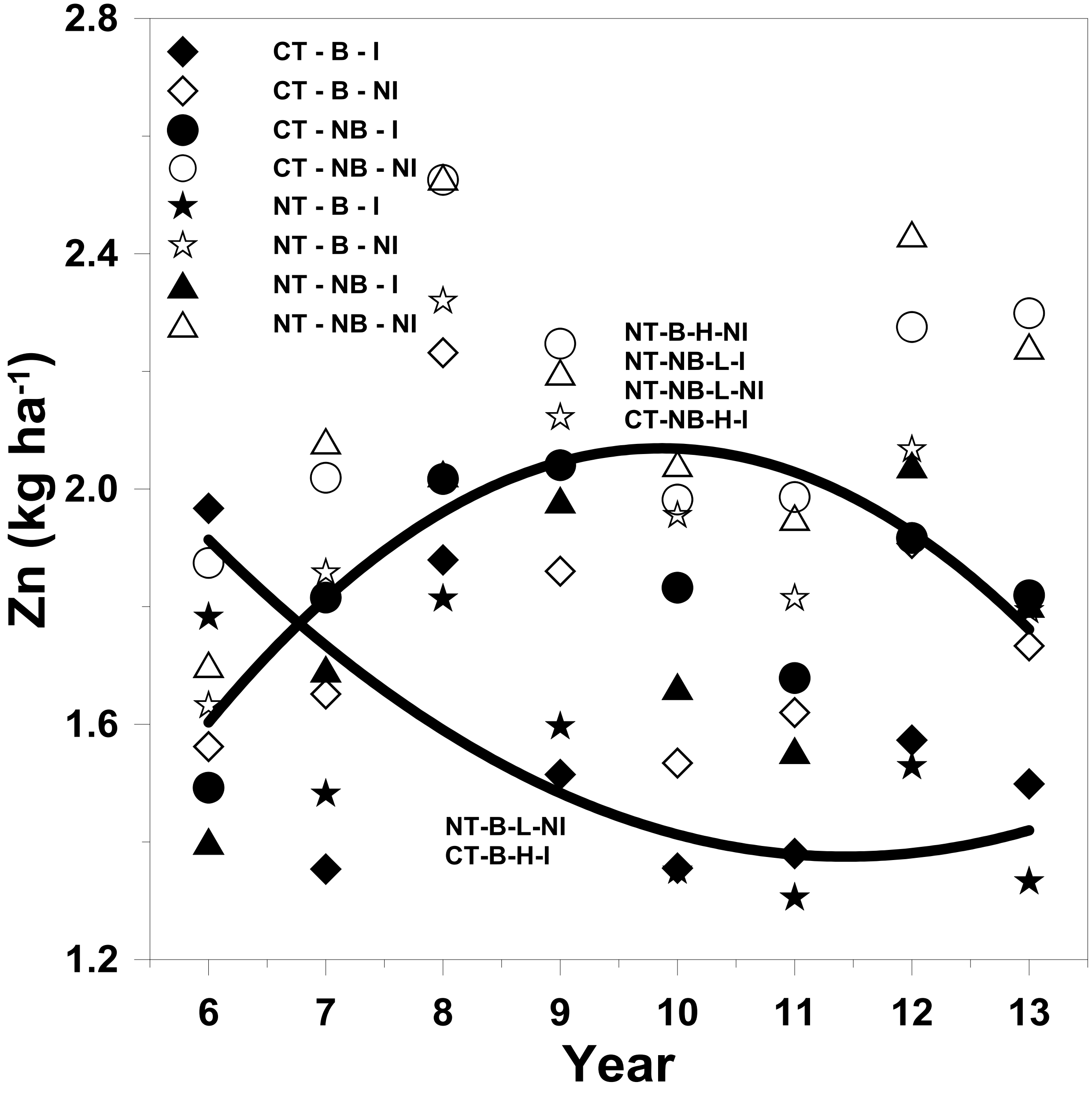

Fig. 17 Influence of tillage [conventional tillage (CT) and no-tillage (NT)], burning [burn (B) and no-burn (NB)], residue level [high (H) and low (L)], and irrigation [irrigated (I) and non-irrigated (NI)] on the trend in zinc (Zn) in the top 10 cm over time after initial conversion to alternative management practices in a wheat-soybean, double-crop system in eastern Arkansas.

Chapter 3

Long-term Effects of Alternative Residue Management Practices on Soil Water Retention in a Wheat-soybean, Double-crop System in Eastern Arkansas

Abstract

Soil water retention characteristics are a critical aspect of agricultural management, especially in areas such as the delta region of eastern Arkansas that face potential water shortages in the near future. Previous studies have linked changes in soil water retention characteristics to agricultural management practices, especially as they affect the accumulation of soil organic matter (SOM). Therefore, the objective of this study was to determine the relationship between soil water potential and gravimetric soil water content in the top 7.5 cm as affected by residue burning (burning and non-burning), tillage (conventional and no-tillage), irrigation (irrigated and non-irrigated), and nitrogen (N)-fertilization/residue level (high and low) in a wheat (*Triticum aestivum* L.)-soybean [*Glycine max* (L.) Merr.], double-crop production system in eastern Arkansas using soil wetting curves. The field site has been consistently managed for 13 years at the University of Arkansas Lon Mann Cotton Research Station near Marianna, Arkansas on a Calloway silt-loam (fine silty, mixed, active, thermic Glossaquic Fraglossudalf). The slope terms characterizing the relationship between the natural logarithm of the soil water potential and the gravimetric soil water content was only affected ($P < 0.05$) by the N-fertilization/residue level treatment, and the intercept terms were statistically similar across all treatment combinations. Averaged across tillage, burning, and irrigation, the soil water contents under the high- exceeded those under low-N-fertilization/residue level treatment at the same water potential, with the greatest differences observed at the largest water contents (i.e., > 0.12 g g^{-1}). Nitrogen-fertilization/residue level differences indicated greater soil water retention under the high- than the low-residue treatment, possibly as a result of increased biomass inputs, SOM accumulation, and soil aggregation. Understanding the ways in which alternative residue management practices affect soil water retention characteristics is an important component of

conserving irrigation water resources.

Introduction

Management practices that promote formation of soil organic matter (SOM) and soil aggregation, such as reduced tillage and diversifying crop rotations, can increase plant available water in the soil (Nielson et al., 2002) and likely have many more positive, long-term effects on soil water characteristics. For example, significant differences have been observed for soil moisture release curves for the top 10 cm between native prairie (SOM = 22 g kg^{-1}) and cultivated agricultural soil (SOM = 10.8 g kg^{-1}) in eastern Arkansas (Brye, 2003). Specifically, the native prairie soil contained a greater soil water content than the cultivated agricultural soil at the same water potential, indicating a possible correlation between increased SOM and water retention. Similarly, decreased soil water retention under conventional tillage (CT) management was reported compared to increased soil water retention and unsaturated hydraulic conductivity under no-tillage (NT) management in a continuous corn (*Zea mays* L.) study on Mollisols in Iowa (Hill et al., 1985). Verkler et al. (2009) reported a slower dry-down of soil under non-burned management compared to burning management, as well as a slower dry-down of soil under NT compared to CT when examining soil water content dynamics in a wheat (*Triticum aestivum* L.)-soybean [*Glycine max* (L.) Merr.], double-crop system on a silt-loam soil in eastern Arkansas after three years and four complete cropping cycles. Clearly, residue and field management practices influence soil water retention characteristics, which may be related to agricultural management effects on soil aggregation and SOM.

Increases in SOM have been associated with increased infiltration, greater hydraulic conductivity, and increased water retention (Azooz and Arshad, 1996). Therefore, management practices such as tillage and nitrogen (N)-fertilization that may affect the accumulation of SOM may also affect soil water retention characteristics. In a previous study of alternative residue management practice effects on near-surface soil properties in a wheat-soybean, double-crop production system on a silt-loam soil in eastern Arkansas, Amuri et al. (2008) reported increasing soil carbon (C) and SOM over time in the top 10 cm across all treatment combinations over the course of six years and seven complete wheat-soybean cropping cycles following conversion to alternative management practices, likely due to the increase in crop residue returned to the soil as a result of conversion from monoculture soybean prior to double cropping. Smith et al. (2014) reported that the abundance of water-stable aggregates was affected ($P < 0.05$) by tillage, irrigation, and N-fertilization treatments. Nitrogen-fertilizer promotes wheat biomass, which may eventually contribute to an increase in SOM and soil aggregation. Therefore, N-fertilization, and other management practices that promote SOM and soil aggregation, may affect the relationship between soil water content and the soil water potential. For example, Bowman and Halvorson (1998) reported significant increases in soil organic C (SOC), and therefore SOM, in the top 5 cm under increased N-fertilization management. Similarly, SOC and SOM increased at a greater rate under a high (134 kg N ha^{-1} yr^{-1}) than under low N-rate treatment in a wheat-containing rotation managed consistently for 10 yr near Akron, Colorado (Halvorson et al., 1999).

An understanding of soil water retention characteristics is critical to determining best management practices, especially in areas such as eastern Arkansas that face potential water shortages in the future. Scott et al. (1998) used a regression equation based on annual water use rate to determine that 75% of the Alluvial Aquifer, the shallowest aquifer underlying most of the delta region eastern Arkansas, will be depleted due to irrigation use by 2041. Therefore, the objective of this study was to determine the relationship between soil water potential and gravimetric soil water content in the top 7.5 cm as affected by residue burning (burning and non-burning), tillage (conventional and no-tillage), irrigation (irrigated and non-irrigated), and N-fertilization/residue level (high and low) in a wheat-soybean, double-crop production system in eastern Arkansas using soil wetting curves. It was hypothesized that tillage would strongly affect the relationship between soil water potential and soil water content in the top 7.5 cm, such that when soil water potentials for CT and NT were equal, the NT soil water content would be greater compared to that for CT.

Materials and Methods

Site Description

A field study was initiated in Fall 2001 at the University of Arkansas Lon Mann Cotton Research Station (N34°, 44', 2.26"; W90°, 45' 51.56"; Cordell et al., 2007) in the Southern Mississippi Alluvium [Major Land Resource Area (MLRA) 131A], which is located along the Mississippi River alluvial plain. The relief in most of the region is less than 5 m (USDA, 2006), and topography tends to be level to depressional to gently undulating plains (USDA, 2006). The 30-yr mean air annual temperature of the region is 15.6°C and the 30-yr mean annual precipitation is 128 cm (NOAA, 2002). The 30-yr mean maximum and minimum air temperatures of the region are 32.8°C in July and 2.4°C in January, respectively (NOAA, 2002). The fertile alluvial sediments, relatively flat topography, and relatively warm and wet climate of MLRA 131A make for a highly agriculturally productive region. The site of this field study is on a Calloway silt loam (fine silty, mixed, active, thermic Glossaquic Fraglossudalf; Gray, 1977; NRCS, 2015), which has 16% sand, 73% silt, and 11% clay in the top 10 cm (Brye et al., 2006). The current study on this site was preceded by several other studies analyzing a variety of short- and long-term effects of alternative management practices effects on plant and soil physical and chemical properties (Amuri et al., 2008; Verkler et al., 2009; Smith et al., 2014).

Experimental Design

Originally, the study utilized a three-factor, split-strip-plot, randomized complete block experimental design with six replications of each of eight treatment combinations (Cordell et al., 2007). The three factors were i) N-fertilization/residue level (high N-fertilization/residue level, achieved with a split application of N fertilizer, or low N-fertilization/residue level, achieved with minimal to no N additions); ii) burning of residue (burning or non-burning); and iii) tillage (CT or NT) (Cordell et al., 2007). However, an irrigation factor was introduced in 2005 and divided the site into two irrigated (I) and two non-irrigated blocks (Verkler et al., 2009). Since 2005, the experimental area has consisted of 48, 3- x 6-m plots with six replications for every tillage-burning-residue-level combination and three replications for every tillage-irrigation-burning-residue level combination (Fig. 1; Amuri et al., 2008).

Field Management

Prior to the initiation of the study, the site was managed as a continuous, mono-cropped soybean system using CT (Cordell et al., 2007). Initial field preparations in Fall 2001 involved disking twice followed by broadcast applications of N, phosphorous, potassium, and pelletized limestone at rates of 20, 22.5, 56, and 1120 kg ha^{-1}, respectively, prior to wheat planting. Wheat was drill seeded with a 19-cm row spacing each Fall. All plots were manually broadcast fertilized in early March 2002 through 2004 with urea (46% N) at the rate of 101 kg N ha^{-1}. High-residue plots (n = 24) were manually broadcast fertilized in late March at approximately the late-jointing stage with an additional 101 kg N ha^{-1} to produce different levels of wheat residue. No N-fertilizer was applied in Spring 2005 due to a failure to establish wheat stands caused by prolonged wet soil conditions in Fall 2004. Since 2006, initial application of 56 kg N ha^{-1} as urea were broadcast on high N-fertilization/residue level plots in approximately late February, followed by a split application of an additional 56 kg N ha^{-1} at the late-jointing stage in approximately late March. Since 2006, the low-residue plots have not received any N fertilization in order to achieve the residue-level difference.

Wheat was harvested using a plot combine in approximately early June each year. Wheat residue left behind the plot combine was uniformly spread by hand over each plot immediately following wheat harvest. Any remaining wheat stubble was mowed with a rotary mower to a height of ~ 3 cm from the soil surface in order to achieve a uniform residue-covered surface for soybean planting. Following mowing, the burning treatment was executed on half of the plots by propane flaming. The residue-burning treatment was not able to be imposed in 2005, 2007, and 2012 due to the absence of a wheat stand in Spring 2005, prolonged wet soil conditions in Spring 2007, and weedy conditions in 2012. Imposition of the burning treatment was followed by imposing the tillage treatment each year. The CT plots were disked at least twice with a tandem disk to a depth of ~ 10 cm followed by seedbed smoothing with at least three passes of a soil conditioner, which is representative of widely used pre-soybean-planting tillage operations in the region.

A glyphosate-resistant soybean cultivar, maturity group 5.3 or 5.4, was drill-seeded with 19-cm row spacing at a rate of approximately 47 kg seed ha^{-1} in approximately mid-June each year. Potassium fertilizer was applied according to recommended rates (UACES, 2000) when the previous year’s soil test indicated potassium was needed. In 2002 through 2004, all plots were furrow-irrigated as needed, three to four times each soybean-growing season. A levee was created in 2005 to exclude furrow-irrigation water from the non-irrigation treatment, which received only natural rainfall. Weeds and insects were managed consistently throughout the entire study area as necessary based on University of Arkansas Cooperative Extension Service recommendations, which generally consisted of herbicide and insecticide applications during both the wheat- and soybean-growing seasons (UACES, 2000). Soybean were harvested with a plot combine from late October to early November each year. Each year from May to June, the wheat crop was sown into the soybean residue, which was left in place.

Soil Sample Collection and Processing

To assess field treatment effects on the relationship between soil water potential and soil water content, in May 2014, 12, ~ 2-cm diameter soil samples were collected from each plot from the top 7.5 cm and combined into one sample per plot. Each sample was manually homogenized and air-dried for approximately 5 d, ground, and sieved to pass through a 2-mm mesh screen. Subsamples were weighed, oven-dried at 70°C for 48 hr, and reweighed to obtain the initial moisture content of the air-dried sample. Following the procedures of Brye (2003), seven, 5 ± 0.01-g subsamples of air-dried soil from each of the 48 plots were added to small mixing cups. Drops of distilled water (i.e., 2, 4, 6, 10, 12, 15, and 20 drops) were added to each of the seven mixing cups with an eyedropper and homogenized with a spatula to achieve a range of soil water contents. The moist soil in each mixing cup was transferred to small plastic instrument cups, 4 cm in diameter by 1 cm tall, and lightly packed to a uniform bulk density of ~ 0.7 g cm^{-3}. Instrument cups were capped and allowed to equilibrate overnight to room temperature (i.e., ~20^{o} C). The water potential was subsequently measured with a WP4 Dewpoint PotentiaMeter (Decagon Devices, Inc., Pullman, WA), which was calibrated using a standard potassium chloride solution. After the water potential was recorded, each instrument cup was weighed, oven-dried at 70°C for 48 hr, then reweighed for gravimetric water content determination.

10 soil cores from the top 10 cm were collected from each plot after wheat harvest and prior to residue burning, and combined into a single composite sample per plot from 2002 until 2008. After 2008, a single soil sample was collected from the top 10 cm instead of 10 soil cores, using a 4.8-cm-diameter stainless steel core chamber. Soil samples were oven-dried for 48 hr at 70^{o}C, ground to pass through a 2-mm mesh screen (Verkler et al., 2009), and analyzed for soil chemical properties (Brye et al., 2006). Total soil C and N were determined by high-temperature combustion with a LECO CN-2000 analyzer (LECO Corp., St. Joseph, MI) or an Elementar VarioMAX Total C and N Analyzer (Elementar Americas Inc., Mt. Laurel, NJ), and all soil C in the top 10 cm was assumed to be organic C given the lack of effervesce upon treatment with dilute hydrochloric acid (HCl) (Brye et al., 2006). Soil C:N ratio was calculated from measured C and N concentrations. Soil OM was determined by weight-loss-on-ignition after 2 hr at 360^{o}C (Schulte and Hopkins, 1996). Soil pH was determined potentiometrically using an electrode in a 1:2 (w/v) soil-to-water solution.

To determine bulk density using mid-season soil samples, soil cores were also collected between approximately 8 and 10 weeks after soybean planting by extracting a single 4.8-cm-diameter soil core from the top 10 cm using the methods outlined by Brye et al. (2006). Soil cores were oven-dried at 70^{o}C for 48 hr and weighed for bulk density determinations.

Statistical Analyses

An analysis of covariance (ANCOVA) was conducted using SAS (version 9.3, SAS Institute, Inc., Cary, NC) to evaluate the long-term effects of residue level, tillage, burning, and irrigation on the relationship between water potential (ψ) and gravimetric water content (θg) from the soil wetting-curve data. While the experimental field design was a strip-split-plot, randomized complete block, the experimental designed was assumed to be completely random with three replications of each of 16 treatment combinations in order to facilitate the ANCOVA. The full ANCOVA model was reduced using a hierarchal principle to remove non-significant terms, and non-significant terms were only included the final model when they participated in higher-order, complex treatment combinations. Original measured water potentials were natural-log transformed to linearize the data and facilitate the ANCOVA. When appropriate, treatment means for linear slopes and intercepts from the log-transformed relationships were separated by least significant difference (LSD) at the 0.05 level.

An analysis of variance (ANOVA) was also conducted, based on the strip-split-plot design of the field treatments (Fig. 1), to evaluate the effects of N-fertilization/residue level, tillage, burning, and irrigation on select soil properties from 2014 associated with soil water retention, i.e., bulk density (g cm^{-3}), pH, SOM, total N and C contents (kg m^{-2}), and C:N ratio, using samples collected from the top 10 cm. Due to practical limitations of the study area, the addition of the irrigation treatment since 2005 was superimposed on the burning treatment (Fig. 1). Therefore, irrigation and burning treatments cannot be simultaneously analyzed within this experimental design. Two separate ANOVAs were conducted, each excluding one of the confounding factors. When appropriate, treatment means were also separated based on LSD at the 0.05 level.

Results and Discussion

Initial Soil Properties

After 13 complete wheat-soybean cropping cycles (i.e., 2001 to 2014) and 12 years of consistent management, soil C and N contents, soil C:N ratio, and soil pH in the top 10 cm were affected ($P < 0.05$) by field treatments. Soil C content ($P = 0.038$) and soil C:N ratio ($P = 0.033$) differed between burn treatments in 2014. Averaged across tillage, N-fertilization/residue level, and irrigation, soil C content averaged 1.22 and 1.42 kg m^{-2}, while the soil C:N ratio averaged 9.23 and 10.2 under burning and non-burning, respectively. Furthermore, soil N content differed ($P = 0.032$) between the N-fertilizer/residue level treatments (Table 1). Averaged across tillage, burning, and irrigation, soil N content averaged 0.14 and 0.13 kg m^{-2} under the high- and low-N-fertilization/residue level treatments, respectively. Similarly, the soil C:N ratio also differed ($P = 0.021$) between the N-fertilizer/residue level treatments (Table 1). Averaged across tillage, burning, and irrigation, the soil C:N ratio averaged 9.44 and 10.0 under the high- and low-N-fertilization/residue level treatments, respectively.

In 2014, soil pH in the top 10 cm differed ($P = 0.021$) between irrigation treatments within N-fertilizer/residue level treatments (Table 1). Averaged across tillage and burning, soil pH was greater under irrigation regardless of N-fertilization/residue level (i.e., soil pH averaged 7.26 under the high and 7.28 under the low N-fertilization/residue level) than that under the dryland treatment, where soil pH averaged 6.67 under the low, which was greater than that under the high N-fertilization/residue level (i.e., pH averaged 6.48). However, all pH values, regardless of management, exceeded the minimum soil pH threshold of 6.0, below which soybean yield reductions can be expected on silt-loam soils in eastern Arkansas (Slaton et al., 2013). Therefore, the differences in soil pH among irrigation and N-fertilization/residue level treatment combinations were agronomically non-significant with regards to soybean production on silt-loam soils in eastern Arkansas.

In contrast to other initial soil properties, after 13 complete wheat-soybean cropping cycles (i.e., 2001 to 2014) and 12 years of consistent management, bulk density and SOM were unaffected ($P > 0.05$) by any of the field treatments imposed in 2014 (Table 1). Therefore, in 2014, averaged across all field treatments, bulk density averaged 1.21 g cm^{-3} [standard error (SE) = 0.01] and SOM content averaged 2.9 kg m^{-2} (SE = 0.06).

Soil Water Retention

As was expected, the relationship between the natural-logarithm-transformed water potential and gravimetric water content followed a curvilinear pattern, where the water potential increased exponentially as gravimetric soil water content increased (Fig. 2). After 13 complete wheat-soybean cropping cycles (i.e., 2001 to 2014) and 12 years of consistent management, the trend in the relationship between the natural logarithm of water potential and gravimetric water content in the top 7.5 cm was affected ($P = 0.007$) by only the N-fertilization/residue level treatment, and was unaffected ($P > 0.05$) by tillage, burning, and irrigation treatments or any interactions (Table 2). Averaged across tillage, burning, and irrigation, the gravimetric soil water content was greater under high- than under low-N-fertilization/residue management at the same water potential (Fig. 3). The greatest differences between high- and low-N-fertilization/residue treatments were observed at the largest water contents (i.e., approximately 0.16 g g^{-1}; Fig. 3). Conversely, as soil water potential under both high- and low-N-fertilization/residue management decreased, gravimetric water contents became increasingly similar under both N-fertilization/residue treatments. These results were similar to the soil moisture characteristic curve results reported by Brye (2003) using a similar wetting-curve approach in which water contents in both native prairie and cultivated agricultural silt-loam soils in eastern Arkansas became increasingly similar as soil water potential approached permanent wilting point (i.e., -1.5 MPa), regardless of field treatments imposed. Verkler et al. (2008) also reported numerically greater maximum soil water contents at the 7.5 cm depth under the high- compared with the low-N-fertilization/residue level treatment, although the differences were statistically non-significant. Management practices that increase the amount of crop residue returned to the soil, such as with greater above- and belowground biomass achieved with differential N fertilization, have been shown to increase infiltration, bulk density, and water storage capacity (Shaver et al., 2002).

Once the water potential data were natural-logarithm-transformed, the relationship with gravimetric soil water content became linearized to facilitate statistical analyses of treatment effects. The intercept terms characterizing the linear relationship between the natural logarithm of water potential and the gravimetric water content under high- and low-N-fertilization/residue management (3.11 and 3.36, respectively) were statistically similar (Table 3). However, the slope terms characterizing the linear relationship between the natural logarithm of water potential and the gravimetric water content under high- and low-N-fertilization/residue management (-39.7 and -45.2, respectively) differed significantly (Table 3). As gravimetric water content increased, the natural logarithm of water potential under the low- decreased ($P < 0.05$) at a significantly greater rate than under the high-N-fertilization/residue management treatment combination (Table 3; Fig. 3). Though N-fertilization/residue level did not affect SOM contents in the top 10 cm in 2014, one possible explanation for the significant effect of N-fertilization/residue level on the relationship between the natural logarithm of water potential and the gravimetric soil water content was that the high-N-fertilization/residue treatment promoted increased soil structure development and SOM more than the low-N-fertilization/residue treatment. While it was concluded in a previous study analyzing soil properties in the same plots used in the current study that N-fertilization/residue level had no obvious, observable effects on the trend in SOM content (kg m^{-2}) in the top 10 cm over time, N-fertilization/residue level did affect ($P < 0.05$) the trend in SOM content over time as part of complex treatment combinations (Norman et al., 2015). Moreover, it is possible that N-fertilization/residue level may have impacted SOM content and soil aggregates in the top 7.5 cm differently than in the top 10 cm, due to the greater accumulation of both above- and below-ground plant biomass concentrated near the soil surface. A previous study analyzing water-stable aggregates in the top 10 cm in the same plots used in the current study reported that the concentration of water-stable aggregates was 11% greater in the top 5 cm than in the 5 to 10 cm depth interval after 7 years of consistent management (Smith et al., 2013), suggesting that SOM and soil aggregates may be more concentrated in the 7.5 cm depth samples used for the current study than in the 10 cm depth samples used for previous studies (i.e., Amuri et al., 2008; Norman et al., 2015). Therefore, it is possible that the N-fertilization/residue level treatment affected the < 2-mm-sized soil aggregates, which may have occluded SOM, in the top 7.5 cm, without clearly and obviously affecting SOM contained in the aggregate size classes larger than 2 mm in the top 10 cm. Such an increase in occluded SOM in smaller aggregates might account for an increase in soil water content (Azooz and Arshad, 1996; Dao, 1993). For example, Brye (2003) reported greater soil water contents in the top 10 cm of a native prairie soil than soil water contents of cultivated agricultural soils at the same water potential, possibly as a result of the greater SOM content in prairie soils (SOM = 22 g kg^{-1}) compared with cultivated agricultural soils (SOM = 10.8 g kg^{-1}).

Tillage, burning, and irrigation treatments had no observable effect ($P > 0.05$; Table 2) on the relationship between the natural logarithm of water potential and the gravimetric soil water content after 12 complete cropping cycles. These results are in contrast with the original hypothesis that tillage would strongly affect the relationship between soil water potential and soil water content, such that soil water content under NT would exceed that under CT at the same water potential. In contrast to these results, other soil moisture characteristic studies have reported significant relationships between cultivation and the near-surface soil water retention characteristics (Azooz and Arshad, 1996; Brye 2003; Hill et al., 1985), likely due to the increased hydraulic conductivity and infiltration rates associated undisturbed and NT soils. Similarly, it might be expected that the burning treatment would affect soil water retention characteristics in the top 7.5 cm due to the near-surface accumulation of ash, which can be hydrophobic. In contrast to these results, Verkler et al. (2008) reported that residue burning significantly affected maximum soil water contents during irrigation events, and that the mean maximum soil water content was 3% (v/v) greater under residue burning compared with non-burning. However, the water content measurements conducted by Verkler et al. (2008) were in situ, i.e., undisturbed, and are therefore fundamentally different from the oven-dried, ground, sieved, and rewetted samples used in the current study.

It is possible that effects of tillage, burning, and irrigation were not be observed due to the sampling and measuring processes, which including oven-drying, grinding, and sieving out all particles greater than 2 mm. Effects which might have been observable in larger, intact soil cores may not have carried over to the < 2-mm-sized, sieved soil particles and aggregates. Tillage, for instance, may destroy larger soil aggregates while leaving smaller aggregates intact, thus leaving an occluded fraction of SOM more protected against oxidation. Therefore, the effects of tillage on certain soil properties associated with water retention characteristics, i.e., SOM and bulk density, may be more apparent in samples using larger, undisturbed cores than in the ground and sieved samples used in the current study. A previous study analyzing soil properties in the same plots as the current study reported that irrigation was the most significant overall treatment factor affecting the change in SOM content (kg m^{-2}) in the top 10 cm over the course of 13 consecutive years following conversion to alternative management practices (Norman et al., 2015). In the current study, irrigation may have affected the accumulation and decomposition of SOM in the top 7.5 cm, but too much variability occurred between irrigation treatments for a statistical relationship to be identified. In contrast, the significant effects of N-fertilization/residue level treatment on the linear relationship between the natural logarithm of water potential and the gravimetric water content suggest that the N-fertilization/residue level treatment affected the accumulation of smaller aggregates and occluded SOM in the < 2-mm-sized aggregates.

Summary and Conclusions

Following conversion to alternative residue and water management practices and after 13 consecutive years (i.e., 2001 to 2014) of management, the N-fertilization/residue level treatment significantly affected the linear relationship between the natural logarithm of water potential and the gravimetric soil water content as determined by soil wetting curves. The water-curve approach was useful to evaluate the various long-term field treatment effects on water retention. Contrary to the original hypothesis, tillage did not affect the same relationship, possibly due in part to the disturbed nature of soil samples used. It can be inferred from this study that differences in N-fertilization/residue level management affect soil water retention characteristics, possibly as a result of the increased soil aggregation and SOM associated with increased crop residue, both above and below ground, under high residue level management. Consideration of soil water retention characteristics is vital to planning out sustainable use of irrigation water, especially in areas such as the Delta region of eastern Arkansas that will face potential water shortages in the near future.

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Table 1. Analysis of variance summary of the effects of residue level (N), tillage (T), and irrigation (I) on soil bulk density (g cm^{-3}), pH, soil organic matter (SOM; kg m^{-2}), total carbon (C; kg m^{-2}), total nitrogen (N; kg m^{-2}), and the C:N ratio in the top 10 cm from spring 2014 in a wheat-soybean, double-crop system in eastern Arkansas.

Source of Variation	Bulk Density	pH	SOM	C	N	C:N
N	ns†	ns	ns	ns	0.032	0.021
T	ns	ns	ns	ns	ns	ns
I	ns	0.023	ns	ns	ns	ns
N*T	ns	ns	ns	ns	ns	ns
N*I	ns	0.021	ns	ns	ns	ns
T*I	ns	ns	ns	ns	ns	ns
N*T*I	ns	ns	ns	ns	ns	ns

† not significant (ns), i.e. $P > 0.05$.

Table 2. Analysis of covariance summary of the effects of residue level (N), burning (B), tillage (T), and irrigation (I) on the linear relationship between the natural logarithm of soil water potential and the gravimetric soil water content in the top 7.5 cm in a wheat-soybean, double-crop system under consistent management for 13 years (i.e., 2001 to 2014) in eastern Arkansas. Non-significant interactions (*P* > 0.05) were removed in the final model, except when non-significant terms participated in higher-order, complex treatment combinations. Water content refers to the linear term.

Intercept term and interactions	*P*	Linear terms and interactions	*P*
		Water Content	< 0.001
N	ns†	N*Water Content	0.007
B	ns	B*Water Content	ns
T	ns	T*Water Content	ns
I	ns	I*Water Content	ns
N*B	ns	N*B*Water Content	ns
N*T	ns	N*T*Water Content	ns
N*I	ns	N*I*Water Content	ns
B*T	ns	B*T*Water Content	ns
B*I	ns	B*I*Water Content	ns
T*I	ns	T*I*Water Content	ns
N*B*T	ns	N*B*T*Water Content	ns
N*B*I	ns	N*B*I*Water Content	ns
N*T*I	ns	N*T*I *Water Content	ns
B*T*I	ns	B*T*I*Water Content	ns
N*B*T*I	ns	N*B*T*I*Water Content	ns

† not significant (ns), i.e. *P* > 0.05.

Table 3. Summary of estimate parameters of specific treatment combinations, i.e. residue-level [high (H) and low (L)], for the linear relationship between the natural logarithm of soil water potential and the gravimetric soil water content in the top 7.5 cm in a wheat-soybean, double-crop system under consistent management for 13 years (i.e., 2001 to 2014) in eastern Arkansas. Coefficient estimates with the same lower case letter do not differ (*P* > 0.05).

Significant regression term†	Treatment combination	Coefficient estimate	*P*†
Intercept	H	3.108 a	< 0.001
	L	3.357 a	0.002
Linear	H	-39.712 a	< 0.001
	L	-45.207 b	0.001

† *P* < 0.05 indicates coefficient estimate was significantly different from 0.

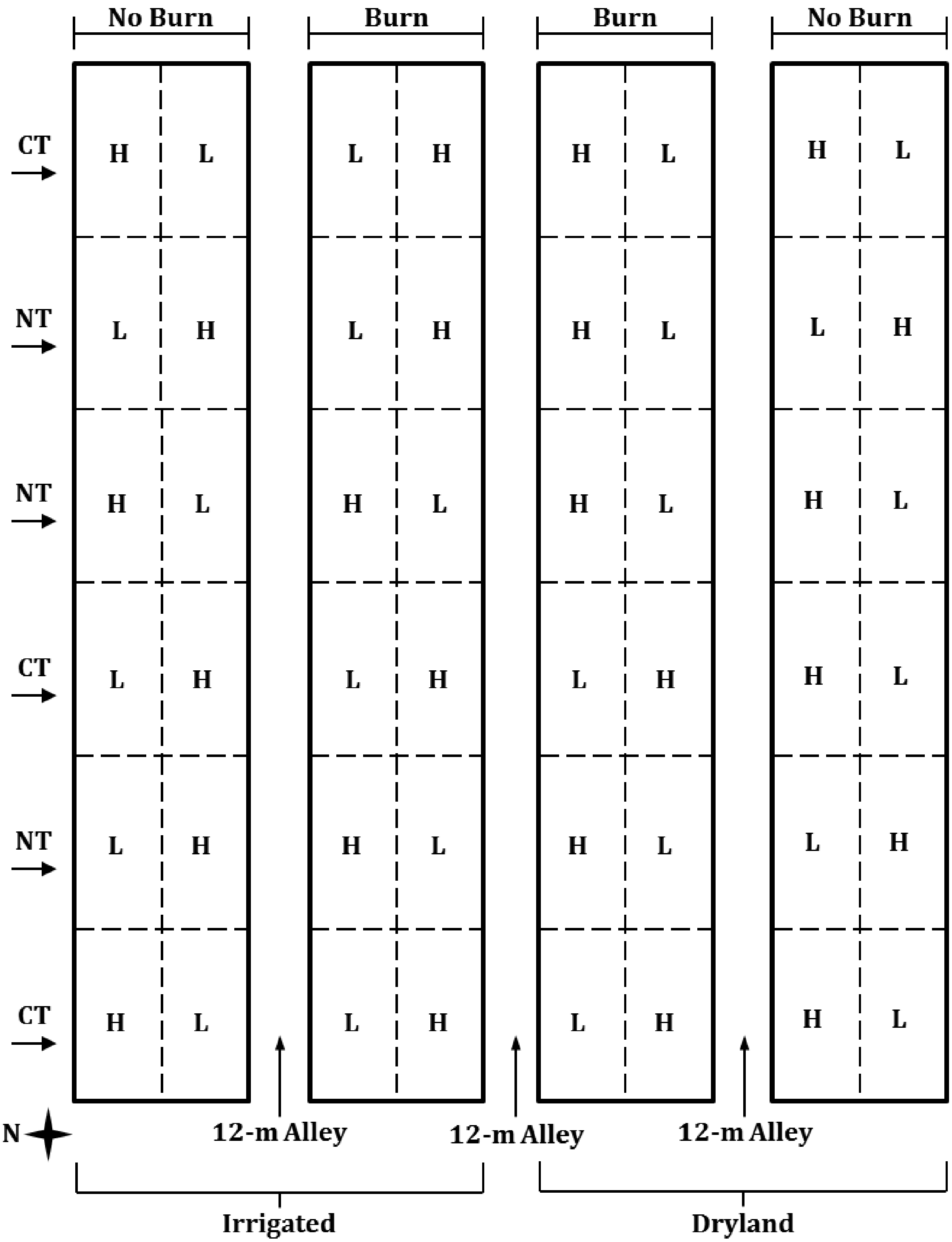


Fig. 1. Experimental layout at the Lon Mann Cotton Branch Experiment Station in eastern Arkansas depicting 48, 3- x 6-m plots subjected to residue-level [high (H) and low (L)], burn, tillage [conventional tillage (CT) and no-tillage (NT)], and irrigation treatments.

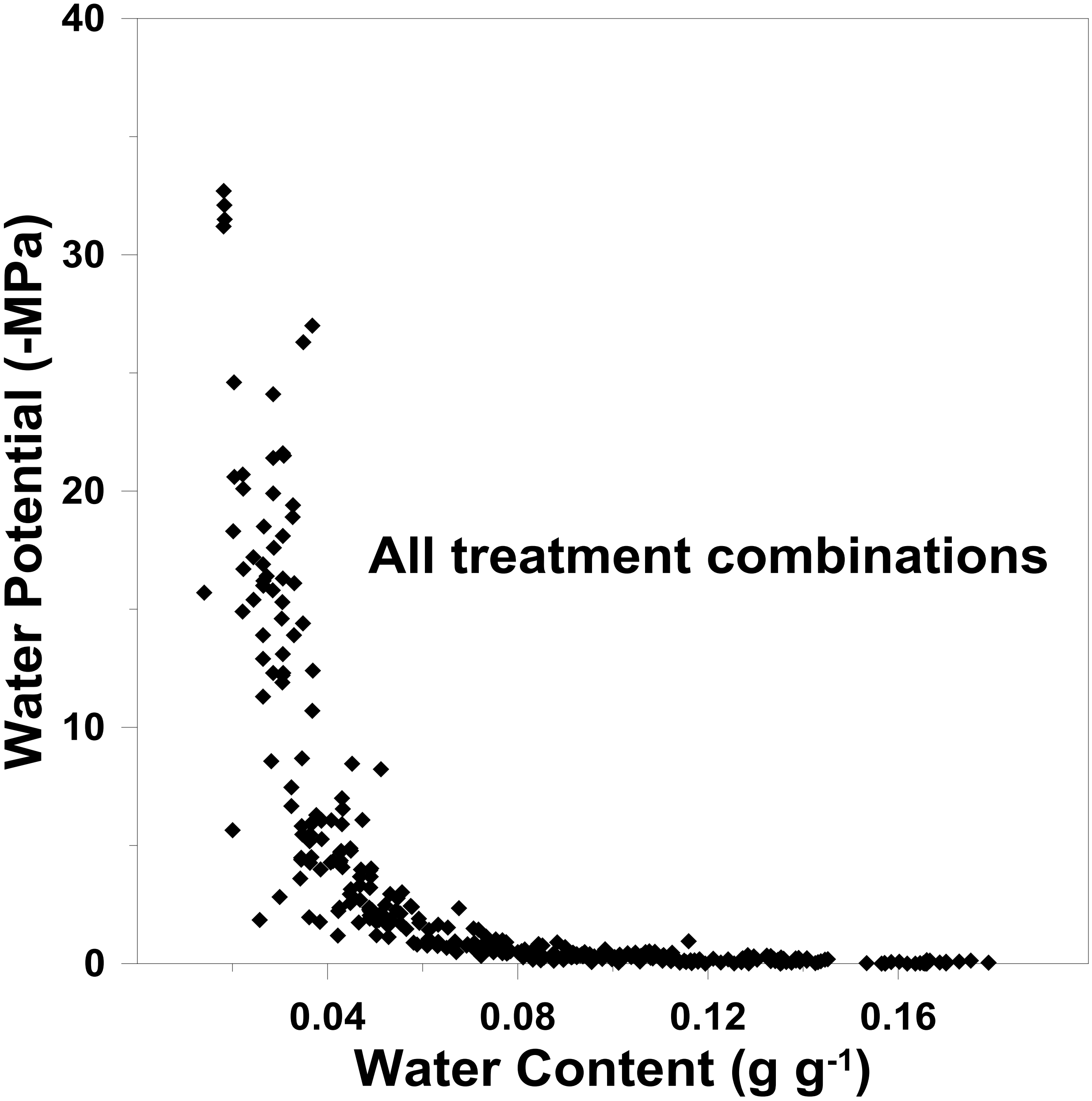


Fig. 2 Raw data from all treatment combinations depicting the relationship between the soil water potential and the gravimetric soil water content from soil wetting curves for the top 7.5 cm in a wheat-soybean, double-crop system in eastern Arkansas after 13 years (i.e., 2001 to 2014) of consistent management.

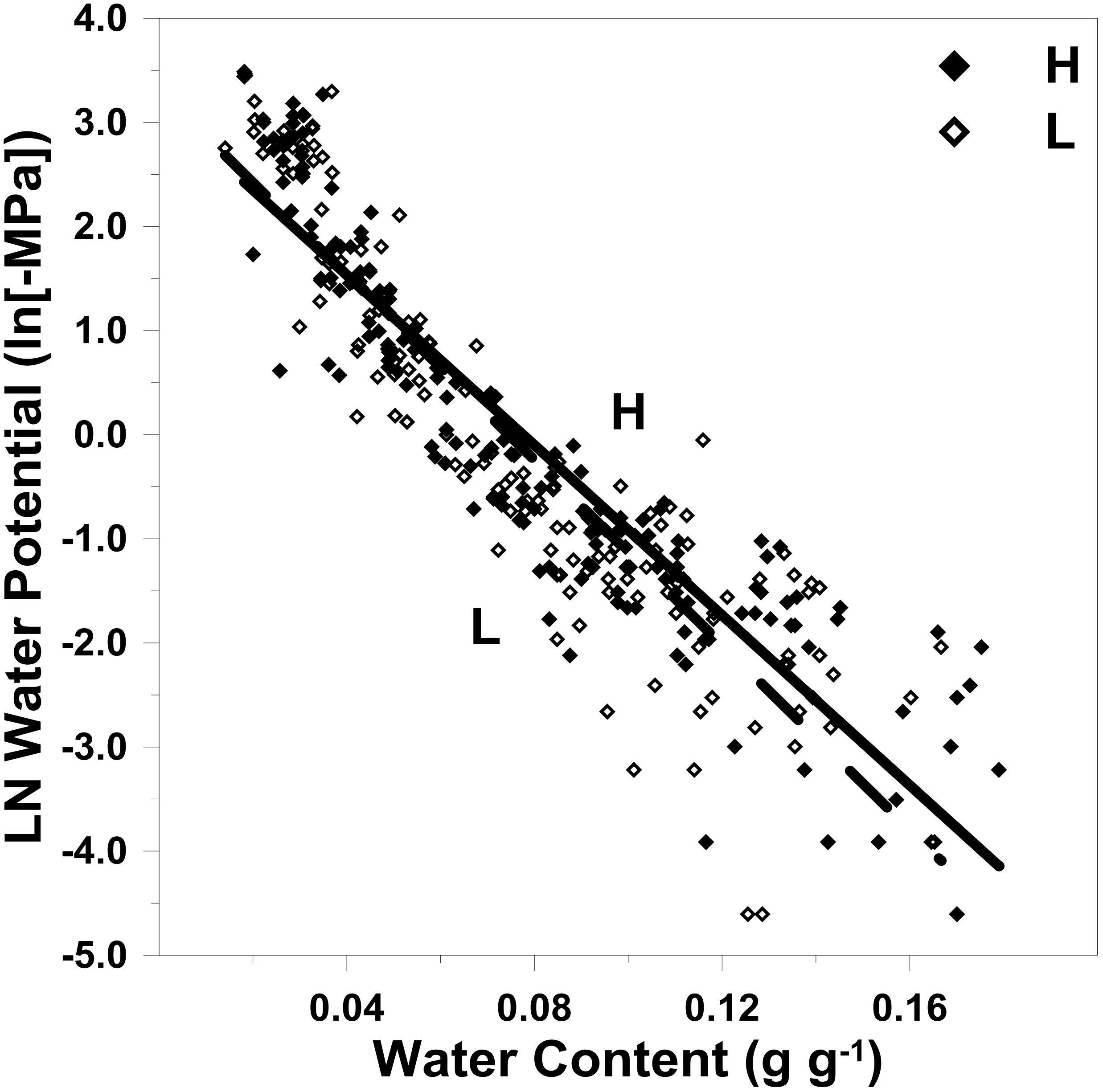


Fig. 3 Influence of residue level [high (H) and low (L)] on the relationship between the natural logarithm (LN) of water potential and the gravimetric soil water content from soil wetting curves for the top 7.5 cm in a wheat-soybean, double-crop system in eastern Arkansas after 13 years (i.e., 2001 to 2014) of consistent management. LN refers to the natural log of water potential.

Overall Conclusions

All field treatments evaluated in this study affected trends in one or more measured soil properties over the course of seven complete wheat-soybean cropping cycles (i.e., 2007 to 2014), following conversion to alternative management practices in treatment combinations managed consistently for 13 consecutive years (i.e., 2002 to 2014). Irrigation management was responsible for the greatest differences in trends in soybean yield, C fraction of SOM, and SOM, C, N, P, Cu contents over time. Burning also significantly affected the trend in SOM and C contents over time. Irrigation and burn treatment combinations were responsible for the greatest differences in trends in soil Ca, Mg, and Mn contents over time. Residue level was responsible for the greatest differences in trends in soil C:N ratio and pH over time. Trends in wheat yield, EC, and Fe, Na, and S contents were unaffected by any of the field treatments evaluated, but all varied significantly over time. Trends in bulk density, and K and Zn contents over time were affected by complex treatment combinations that included interactions among tillage, burning, and irrigation. Tillage did not significantly affect either soybean or wheat yield, which indicates that some producers may be able reduce costs associated with tillage without significantly reducing crop yield.

As originally hypothesized, SOM and C contents increased over time under non-burning and decreased over time under burning. Contrary to original hypotheses, tillage and residue treatments failed to cause clear and obvious differences in the trends in SOM, C, and extractable nutrient contents over time. In fact, differences between irrigation treatments appeared the have the clearest, most obvious effects on the trends in SOM, C, N, P, and Cu contents over time. Also contrary to that hypothesized, SOM and C contents did not decrease under dryland soybean production. Rather, SOM and C contents increased over time under dryland production until approximately year 9 (i.e., 2010), then decreased thereafter.

Following conversion to alternative residue and water management practices and after 13 consecutive years (i.e., 2001 to 2014) of management, the N-fertilization/residue level treatment significantly affected the linear relationship between the natural logarithm of water potential and the gravimetric soil water content as determined by soil wetting curves. The water-curve approach was useful to evaluate the various long-term field treatment effects on water retention. Contrary to the original hypothesis, tillage did not affect the same relationship, possibly due in part to the disturbed nature of soil samples used. It can be inferred from this study that differences in N-fertilization/residue level management affect soil water retention characteristics, possibly as a result of the increased soil aggregation and SOM associated with increased crop residue, both above and below ground, under high residue level management. Consideration of soil water retention characteristics is vital to planning out sustainable use of irrigation water, especially in areas such as the Delta region of eastern Arkansas that will face potential water shortages in the near future.

Overall, it can be inferred from this study that irrigation management plays a critical role in the long-term trends in SOM, C, and N contents and other soil physical and chemical properties over time. Moreover, the accumulation of SOM, C, and N appears to be greatly influenced by growing season weather patterns, especially under dryland production. Crop management that strikes a balance between increasing crop biomass and decreasing the rate of microbial turnover of SOM can maintain or increase SOM levels, and thereby work towards long-term soil improvement and soil C sequestration.

Appendix A

This appendix contains a summary of the analysis of covariance (ANCOVA) effects of residue level (N), burning (B), tillage (T), irrigation (I), and time (Year) on changes in soil and plant properties over time.

Table 1. Analysis of covariance (ANCOVA) summary on the effects of residue level (N), burning (B), tillage (T), irrigation (I), and time (Year) on changes in bulk density (BD; g cm^{-3}) and wheat (Wht) and soybean (Soy) yields (Mg ha^{-1}) over time between 2007 and 2014 in a wheat-soybean, double-crop system in eastern Arkansas. Only significant interactions ($P < 0.05$) were included in the final model, except when non-significant terms participated in significant treatment combinations. Year refers to the linear term, and Year^2 refers to the quadratic term.

Linear term and interactions	BD†	Wht†	Soy†	Quadratic term and interactions	BD	Wht	Soy
Year	<0.001	<0.001	0.0178	Year^2	<0.001	<0.001	ns
N*Year	ns‡	<0.001	ns	N*Year^2	Ns	ns	ns
B*Year	ns	0.002	ns	B*Year^2	Ns	ns	ns
T*Year	0.006	<0.001	ns	T*Year^2	0.004	ns	ns
I*Year	ns	<0.001	<0.001	I*Year^2	Ns	ns	<0.001
N*B*Year	0.015	ns	ns	N*B*Year^2	0.017	ns	ns
N*T*Year	ns	ns	ns	N*T*Year^2	Ns	ns	ns
N*I*Year	ns	ns	ns	N*I*Year^2	Ns	ns	ns
B*T*Year	ns	0.035	ns	B*T*Year^2	Ns	ns	ns
B*I*Year	<0.001	ns	ns	B*I*Year^2	Ns	ns	ns
T*I*Year	0.037	ns	ns	T*I*Year^2	0.047	ns	ns
N*B*T*Year	ns	0.007	ns	N*B*T*Year^2	Ns	ns	ns
N*B*I*Year	ns	ns	ns	N*B*I *Year^2	Ns	ns	ns
N*T*I *Year	0.018	ns	ns	N*T*I*Year^2	0.015	ns	ns
B*T*I*Year	ns	ns	ns	B*T*I*Year^2	Ns	ns	ns
N*B*T*I*Year	ns	ns	ns	N*B*T*I*Year^2	Ns	ns	ns

† Degrees of freedom were 300 and 332 for BD and Soy respectively. Degrees of freedom were 34.7 and 331 for Wht linear terms and quadratic terms, respectively.

‡ not significant (ns), i.e. $P > 0.05$.

Table 2. Analysis of covariance (ANCOVA) summary on the effects of residue level (N), burning (B), tillage (T), irrigation (I), and time (Year) on changes in soil organic matter (SOM), total carbon (TC), and total nitrogen (TN) contents (kg m^{-2}) over time between 2007 and 2014 in a wheat-soybean, double-crop system in eastern Arkansas. Only significant interactions ($P < 0.05$) were included in the final model, except when non-significant terms participated in significant treatment combinations. Year refers to the linear term, and Year^2 refers to the quadratic term.

Linear term and interactions	SOM†	TC	TN	Quadratic term and interactions	SOM	TC	TN
Year	<0.001	ns	<0.001	Year^2	<0.001	ns	<0.001
N*Year	ns‡	ns	ns	N*Year^2	ns	ns	ns
B*Year	0.015	ns	ns	B*Year^2	ns	0.002	ns
T*Year	ns	ns	ns	T*Year^2	ns	ns	ns
I*Year	<0.001	<0.001	<0.001	I*Year^2	<0.001	<0.001	<0.001
N*B*Year	ns	ns	ns	N*B*Year^2	ns	ns	ns
N*T*Year	ns	ns	ns	N*T*Year^2	ns	ns	ns
N*I*Year	ns	ns	ns	N*I*Year^2	ns	ns	ns
B*T*Year	ns	ns	ns	B*T*Year^2	ns	ns	ns
B*I*Year	ns	ns	ns	B*I*Year^2	ns	ns	ns
T*I*Year	ns	ns	ns	T*I*Year^2	ns	ns	ns
N*B*T*Year	ns	ns	ns	N*B*T*Year^2	ns	ns	ns
N*B*I*Year	ns	ns	ns	N*B*I *Year^2	ns	ns	ns
N*T*I *Year	0.011	0.044	ns	N*T*I*Year^2	ns	ns	ns
B*T*I*Year	ns	ns	ns	B*T*I*Year^2	ns	ns	ns
N*B*T*I*Year	ns	ns	ns	N*B*T*I*Year^2	ns	ns	ns

† Degrees of freedom were 325, 325, and 332 for SOM, TC, and TN, respectively.

‡ not significant (ns), i.e. $P > 0.05$.

Table 3. Analysis of covariance (ANCOVA) summary on the effects of residue level (N), burning (B), tillage (T), irrigation (I), and time (Year) on changes in carbon to nitrogen ratio (C:N), carbon fraction of soil organic matter (C:SOM), and nitrogen fraction of soil organic matter (N:SOM) over time between 2007 and 2014 in a wheat-soybean, double-crop system in eastern Arkansas. Only significant interactions ($P < 0.05$) were included in the final model, except when non-significant terms participated in significant treatment combinations. Year refers to the linear term, and Year^2 refers to the quadratic term.

Linear term and interactions	C:N	C:SOM	N:SOM	Quadratic term and interactions	C:N	C:SOM	N:SOM
Year				Year^2			
N*Year	ns	ns	ns	N*Year^2	0.0483	ns	ns
B*Year	0.015	ns	ns	B*Year^2	<0.001	0.0015	ns
T*Year	ns	ns	ns	T*Year^2	Ns	ns	ns
I*Year	<.001	<.001	ns	I*Year^2	Ns	<0.001	ns
N*B*Year	ns	ns	ns	N*B*Year^2	Ns	ns	ns
N*T*Year	ns	ns	ns	N*T*Year^2	Ns	ns	ns
N*I*Year	ns	ns	ns	N*I*Year^2	Ns	ns	ns
B*T*Year	ns	ns	ns	B*T*Year^2	Ns	ns	ns
B*I*Year	ns	ns	ns	B*I*Year^2	Ns	ns	ns
T*I*Year	ns	ns	ns	T*I*Year^2	Ns	ns	ns
N*B*T*Year	ns	ns	ns	N*B*T*Year^2	Ns	ns	ns
N*B*I*Year	ns	ns	ns	N*B*I *Year^2	Ns	ns	ns
N*T*I *Year	0.011	0.044	0.0232	N*T*I*Year^2	Ns	ns	ns
B*T*I*Year	ns	ns	ns	B*T*I*Year^2	Ns	ns	ns
N*B*T*I*Year	ns	ns	ns	N*B*T*I*Year^2	Ns	ns	ns

† Degrees of freedom were 325, 325, and 332 for SOM, TC, and TN, respectively.

‡ not significant (ns), i.e. $P > 0.05$.

Table 4. Analysis of covariance (ANCOVA) summary on the effects of residue level (N), burning (B), tillage (T), irrigation (I), and time (Year) on changes in EC (dS m^{-1}) and iron (Fe), sodium (Na), and sulfur (S) contents (kg ha^{-1}) over time between 2007 and 2014 in a wheat-soybean, double-crop system in eastern Arkansas. Only significant interactions ($P < 0.05$) were included in the final model, except when non-significant terms participated in significant treatment combinations. Year refers to the linear term, and $Year^2$ refers to the quadratic term.

Linear term and interactions	EC†	Fe	Na	S	Quadratic term and interactions	EC	Fe	Na	S
Year	<0.001	<0.001	<0.001	<0.001	$Year^2$	<0.001	<0.001	ns	<0.001
N*Year	ns‡	ns	ns	ns	N*$Year^2$	ns	ns	ns	ns
B*Year	ns	ns	ns	ns	B*$Year^2$	ns	ns	ns	ns
T*Year	ns	ns	ns	ns	T*$Year^2$	ns	ns	ns	ns
I*Year	ns	ns	ns	ns	I*$Year^2$	ns	ns	ns	ns
N*B*Year	ns	ns	ns	ns	N*B*$Year^2$	ns	ns	ns	ns
N*T*Year	ns	ns	ns	ns	N*T*$Year^2$	ns	ns	ns	ns
N*I*Year	ns	ns	ns	ns	N*I*$Year^2$	ns	ns	ns	ns
B*T*Year	ns	ns	ns	ns	B*T*$Year^2$	ns	ns	ns	ns
B*I*Year	ns	ns	ns	ns	B*I*$Year^2$	ns	ns	ns	ns
T*I*Year	ns	ns	ns	ns	T*I*$Year^2$	ns	ns	ns	ns
N*B*T*Year	ns	ns	ns	ns	N*B*T*$Year^2$	ns	ns	ns	ns
N*B*I*Year	ns	ns	ns	ns	N*B*I *$Year^2$	ns	ns	ns	ns
N*T*I *Year	ns	ns	ns	ns	N*T*I*$Year^2$	ns	ns	ns	ns
B*T*I*Year	ns	ns	ns	ns	B*T*I*$Year^2$	ns	ns	ns	ns
N*B*T*I*Year	ns	ns	ns	ns	N*B*T*I*$Year^2$	ns	ns	ns	ns

† Degrees of freedom were 334, 334, 335, and 334 for EC, Fe, Na, and S, respectively.

‡ not significant (ns), i.e. $P > 0.05$.

Table 5. Analysis of covariance (ANCOVA) summary on the effects of residue level (N), burning (B), tillage (T), irrigation (I), and time (Year) on changes in pH and phosphorus (P) and copper (Cu) contents (kg ha^{-1}) over time between 2007 and 2014 in a wheat-soybean, double-crop system in eastern Arkansas. Only significant interactions (*P* < 0.05) were included in the final model, except when non-significant terms participated in significant treatment combinations. Year refers to the linear term, and Year^2 refers to the quadratic term.

Linear term and interactions	pH†	P	Cu	Quadratic term and interactions	pH	P	Cu
Year	<0.001	<0.001	<0.001	Year^2	<0.001	<0.001	0.002
N*Year	0.003	<0.001	ns	N*Year^2	0.005	ns	ns
B*Year	ns‡	ns	ns	B*Year^2	ns	ns	ns
T*Year	ns	ns	ns	T*Year^2	ns	ns	ns
I*Year	<0.001	0.019	0.009	I*Year^2	ns	0.026	0.015
N*B*Year	ns	ns	ns	N*B*Year^2	ns	ns	ns
N*T*Year	ns	ns	ns	N*T*Year^2	ns	ns	ns
N*I*Year	0.013	ns	ns	N*I*Year^2	ns	ns	ns
B*T*Year	ns	ns	ns	B*T*Year^2	ns	ns	ns
B*I*Year	ns	ns	ns	B*I*Year^2	ns	ns	ns
T*I*Year	ns	ns	ns	T*I*Year^2	ns	ns	ns
N*B*T*Year	0.025	ns	ns	N*B*T*Year^2	0.041	ns	ns
N*B*I*Year	ns	ns	ns	N*B*I *Year^2	ns	ns	ns
N*T*I *Year	ns	ns	ns	N*T*I*Year^2	ns	ns	ns
B*T*I*Year	ns	ns	ns	B*T*I*Year^2	ns	ns	ns
N*B*T*I*Year	ns	ns	ns	N*B*T*I*Year^2	ns	ns	ns

† Degrees of freedom were 318, 331, and 332 for pH, P, and Cu, respectively.

‡ not significant (ns), i.e. *P* > 0.05.

Table 6. Analysis of covariance (ANCOVA) summary on the effects of residue level (N), burning (B), tillage (T), irrigation (I), and time (Year) on changes in calcium (Ca), magnesium (Mg), and manganese (Mn) contents (kg ha^{-1}) over time between 2007 and 2014 in a wheat-soybean, double-crop system in eastern Arkansas. Only significant interactions (P < 0.05) were included in the final model, except when non-significant terms participated in significant treatment combinations. Year refers to the linear term, and Year^2 refers to the quadratic term.

Linear term and interactions	Ca†	Mg	Mn	Quadratic term and interactions	Ca	Mg	Mn
Year	<0.001	<0.001	<0.001	Year^2	<0.001	<0.001	<0.001
N*Year	ns‡	ns	ns	N*Year^2	ns	ns	ns
B*Year	ns	0.004	0.032	B*Year^2	ns	0.009	ns
T*Year	ns	<0.001	0.002	T*Year^2	ns	ns	ns
I*Year	<0.001	<0.001	ns	I*Year^2	<0.001	<0.001	ns
N*B*Year	ns	ns	ns	N*B*Year^2	ns	ns	ns
N*T*Year	ns	ns	ns	N*T*Year^2	ns	ns	ns
N*I*Year	ns	ns	ns	N*I*Year^2	ns	ns	ns
B*T*Year	ns	ns	ns	B*T*Year^2	ns	ns	ns
B*I*Year	<0.001	<0.001	0.003	B*I*Year^2	<0.001	<0.001	0.007
T*I*Year	ns	0.029	ns	T*I*Year^2	ns	ns	ns
N*B*T*Year	<0.001	ns	ns	N*B*T*Year^2	ns	ns	ns
N*B*I*Year	ns	ns	ns	N*B*I *Year^2	ns	ns	ns
N*T*I *Year	0.012	0.003	ns	N*T*I*Year^2	0.031	ns	ns
B*T*I*Year	ns	ns	ns	B*T*I*Year^2	ns	ns	ns
N*B*T*I*Year	ns	ns	ns	N*B*T*I*Year^2	ns	ns	ns

† Degrees of freedom were 313, 322, and 327 for Ca, Mg, and Mn, respectively.

‡ not significant (ns), i.e. P > 0.05.

Table 7. Analysis of covariance (ANCOVA) summary on the effects of residue level (N), burning (B), tillage (T), irrigation (I), and time (Year) on changes in potassium (K) and zinc (Zn) contents (kg ha^{-1}) over time between 2007 and 2014 in a wheat-soybean, double-crop system in eastern Arkansas. Only significant interactions ($P < 0.05$) were included in the final model, except when non-significant terms participated in significant treatment combinations. Year refers to the linear term, and Year^2 refers to the quadratic term.

Linear term and interactions	K†	Zn	Quadratic term and interactions	K	Zn
Year	<0.001	0.002	Year^2	<0.001	0.002
N*Year	ns‡	ns	N*Year^2	ns	ns
B*Year	ns	0.035	B*Year^2	ns	0.095
T*Year	ns	ns	T*Year^2	ns	ns
I*Year	0.002	0.032	I*Year^2	0.007	ns
N*B*Year	ns	ns	N*B*Year^2	ns	ns
N*T*Year	ns	ns	N*T*Year^2	ns	ns
N*I*Year	ns	ns	N*I*Year^2	ns	ns
B*T*Year	ns	ns	B*T*Year^2	ns	ns
B*I*Year	<0.001	0.001	B*I*Year^2	ns	0.002
T*I*Year	ns	ns	T*I*Year^2	ns	ns
N*B*T*Year	0.014	0.004	N*B*T*Year^2	0.032	0.005
N*B*I*Year	ns	ns	N*B*I *Year^2	ns	ns
N*T*I *Year	0.012	ns	N*T*I*Year^2	0.013	ns
B*T*I*Year	0.011	ns	B*T*I*Year^2	ns	ns
N*B*T*I*Year	ns	ns	N*B*T*I*Year^2	ns	ns

† Degrees of freedom were 312 and 316 for K and Zn, respectively.

‡ not significant (ns), i.e. $P > 0.05$.

Appendix B

This appendix contains a summary of least significant differences (LSD) among estimate parameters of specific treatment combinations.

Table 1. Summary of the separation of estimate parameters of specific treatment combinations, i.e. residue-level [high (H) and low (L)], burning [burn (B) and no-burn (NB)], tillage [conventional tillage (CT) and no-tillage (NT)], and irrigation [irrigated (I) and non-irrigated (NI)], for bulk density (g cm^{-3}) trends over time between 2007 and 2014 in a wheat-soybean, double-crop system in eastern Arkansas. Coefficient estimates are categorized according to least significant differences (LSD), and coefficient estimates sharing a letter category are statistically similar.

Significant regression term†	Treatment combination	Coefficient estimate	*P*
Linear	NT-B-H-NI	0.269 a	< 0.001
	NT-NB-H-NI	0.194 ab	< 0.001
	NT-NB-L-I	0.174 b	< 0.001
	CT-B-H-I	0.163 b	< 0.001
	NT-B-H-I	0.155 bc	< 0.001
	CT-NB-L-I	0.141 bc	< 0.001
	NT-B-L-I	0.138 bc	< 0.001
	NT-NB-L-NI	0.118 bc	< 0.001
	CT-B-L-I	0.105 bc	0.001
	CT-NB-H-I	0.103 bc	0.001
	CT-B-H-NI	0.103 bc	0.001
	NT-B-L-NI	0.098 bc	0.002
	CT-NB-L-NI	0.096 bc	0.002
	NT-NB-H-I	0.096 bc	0.002
	CT-B-L-NI	0.076 c	0.014
	CT-NB-H-NI	0.028 c	0.367
Quadratic	CT-NB-H-NI	-0.002 a	0.317
	CT-B-L-NI	-0.004 a	0.025
	NT-B-L-NI	-0.005 a	0.003
	CT-B-H-NI	-0.005 a	0.002
	NT-NB-H-I	-0.005 a	0.002
	CT-NB-L-NI	-0.005 a	0.001
	CT-NB-H-I	-0.005 a	0.001
	CT-B-L-I	-0.005 ab	0.001
	NT-NB-L-NI	-0.006 b	< 0.001
	CT-NB-L-I	-0.007 b	< 0.001
	NT-B-L-I	-0.008 b	< 0.001
	NT-B-H-I	-0.008 b	< 0.001
	CT-B-H-I	-0.009 b	< 0.001
	NT-NB-L-I	-0.009 bc	< 0.001
	NT-NB-H-NI	-0.010 cd	< 0.001
	NT-B-H-NI	-0.014 d	< 0.001

† Significant linear term indicates a trend over time that is statistically different from 0, and a significant quadratic term indicates a shift in the trend over time.

Table 2. Summary of the separation of estimate parameters of specific treatment combinations, i.e. residue-level [high (H) and low (L)], burning [burn (B) and no-burn (NB)], tillage [conventional tillage (CT) and no-tillage (NT)], and irrigation [irrigated (I) and non-irrigated (NI)], for soil organic matter content (kg m^{-2}) trends over time between 2007 and 2014 in a wheat-soybean, double-crop system in eastern Arkansas. Coefficient estimates are categorized according to least significant differences (LSD), and coefficient estimates sharing a letter category are statistically similar.

Significant regression term†	Treatment combination	Coefficient estimate	*P*
Linear	CT-NB-H-NI	0.630 a	< 0.001
	CT-B-H-NI	0.592 a	< 0.001
	NT-NB-L-NI	0.572 a	< 0.001
	CT-NB-L-NI	0.562 a	< 0.001
	NT-NB-H-NI	0.561 a	< 0.001
	NT-B-L-NI	0.535 a	< 0.001
	CT-B-L-NI	0.524 a	< 0.001
	NT-B-H-NI	0.524 a	< 0.001
	CT-NB-L-I	0.072 b	0.495
	NT-NB-H-I	0.057 b	0.590
	CT-B-L-I	0.035 b	0.743
	NT-NB-L-I	0.035 b	0.745
	NT-B-H-I	0.020 b	0.853
	CT-NB-H-I	0.017 b	0.875
	NT-B-L-I	-0.003 b	0.977
	CT-B-H-I	-0.021 b	0.844
Quadratic	I	-0.002 a	0.720
	NI	-0.029 b	< 0.001

† Significant linear term indicates a trend over time that is statistically different from 0, and a significant quadratic term indicates a shift in the trend over time.

Table 3. Summary of the separation of estimate parameters of specific treatment combinations, i.e. residue-level [high (H) and low (L)], burning [burn (B) and no-burn (NB)], tillage [conventional tillage (CT) and no-tillage (NT)], and irrigation [irrigated (I) and non-irrigated (NI)], for carbon content (kg m^{-2}) trends over time between 2007 and 2014 in a wheat-soybean, double-crop system in eastern Arkansas. Coefficient estimates are categorized according to least significant differences (LSD), and coefficient estimates sharing a letter category are statistically similar.

Significant regression term†	Treatment combination	Coefficient estimate	*P*
Linear	CT-H-NI	0.180 a	< 0.001
	NT-H-NI	0.159 a	0.002
	NT-L-NI	0.157 a	0.002
	CT-L-NI	0.152 a	0.002
	CT-L-I	-0.141 b	0.005
	NT-H-I	-0.161 b	0.001
	NT-L-I	-0.166 b	0.001
	CT-H-I	-0.170 b	0.001
Quadratic	NB-I	0.010 a	< 0.001
	B-I	0.008 a	0.001
	NB-NI	-0.008 b	0.004
	B-NI	-0.009 b	0.001

† Significant linear term indicates a trend over time that is statistically different from 0, and a significant quadratic term indicates a shift in the trend over time.

Table 4. Summary of the separation of estimate parameters of specific treatment combinations, i.e. burning [burn (B) and no-burn (NB)], tillage [conventional tillage (CT) and no-tillage (NT)], and irrigation [irrigated (I) and non-irrigated (NI)], for the trend in carbon fraction of soil organic matter over time between 2007 and 2014 in a wheat-soybean, double-crop system in eastern Arkansas. Coefficient estimates are categorized according to least significant differences (LSD), and coefficient estimates sharing a letter category are statistically similar.

Significant regression term†	Treatment combination	Coefficient estimate	*P*
Linear	NT-B-NI	-0.023 a	0.040
	CT-NB-NI	-0.025 a	0.027
	NT-NB-NI	-0.026 a	0.018
	CT-B-NI	-0.027 a	0.015
	NT-NB-I	-0.055 b	< 0.001
	CT-NB-I	-0.056 b	< 0.001
	CT-B-I	-0.057 b	< 0.001
	NT-B-I	-0.063 b	< 0.001
Quadratic	I	0.003 a	< 0.001
	NI	0.001 b	0.016

† Significant linear term indicates a trend over time that is statistically different from 0, and a significant quadratic term indicates a shift in the trend over time.

Table 5. Summary of the separation of estimate parameters of specific treatment combinations, i.e. residue-level [high (H) and low (L)], burning [burn (B) and no-burn (NB)], tillage [conventional tillage (CT) and no-tillage (NT)], and irrigation [irrigated (I) and non-irrigated (NI)], for carbon to nitrogen (C:N) ratio trends over time between 2007 and 2014 in a wheat-soybean, double-crop system in eastern Arkansas. Coefficient estimates are categorized according to least significant differences (LSD), and coefficient estimates sharing a letter category are statistically similar.

Significant regression term†	Treatment combination	Coefficient estimate	*P*
Linear	NT-B-H-I	-0.635 a	0.006
	CT-B-H-NI	-0.657 ab	0.004
	CT-B-H-I	-0.686 abc	0.003
	NT-NB-H-I	-0.751 abcd	0.001
	NT-B-H-NI	-0.758 abcd	0.001
	CT-NB-H-NI	-0.773 abcde	0.001
	CT-NB-H-I	-0.802 abcde	0.001
	NT-NB-H-NI	-0.874 abcdef	< 0.001
	CT-B-L-I	-1.184 abcdef	< 0.001
	NT-B-L-I	-1.245 abcdef	< 0.001
	NT-B-L-NI	-1.293 bcdef	< 0.001
	CT-NB-L-I	-1.300 cdef	< 0.001
	NT-NB-L-I	-1.361 def	< 0.001
	CT-B-L-NI	-1.372 def	< 0.001
	NT-NB-L-NI	-1.409 ef	< 0.001
	CT-NB-L-NI	-1.488 f	< 0.001
Quadratic	NB-L	0.080 a	< 0.001
	B-L	0.068 ab	< 0.001
	NB-H	0.047 b	< 0.001
	B-H	0.035 b	0.004

† Significant linear term indicates a trend over time that is statistically different from 0, and a significant quadratic term indicates a shift in the trend over time.

Table 6. Summary of the separation of estimate parameters of specific treatment combinations, i.e. irrigation [irrigated (I) and non-irrigated (NI)], for nitrogen content (kg m^{-2}) trends over time between 2007 and 2014 in a wheat-soybean, double-crop system in eastern Arkansas. Coefficient estimates are categorized according to least significant differences (LSD), and coefficient estimates sharing a letter category are statistically similar.

Significant regression term†	Treatment combination	Coefficient estimate	*P*
Linear	NI	0.030 a	< 0.001
	I	0.003 b	0.531
Quadratic	I	< 0.001 a	0.498
	NI	-0.002 b	< 0.001

† Significant linear term indicates a trend over time that is statistically different from 0, and a significant quadratic term indicates a shift in the trend over time.

Table 7. Summary of the separation of estimate parameters of specific treatment combinations, i.e. residue-level [high (H) and low (L)], burning [burn (B) and no-burn (NB)], tillage [conventional tillage (CT) and no-tillage (NT)], and irrigation [irrigated (I) and non-irrigated (NI)], for the nitrogen fraction of soil organic matter trends over time between 2007 and 2014 in wheat-soybean, double-crop system in eastern Arkansas. Coefficient estimates are categorized according to least significant differences (LSD), and coefficient estimates sharing a letter category are statistically similar.

Significant regression term†	Treatment combination	Coefficient estimate	*P*
Linear	NT-H-NI	0.001 a	0.103
	CT-H-I	< 0.001 a	0.123
	CT-L-NI	< 0.001 a	0.460
	NT-L-I	< 0.001 a	0.989
	CT-L-I	< 0.001 a	0.668
	NT-H-I	< 0.001 a	0.629
	NT-L-NI	< 0.001 a	0.601
	CT-H-NI	< 0.001 a	0.282

† Significant linear term indicates a trend over time that is statistically different from 0. No significant quadratic terms existed (Appendix A-Table 3)

Table 8. Summary of the separation of estimate parameters of specific treatment combinations, i.e. irrigation [irrigated (I) and non-irrigated (NI)] for soybean yield (Mg ha^{-1}) trends over time between 2007 and 2014 in wheat-soybean, double-crop system in eastern Arkansas. Coefficient estimates are categorized according to least significant differences (LSD), and coefficient estimates sharing a letter category are statistically similar.

Significant regression term†	Treatment combination	Coefficient estimate	*P*
Linear	I	0.654 a	0.010
	NI	-1.502 b	< 0.001
Quadratic	NI	0.069 a	0.003
	I	-0.039 b	< 0.001

† Significant linear term indicates a trend over time that is statistically different from 0, and a significant quadratic term indicates a shift in the trend over time.

Table 9. Summary of the separation of estimate parameters of specific treatment combinations, i.e. residue-level [high (H) and low (L)], burning [burn (B) and no-burn (NB)], tillage [conventional tillage (CT) and no-tillage (NT)], and irrigation [irrigated (I) and non-irrigated (NI)], for wheat yield (Mg ha^{-1}) trends over time between 2007 and 2014 in a wheat-soybean, double-crop system in eastern Arkansas. Coefficient estimates are categorized according to least significant differences (LSD), and coefficient estimates sharing a letter category are statistically similar.

Significant regression term†	Treatment combination	Coefficient estimate	*P*
Linear	NT-B-H-NI	2.470 a	< 0.001
	NT-NB-H-NI	2.393 a	< 0.001
	CT-NB-H-NI	2.388 a	< 0.001
	CT-B-H-NI	2.382 a	< 0.001
	NT-B-H-I	2.336 a	< 0.001
	NT-B-L-NI	2.301 a	< 0.001
	CT-B-L-NI	2.292 a	< 0.001
	NT-NB-L-NI	2.287 a	< 0.001
	CT-NB-L-NI	2.268 a	< 0.001
	NT-NB-H-I	2.259 a	< 0.001
	CT-NB-H-I	2.255 a	< 0.001
	CT-B-H-I	2.248 a	< 0.001
	NT-B-L-I	2.168 a	< 0.001
	CT-B-L-I	2.159 a	< 0.001
	NT-NB-L-I	2.154 a	< 0.001
	CT-NB-L-I	2.134 a	< 0.001
Quadratic	Quadratic‡	-0.119 a	< 0.001

† Significant linear term indicates a trend over time that is statistically different from 0, and a significant quadratic term indicates a shift in the trend over time.

‡ Quadratic coefficient was significant, but not in combination with any field treatment.

Table 10. Summary of the separation of estimate parameters for electrical conductivity (dS m^{-1}) trends over time between 2007 and 2014 in a wheat-soybean, double-crop system in eastern Arkansas.

Significant regression term†	Treatment combination	Coefficient estimate	*P*
Linear	Linear‡	0.095	< 0.001
Quadratic	Quadratic‡	-0.005	< 0.001

† Significant linear term indicates a trend over time that is statistically different from 0, and a significant quadratic term indicates a shift in the trend over time.

‡ Coefficient was significant, but not in combination with any field treatment.

Table 11. Summary of the separation of estimate parameters for iron content (kg ha^{-1}) trends over time between 2007 and 2014 in a wheat-soybean, double-crop system in eastern Arkansas.

Significant regression term†	Treatment combination	Coefficient estimate	*P*
Linear	Linear‡	28.5722	< 0.001
Quadratic	Quadratic‡	-1.3504	< 0.001

† Significant linear term indicates a trend over time that is statistically different from 0, and a significant quadratic term indicates a shift in the trend over time.

‡ Coefficient was significant, but not in combination with any field treatment.

Table 12. Summary of the separation of estimate parameters for sodium content (kg ha^{-1}) trends over time between 2007 and 2014 in a wheat-soybean, double-crop system in eastern Arkansas.

Significant regression term†	Treatment combination	Coefficient estimate	*P*
Linear	Linear‡	-1.365	< 0.001

† Significant linear term indicates a trend over time that is statistically different from 0, and a significant quadratic term indicates a shift in the trend over time.

‡ Coefficient was significant, but not in combination with any field treatment.

Table 13. Summary of the separation of estimate parameters for sulfur content (kg ha^{-1}) trends over time between 2007 and 2014 in a wheat-soybean, double-crop system in eastern Arkansas.

Significant regression term†	Treatment combination	Coefficient estimate	*P*
Linear	Linear‡	19.522	< 0.001
Quadratic	Quadratic‡	-1.070	< 0.001

† Significant linear term indicates a trend over time that is statistically different from 0, and a significant quadratic term indicates a shift in the trend over time.

‡ Coefficient was significant, but not in combination with any field treatment.

Table 14. Summary of the separation of estimate parameters of specific treatment combinations, i.e. residue-level [high (H) and low (L)], burning [burn (B) and no-burn (NB)], tillage [conventional tillage (CT) and no-tillage (NT)], and irrigation [irrigated (I) and non-irrigated (NI)], for pH trends over time between 2007 and 2014 in a wheat-soybean, double-crop system in eastern Arkansas. Coefficient estimates are categorized according to least significant differences (LSD), and coefficient estimates sharing a letter category are statistically similar.

Significant regression term†	Treatment combination	Coefficient estimate	*P*
Linear	NT-B-L-I	-0.327 a	< 0.001
	NT-B-L-NI	-0.406 ab	< 0.001
	CT-NB-L-I	-0.503 abc	< 0.001
	CT-NB-L-NI	-0.582 abcd	< 0.001
	NT-NB-L-I	-0.681 abcde	< 0.001
	NT-NB-L-NI	-0.760 abcdef	< 0.001
	NT-NB-H-I	-0.824 bcdef	0.004
	CT-B-H-I	-0.859 bcdef	0.001
	CT-B-L-I	-0.871 bcdef	< 0.001
	CT-B-L-NI	-0.950 cdef	< 0.001
	NT-NB-H-NI	-0.967 cdef	0.058
	NT-B-H-I	-0.969 cdef	0.019
	CT-B-H-NI	-1.002 def	< 0.001
	CT-NB-H-I	-1.080 ef	< 0.001
	NT-B-H-NI	-1.112 ef	< 0.001
	CT-NB-H-NI	-1.223 f	< 0.001
Quadratic	CT-NB-H	0.056 a	< 0.001
	NT-B-H	0.050 ab	< 0.001
	CT-B-H	0.046 ab	< 0.001
	CT-B-L	0.044 ab	0.003
	NT-NB-H	0.043 ab	< 0.001
	NT-NB-L	0.034 bc	0.069
	CT-NB-L	0.027 bc	< 0.001
	NT-B-L	0.016 bc	< 0.001

† Significant linear term indicates a trend over time that is statistically different from 0, and a significant quadratic term indicates a shift in the trend over time.

Table 15. Summary of the separation of estimate parameters of specific treatment combinations, i.e. residue-level [high (H) and low (L)] and irrigation [irrigated (I) and non-irrigated (NI)], for phosphorus content (kg ha^{-1}) trends over time between 2007 and 2014 in a wheat-soybean, double-crop system in eastern Arkansas. Coefficient estimates are categorized according to least significant differences (LSD), and coefficient estimates sharing a letter category are statistically similar.

Significant regression term†	Treatment combination	Coefficient estimate	*P*
Linear	L-NI	11.481 a	< 0.001
	H-NI	11.019 a	< 0.001
	L-I	3.960 b	0.08
	H-I	3.497 b	0.12
Quadratic	I	-0.276 a	0.02
	NI	-0.651 b	< 0.001

† Significant linear term indicates a trend over time that is statistically different from 0, and a significant quadratic term indicates a shift in the trend over time.

Table 16. Summary of the separation of estimate parameters of specific treatment combinations, i.e. irrigation [irrigated (I) and non-irrigated (NI)] for copper content (kg ha^{-1}) trends over time between 2007 and 2014 in a wheat-soybean, double-crop system in eastern Arkansas. Coefficient estimates are categorized according to least significant differences (LSD), and coefficient estimates sharing a letter category are statistically similar.

Significant regression term†	Treatment combination	Coefficient estimate	*P*
Linear	NI	-0.105 a	0.466
	I	-0.642 b	< 0.001
Quadratic	I	0.030 a	< 0.001
	NI	0.004 b	0.612

† Significant linear term indicates a trend over time that is statistically different from 0, and a significant quadratic term indicates a shift in the trend over time.

Table 17. Summary of the separation of estimate parameters of specific treatment combinations, i.e. residue-level [high (H) and low (L)], burning [burn (B) and no-burn (NB)], tillage [conventional tillage (CT) and no-tillage (NT)], and irrigation [irrigated (I) and non-irrigated (NI)], for calcium content (kg ha^{-1}) trends over time between 2007 and 2014 in a wheat-soybean, double-crop system in eastern Arkansas. Coefficient estimates are categorized according to least significant differences (LSD), and coefficient estimates sharing a letter category are statistically similar.

Significant regression term†	Treatment combination	Coefficient estimate	*P*
Linear	NT-NB-L-NI	414.550 a	< 0.001
	CT-NB-H-NI	391.220 a	< 0.001
	NT-NB-H-NI	264.420 a	0.010
	CT-NB-L-NI	162.160 ab	0.111
	NT-B-L-NI	-34.718 bc	0.732
	CT-B-H-NI	-78.872 bc	0.437
	NT-B-H-NI	-155.310 cd	0.126
	CT-B-L-I	-187.640 cde	0.065
	CT-B-L-NI	-247.360 cde	0.015
	NT-B-H-I	-280.630 cdef	0.006
	NT-B-L-I	-401.580 defg	< 0.001
	CT-B-H-I	-427.740 defg	< 0.001
	CT-NB-L-I	-450.560 efg	< 0.001
	NT-NB-H-I	-533.340 fg	< 0.001
	NT-NB-L-I	-624.750 g	< 0.001
	CT-NB-H-I	-630.090 g	< 0.001
Quadratic	CT-NB-H-I	32.488 a	< 0.001
	NT-NB-L-I	30.973 a	< 0.001
	NT-NB-H-I	26.424 ab	< 0.001
	CT-NB-L-I	23.105 ab	< 0.001
	CT-B-H-I	21.245 abc	< 0.001
	NT-B-L-I	19.730 abc	< 0.001
	NT-B-H-I	15.180 bcd	0.004
	CT-B-L-I	11.861 bcd	0.026
	CT-B-L-NI	11.748 cd	0.027
	NT-B-H-NI	6.581 d	0.215
	CT-B-H-NI	2.439 de	0.645
	NT-B-L-NI	0.865 de	0.870
	CT-NB-L-NI	-9.990 ef	0.060
	NT-NB-H-NI	-15.157 f	0.005
	CT-NB-H-NI	-19.299 f	< 0.001
	NT-NB-L-NI	-20.873 f	< 0.001

† Significant linear term indicates a trend over time that is statistically different from 0, and a significant quadratic term indicates a shift in the trend over time.

Table 18. Summary of the separation of estimate parameters of specific treatment combinations, i.e. residue-level [high (H) and low (L)], burning [burn (B) and no-burn (NB)], tillage [conventional tillage (CT) and no-tillage (NT)], and irrigation [irrigated (I) and non-irrigated (NI)], for magnesium content (kg ha^{-1}) trends over time between 2007 and 2014 in a wheat-soybean, double-crop system in eastern Arkansas. Coefficient estimates are categorized according to least significant differences (LSD), and coefficient estimates sharing a letter category are statistically similar.

Significant regression term†	Treatment combination	Coefficient estimate	*P*
Linear	CT-NB-H-NI	-13.982 a	0.334
	NT-NB-L-NI	-14.149 a	0.328
	CT-NB-L-NI	-17.664 a	0.222
	NT-NB-H-NI	-21.246 a	0.142
	CT-B-L-I	-39.221 ab	0.007
	CT-B-H-I	-44.523 ab	0.002
	NT-B-H-I	-49.491 ab	0.001
	NT-B-L-I	-51.191 ab	0.001
	CT-B-H-NI	-66.097 b	< 0.001
	NT-B-L-NI	-66.264 b	< 0.001
	CT-B-L-NI	-69.779 b	< 0.001
	NT-B-H-NI	-73.362 b	< 0.001
	CT-NB-L-I	-175.100 c	< 0.001
	CT-NB-H-I	-180.400 c	< 0.001
	NT-NB-H-I	-185.370 c	< 0.001
	NT-NB-L-I	-187.070 c	< 0.001
Quadratic	NB-I	9.581 a	< 0.001
	B-NI	3.223 b	< 0.001
	B-I	3.025 c	< 0.001
	NB-NI	0.626 d	0.405

† Significant linear term indicates a trend over time that is statistically different from 0, and a significant quadratic term indicates a shift in the trend over time.

Table 19. Summary of the separation of estimate parameters of specific treatment combinations, i.e. burning [burn (B) and no-burn (NB)], tillage [conventional tillage (CT) and no-tillage (NT)], and irrigation [irrigated (I) and non-irrigated (NI)], for manganese content (kg ha^{-1}) trends over time between 2007 and 2014 in a wheat-soybean, double-crop system in eastern Arkansas. Coefficient estimates are categorized according to least significant differences (LSD), and coefficient estimates sharing a letter category are statistically similar.

Significant regression term†	Treatment combination	Coefficient estimate	*P*
Linear	CT-NB-I	100.490 a	< 0.001
	NT-NB-I	97.112 a	0.002
	CT-B-NI	52.793 b	0.001
	NT-B-NI	49.414 b	0.001
	CT-NB-NI	40.422 b	0.008
	NT-NB-NI	37.044 b	0.015
	CT-B-I	22.898 b	0.132
	NT-B-I	19.520 b	0.199
Quadratic	B-I	-0.907 a	0.254
	NB-NI	-1.987 a	0.013
	B-NI	-2.586 a	0.001
	NB-I	-4.614 b	< 0.001

† Significant linear term indicates a trend over time that is statistically different from 0, and a significant quadratic term indicates a shift in the trend over time.

Table 20. Summary of the separation of estimate parameters of specific treatment combinations, i.e. residue-level [high (H) and low (L)], burning [burn (B) and no-burn (NB)], tillage [conventional tillage (CT) and no-tillage (NT)], and irrigation [irrigated (I) and non-irrigated (NI)], for potassium content (kg ha^{-1}) trends over time between 2007 and 2014 in a wheat-soybean, double-crop system in eastern Arkansas. Coefficient estimates are categorized according to least significant differences (LSD), and coefficient estimates sharing a letter category are statistically similar.

Significant regression term†	Treatment combination	Coefficient estimate	*P*
Linear	CT-NB-H-NI	14.370 a	0.395
	NT-NB-L-NI	-20.187 ab	0.232
	NT-B-H-NI	-29.996 abc	0.076
	CT-B-H-NI	-34.156 bcd	0.044
	NT-B-L-NI	-42.001 bcd	0.013
	CT-B-L-I	-44.093 bcd	0.009
	NT-B-H-I	-46.386 bcd	0.006
	CT-NB-L-I	-47.346 bcd	0.005
	CT-B-L-NI	-50.672 bcd	0.003
	CT-NB-L-NI	-52.872 bcd	0.002
	NT-NB-H-NI	-53.970 bcd	0.002
	CT-NB-H-I	-55.793 bcd	0.001
	NT-NB-L-I	-62.038 bcde	< 0.001
	NT-NB-H-I	-73.395 cde	< 0.001
	NT-B-L-I	-80.816 de	< 0.001
	CT-B-H-I	-103.270 e	< 0.001
Quadratic	CT-B-H-I	4.730 a	< 0.001
	NT-B-L-I	3.824 ab	< 0.001
	NT-NB-H-I	3.325 abc	< 0.001
	NT-NB-L-I	2.945 abc	< 0.001
	CT-B-L-NI	2.714 abc	0.002
	NT-NB-H-NI	2.610 abc	0.003
	CT-NB-L-NI	2.484 abc	0.005
	CT-NB-H-I	2.366 abc	0.008
	CT-B-L-I	2.244 bc	0.012
	CT-NB-L-I	2.014 bc	0.023
	NT-B-H-I	1.950 bc	0.028
	NT-B-L-NI	1.789 bc	0.044
	CT-B-H-NI	1.435 bc	0.105
	NT-B-H-NI	1.234 c	0.163
	NT-NB-L-NI	0.911 c	0.303
	CT-NB-H-NI	-0.928 d	0.294

† Significant linear term indicates a trend over time that is statistically different from 0, and a significant quadratic term indicates a shift in the trend over time.

Table 21. Summary of the separation of estimate parameters of specific treatment combinations, i.e. residue-level [high (H) and low (L)], burning [burn (B) and no-burn (NB)], tillage [conventional tillage (CT) and no-tillage (NT)], and irrigation [irrigated (I) and non-irrigated (NI)], for zinc content (kg ha^{-1}) trends over time between 2007 and 2014 in a wheat-soybean, double-crop system in eastern Arkansas. Coefficient estimates are categorized according to least significant differences (LSD), and coefficient estimates sharing a letter category are statistically similar.

Significant regression term†	Treatment combination	Coefficient estimate	*P*
Linear	NT-B-H-NI	0.855 a	< 0.001
	NT-NB-L-I	0.604 ab	0.002
	NT-NB-L-NI	0.465 abcv	0.014
	CT-NB-H-I	0.415 abc	0.029
	CT-B-L-NI	0.356 abc	0.060
	CT-NB-L-I	0.304 bc	0.108
	CT-NB-H-NI	0.276 bc	0.145
	NT-B-L-NI	0.218 bcd	0.248
	NT-NB-H-I	0.215 bcd	0.255
	NT-B-H-I	0.202 bcd	0.285
	CT-NB-L-NI	0.165 bcd	0.383
	CT-B-H-NI	0.124 bcd	0.512
	NT-NB-H-NI	0.076 cde	0.687
	CT-B-L-I	-0.297 def	0.117
	NT-B-L-I	-0.435 ef	0.022
	CT-B-H-I	-0.529 f	0.005
Quadratic	CT-B-H-I	0.024 a	0.014
	NT-B-L-I	0.020 ab	0.045
	CT-B-L-I	0.014 abc	0.162
	NT-NB-H-NI	-0.001 abcd	0.887
	CT-B-H-NI	-0.007 bcde	0.482
	CT-NB-L-NI	-0.007 bcde	0.475
	NT-NB-H-I	-0.009 cde	0.350
	NT-B-L-NI	-0.012 cde	0.241
	CT-NB-H-NI	-0.013 cde	0.184
	NT-B-H-I	-0.013 de	0.184
	CT-NB-L-I	-0.015 de	0.133
	CT-B-L-NI	-0.018 def	0.076
	CT-NB-H-I	-0.021 def	0.034
	NT-NB-L-NI	-0.022 def	0.024
	NT-NB-L-I	-0.030 ef	0.002
	NT-B-H-NI	-0.045 f	< 0.001

† Significant linear term indicates a trend over time that is statistically different from 0, and a significant quadratic term indicates a shift in the trend over time.

Appendix C

This appendix contains an example of the SAS program used for the ANCOVA of residue level (N), burning (B), tillage (T), irrigation (I), and time (Year) effects on soil and plant properties trends over time. The full ANCOVA model was reduced using a hierarchal principle to remove non-significant terms, except when non-significant terms participated in higher-order, complex treatment combinations.

```
Title 'Ryan, N: Analysis of Co variance with all trt combn';

Data asa;
length trtcode1 trtcode2 trtcode3 trtcode4 $16;

infile 'OMcontent_sas_soils_data_2014.csv' firstobs=2 delimiter= "," lrecl=400;;

input obs year actualyear Plot tblock bblock rep T $ B $  N $ I $
    OMcontent ;
year2=year*year;
Year3=year2*year;


label obs='observation #'
    year='year'
    plot='plot #'
    tblock='tillage block'
    bblock='burning block'
    rep='replication'
    T='tillage'
    B='burning'
    N='NRate level'
    I='Irrigation'
    OMcontent='Total carbon content (kg/m2)'
    year2='year square'
    year3='year cube';
run;

proc sort data=asa;
by T B N I year;
quit;
ods rtf file='Final_OMcontent_122214.rtf' style=journal bodytitle;
title3 'P<.05';
proc mixed data=asa method=type3 ;
class T B N I rep;
model OMcontent= T
            I
            B
            N
            T*I
            T*B
            I*B
            T*N
            I*N
            B*N
            T*I*B
            T*I*N
            T*B*N
            I*B*N
            T*I*B*N
            year
            year*T
            year*I
            year*B
            year*N
```

```
               year*T*I
               year*T*N
               year*I*N
               year*T*I*N
               year2
               year2*I
              / ddfm=kr ;
random rep(T B N I) ;
id T B N I;

estimate 'Intercept CT-B-H-I'  intercept 1 t 1 0 b 1 0 n 1 0 i 1 0 t*b 1 0 0 0 t*n 1 0 0 0 t*i 1 0 0 0 b*n 1 0 0 0 b*i 1 0
0 0 n*i 1 0 0 0 t*b*n 1 0 0 0 0 0 0 0 t*b*i 1 0 0 0 0 0 0 0 t*n*i 1 0 0 0 0 0 0 0 b*n*i 1 0 0 0 0 0 0 0 t*b*n*i 1 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 ;
estimate 'Intercept CT-B-H-NI' intercept 1 t 1 0 b 1 0 n 1 0 i 0 1 t*b 1 0 0 0 t*n 1 0 0 0 t*i 0 1 0 0 b*n 1 0 0 0 b*i 0 1
0 0 n*i 0 1 0 0 t*b*n 1 0 0 0 0 0 0 0 t*b*i 0 1 0 0 0 0 0 0 t*n*i 0 1 0 0 0 0 0 0 b*n*i 0 1 0 0 0 0 0 0 t*b*n*i 0 1 0 0 0
0 0 0 0 0 0 0 0 0 0 0 ;
estimate 'Intercept CT-B-L-I'  intercept 1 t 1 0 b 1 0 n 0 1 i 1 0 t*b 1 0 0 0 t*n 0 1 0 0 t*i 1 0 0 0 b*n 0 1 0 0 b*i 1 0
0 0 n*i 0 0 1 0 t*b*n 0 1 0 0 0 0 0 0 t*b*i 1 0 0 0 0 0 0 0 t*n*i 0 0 1 0 0 0 0 0 b*n*i 0 0 1 0 0 0 0 0 t*b*n*i 0 0 1 0 0
0 0 0 0 0 0 0 0 0 0 0 ;
estimate 'Intercept CT-B-L-NI' intercept 1 t 1 0 b 1 0 n 0 1 i 0 1 t*b 1 0 0 0 t*n 0 1 0 0 t*i 0 1 0 0 b*n 0 1 0 0 b*i 0 1
0 0 n*i 0 0 0 1 t*b*n 0 1 0 0 0 0 0 0 t*b*i 0 1 0 0 0 0 0 0 t*n*i 0 0 0 1 0 0 0 0 b*n*i 0 0 0 1 0 0 0 0 t*b*n*i 0 0 0 1 0
0 0 0 0 0 0 0 0 0 0 0 ;

estimate 'Intercept CT-NB-H-I'  intercept 1 t 1 0 b 0 1 n 1 0 i 1 0 t*b 0 1 0 0 t*n 1 0 0 0 t*i 1 0 0 0 b*n 0 0 1 0 b*i 0
0 1 0 n*i 1 0 0 0 t*b*n 0 0 1 0 0 0 0 0 t*b*i 0 0 1 0 0 0 0 0 t*n*i 1 0 0 0 0 0 0 0 b*n*i 0 0 0 0 1 0 0 0 t*b*n*i 0 0 0 0
1 0 0 0 0 0 0 0 0 0 0 0 ;
estimate 'Intercept CT-NB-H-NI' intercept 1 t 1 0 b 0 1 n 1 0 i 0 1 t*b 0 1 0 0 t*n 1 0 0 0 t*i 0 1 0 0 b*n 0 0 1 0 b*i 0
0 0 1 n*i 0 1 0 0 t*b*n 0 0 1 0 0 0 0 0 t*b*i 0 0 0 1 0 0 0 0 t*n*i 0 1 0 0 0 0 0 0 b*n*i 0 0 0 0 0 1 0 0 t*b*n*i 0 0 0 0
0 1 0 0 0 0 0 0 0 0 0 0 ;
estimate 'Intercept CT-NB-L-I'  intercept 1 t 1 0 b 0 1 n 0 1 i 1 0 t*b 0 1 0 0 t*n 0 1 0 0 t*i 1 0 0 0 b*n 0 0 0 1 b*i 0 0
1 0 n*i 0 0 1 0 t*b*n 0 0 0 1 0 0 0 0 t*b*i 0 0 1 0 0 0 0 0 t*n*i 0 0 1 0 0 0 0 0 b*n*i 0 0 0 0 0 0 1 0 t*b*n*i 0 0 0 0 0
0 1 0 0 0 0 0 0 0 0 0 ;
estimate 'Intercept CT-NB-L-NI' intercept 1 t 1 0 b 0 1 n 0 1 i 0 1 t*b 0 1 0 0 t*n 0 1 0 0 t*i 0 1 0 0 b*n 0 0 0 1 b*i 0
0 0 1 n*i 0 0 0 1 t*b*n 0 0 0 1 0 0 0 0 t*b*i 0 0 0 1 0 0 0 0 t*n*i 0 0 0 1 0 0 0 0 b*n*i 0 0 0 0 0 0 0 1 t*b*n*i 0 0 0 0
0 0 0 1 0 0 0 0 0 0 0 0 ;

estimate 'Intercept NT-B-H-I'   intercept 1 t 0 1 b 1 0 n 1 0 i 1 0 t*b 0 0 1 0 t*n 0 0 1 0 t*i 0 0 1 0 b*n 1 0 0 0 b*i 1 0
0 0 n*i 1 0 0 0 t*b*n 0 0 0 0 1 0 0 0 t*b*i 0 0 0 0 1 0 0 0 t*n*i 0 0 0 0 1 0 0 0 b*n*i 1 0 0 0 0 0 0 0 t*b*n*i 0 0 0 0 0
0 0 0 1 0 0 0 0 0 0 0 ;
estimate 'Intercept NT-B-H-NI'  intercept 1 t 0 1 b 1 0 n 1 0 i 0 1 t*b 0 0 1 0 t*n 0 0 1 0 t*i 0 0 0 1 b*n 1 0 0 0 b*i 0
1 0 0 n*i 0 1 0 0 t*b*n 0 0 0 0 1 0 0 0 t*b*i 0 0 0 0 0 1 0 0 t*n*i 0 0 0 0 0 1 0 0 b*n*i 0 1 0 0 0 0 0 0 t*b*n*i 0 0 0 0
0 0 0 0 0 1 0 0 0 0 0 0 ;
estimate 'Intercept NT-B-L-I'   intercept 1 t 0 1 b 1 0 n 0 1 i 1 0 t*b 0 0 1 0 t*n 0 0 0 1 t*i 0 0 1 0 b*n 0 1 0 0 b*i 1 0
0 0 n*i 0 0 1 0 t*b*n 0 0 0 0 0 1 0 0 t*b*i 0 0 0 0 1 0 0 0 t*n*i 0 0 0 0 0 0 1 0 b*n*i 0 0 1 0 0 0 0 0 t*b*n*i 0 0 0 0 0
0 0 0 0 0 1 0 0 0 0 0 ;
estimate 'Intercept NT-B-L-NI'  intercept 1 t 0 1 b 1 0 n 0 1 i 0 1 t*b 0 0 1 0 t*n 0 0 0 1 t*i 0 0 0 1 b*n 0 1 0 0 b*i 0
1 0 0 n*i 0 0 0 1 t*b*n 0 0 0 0 0 1 0 0 t*b*i 0 0 0 0 0 1 0 0 t*n*i 0 0 0 0 0 0 0 1 b*n*i 0 0 0 1 0 0 0 0 t*b*n*i 0 0 0 0
0 0 0 0 0 0 0 1 0 0 0 0 ;

estimate 'Intercept NT-NB-H-I'  intercept 1 t 0 1 b 0 1 n 1 0 i 1 0 t*b 0 0 0 1 t*n 0 0 1 0 t*i 0 0 1 0 b*n 0 0 1 0 b*i 0
0 1 0 n*i 1 0 0 0 t*b*n 0 0 0 0 0 0 1 0 t*b*i 0 0 0 0 0 0 1 0 t*n*i 0 0 0 0 1 0 0 0 b*n*i 0 0 0 0 1 0 0 0 t*b*n*i 0 0 0 0
0 0 0 0 0 0 0 0 1 0 0 0 ;
estimate 'Intercept NT-NB-H-NI' intercept 1 t 0 1 b 0 1 n 1 0 i 0 1 t*b 0 0 0 1 t*n 0 0 1 0 t*i 0 0 0 1 b*n 0 0 1 0 b*i 0
0 0 1 n*i 0 1 0 0 t*b*n 0 0 0 0 0 0 1 0 t*b*i 0 0 0 0 0 0 0 1 t*n*i 0 0 0 0 0 1 0 0 b*n*i 0 0 0 0 0 1 0 0 t*b*n*i 0 0 0 0
0 0 0 0 0 0 0 0 0 1 0 0 ;
```

```
estimate 'Intercept NT-NB-L-I'  intercept 1 t 0 1 b 0 1 n 0 1 i 1 0 t*b 0 0 0 1 t*n 0 0 0 1 t*i 0 0 1 0 b*n 0 0 0 1 b*i 0
0 1 0 n*i 0 0 1 0 t*b*n 0 0 0 0 0 0 0 1 t*b*i 0 0 0 0 0 0 1 0 t*n*i 0 0 0 0 0 0 1 0 b*n*i 0 0 0 0 0 0 1 0 t*b*n*i 0 0 0 0
0 0 0 0 0 0 0 0 0 0 1 0 ;
estimate 'Intercept NT-NB-L-NI' intercept 1 t 0 1 b 0 1 n 0 1 i 0 1 t*b 0 0 0 1 t*n 0 0 0 1 t*i 0 0 0 1 b*n 0 0 0 1 b*i 0
0 0 1 n*i 0 0 0 1 t*b*n 0 0 0 0 0 0 0 1 t*b*i 0 0 0 0 0 0 0 1 t*n*i 0 0 0 0 0 0 0 1 b*n*i 0 0 0 0 0 0 0 1 t*b*n*i 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 1 ;

estimate 'Slope CT-B-H-I'  year 1 year*t 1 0 year*b 1 0 year*n 1 0 year*i 1 0 year*t*n 1 0 0 0 year*t*i 1 0 0 0
year*n*i 1 0 0 0 year*t*n*i 1 0 0 0 0 0 0 0 ;
estimate 'Slope CT-B-H-NI' year 1 year*t 1 0 year*b 1 0 year*n 1 0 year*i 0 1 year*t*n 1 0 0 0 year*t*i 0 1 0 0
year*n*i 0 1 0 0 year*t*n*i 0 1 0 0 0 0 0 0 ;
estimate 'Slope CT-B-L-I'  year 1 year*t 1 0 year*b 1 0 year*n 0 1 year*i 1 0 year*t*n 0 1 0 0 year*t*i 1 0 0 0
year*n*i 0 0 1 0 year*t*n*i 0 0 1 0 0 0 0 0 ;
estimate 'Slope CT-B-L-NI' year 1 year*t 1 0 year*b 1 0 year*n 0 1 year*i 0 1 year*t*n 0 1 0 0 year*t*i 0 1 0 0
year*n*i 0 0 0 1 year*t*n*i 0 0 0 1 0 0 0 0 ;

estimate 'Slope CT-NB-H-I'  year 1 year*t 1 0 year*b 0 1 year*n 1 0 year*i 1 0 year*t*n 1 0 0 0 year*t*i 1 0 0 0
year*n*i 1 0 0 0 year*t*n*i 1 0 0 0 0 0 0 0 ;
estimate 'Slope CT-NB-H-NI' year 1 year*t 1 0 year*b 0 1 year*n 1 0 year*i 0 1 year*t*n 1 0 0 0 year*t*i 0 1 0 0
year*n*i 0 1 0 0 year*t*n*i 0 1 0 0 0 0 0 0 ;
estimate 'Slope CT-NB-L-I'  year 1 year*t 1 0 year*b 0 1 year*n 0 1 year*i 1 0 year*t*n 0 1 0 0 year*t*i 1 0 0 0
year*n*i 0 0 1 0 year*t*n*i 0 0 1 0 0 0 0 0 ;
estimate 'Slope CT-NB-L-NI' year 1 year*t 1 0 year*b 0 1 year*n 0 1 year*i 0 1 year*t*n 0 1 0 0 year*t*i 0 1 0 0
year*n*i 0 0 0 1 year*t*n*i 0 0 0 1 0 0 0 0 ;

estimate 'Slope NT-B-H-I'  year 1 year*t 0 1 year*b 1 0 year*n 1 0 year*i 1 0 year*t*n 0 0 1 0 year*t*i 0 0 1 0
year*n*i 1 0 0 0 year*t*n*i 0 0 0 0 1 0 0 0 ;
estimate 'Slope NT-B-H-NI' year 1 year*t 0 1 year*b 1 0 year*n 1 0 year*i 0 1 year*t*n 0 0 1 0 year*t*i 0 0 0 1
year*n*i 0 1 0 0 year*t*n*i 0 0 0 0 0 1 0 0 ;
estimate 'Slope NT-B-L-I'  year 1 year*t 0 1 year*b 1 0 year*n 0 1 year*i 1 0 year*t*n 0 0 0 1 year*t*i 0 0 1 0
year*n*i 0 0 1 0 year*t*n*i 0 0 0 0 0 0 1 0 ;
estimate 'Slope NT-B-L-NI' year 1 year*t 0 1 year*b 1 0 year*n 0 1 year*i 0 1 year*t*n 0 0 0 1 year*t*i 0 0 0 1
year*n*i 0 0 0 1 year*t*n*i 0 0 0 0 0 0 0 1 ;

estimate 'Slope NT-NB-H-I'  year 1 year*t 0 1 year*b 0 1 year*n 1 0 year*i 1 0 year*t*n 0 0 1 0 year*t*i 0 0 1 0
year*n*i 1 0 0 0 year*t*n*i 0 0 0 0 1 0 0 0 ;
estimate 'Slope NT-NB-H-NI' year 1 year*t 0 1 year*b 0 1 year*n 1 0 year*i 0 1 year*t*n 0 0 1 0 year*t*i 0 0 0 1
year*n*i 0 1 0 0 year*t*n*i 0 0 0 0 0 1 0 0 ;
estimate 'Slope NT-NB-L-I'  year 1 year*t 0 1 year*b 0 1 year*n 0 1 year*i 1 0 year*t*n 0 0 0 1 year*t*i 0 0 1 0
year*n*i 0 0 1 0 year*t*n*i 0 0 0 0 0 0 1 0 ;
estimate 'Slope NT-NB-L-NI' year 1 year*t 0 1 year*b 0 1 year*n 0 1 year*i 0 1 year*t*n 0 0 0 1 year*t*i 0 0 0 1
year*n*i 0 0 0 1 year*t*n*i 0 0 0 0 0 0 0 1 ;

estimate 'Quad coeff I'  year2 1 year2*i 1 0 ;
estimate 'Quad coeff NI' year2 1 year2*i 0 1 ;
run;

Quit;
proc print data=new noobs;
  where actualyear < 2014 and abs(student) > 3.0;
  var year actualyear Plot tblock bblock rep T B N I OMcontent predicted sepred
    residual seresid student;
run;

ods rtf close;
```

Appendix D

This appendix contains raw data from Chapter 2 used for the ANCOVA of residue level [i.e., Nrate; high (H) and low (L)], burning [burn (B) and no-burn (NB)], tillage [conventional tillage (CT) and no-tillage (NT)], and irrigation [irrigated (I) and non-irrigated (NI)], and time (Year) effects on soil and plant properties trends over time.

Soy yield (Mg ha^{-1}), wheat yield (Mg ha^{-1}), residue level (Mg ha^{-1}), spring bulk density (g cm^{-3}), summer bulk density (g cm^{-3}), pH, electrical conductivity (EC; ds m^{-1}), phosphorus (P; kg ha^{-1}), potassium (K; kg ha^{-1}), and calcium (Ca; kg ha^{-1}).

obs #	yr	actual yr	plot	T block	B block	rep	till	burn	Nrate	Irr	Soy Yld	Wht Yld	Res Level	Spring BD	Summer BD	pH	EC	P	K	Ca
1	6	2007	1	1	1	1	CT	NB	H	I	2.34	0.47	5.34	1.19	1.19	7.56	0.08	36	137	1661
2	6	2007	2	1	1	1	NT	NB	L	I	2.55	0.7	5.41	1.20	1.12	7.48	0.07	33	123	1791
3	6	2007	3	2	1	1	NT	NB	H	I	2.58	0.49	4.77	1.29	1.25	7.32	0.08	38	120	1746
4	6	2007	4	2	1	1	CT	NB	L	I	2.3	0.89	10.66	1.22	1.14	7.44	0.08	35	114	1642
5	6	2007	5	3	1	2	NT	NB	L	I	2.89	1.9	9.75	1.15	1.22	7.45	0.08	36	137	1894
6	6	2007	6	3	1	2	CT	NB	H	I	3.22	1.61	10.82	1.26	1.20	7.38	0.09	33	124	1758
7	6	2007	7	1	1	2	CT	NB	L	I	1.55	0.48	8.43	1.22	1.18	7.07	0.10	38	149	1752
8	6	2007	8	1	1	2	NT	NB	H	I	1.35	0.25	5.42	1.25	1.21	6.98	0.07	37	162	1743
9	6	2007	9	2	1	3	NT	NB	L	I	1.28	0.37	5.54	1.19	1.22	6.98	0.07	41	169	1973
10	6	2007	10	2	1	3	CT	NB	H	I	1.68	0.56	5.16	1.23	1.17	7.14	0.08	47	162	1800
11	6	2007	11	3	1	3	NT	NB	H	I	1.23	1.85	7.93	1.16	1.17	6.93	0.08	34	134	1715
12	6	2007	12	3	1	3	CT	NB	L	I	1.59	1.5	11.63	1.19	1.18	7.04	0.08	34	148	1864
13	6	2007	13	1	1	1	CT	B	L	I	2.78	1.23	9.16	1.19	1.19	7.73	0.10	44	106	1629
14	6	2007	14	1	1	1	NT	B	L	I	2.16	0.64	6.69	1.14	1.22	7.54	0.08	32	123	1484
15	6	2007	15	2	1	1	NT	B	H	I	1.82	1.55	9.72	1.20	1.22	7.46	0.08	29	127	1637
16	6	2007	16	2	1	2	CT	B	L	I	2.12	0.71	6.54	1.18	1.20	7.38	0.08	41	99	1380
17	6	2007	17	3	1	2	NT	B	H	I	2.17	1.75	8.37	1.17	1.28	7.47	0.08	26	88	1295
18	6	2007	18	3	1	3	CT	B	L	I	2.18	0.91	5.95	1.18	1.29	7.28	0.08	35	129	1727
19	6	2007	19	1	1	1	CT	B	H	I	2.38	0.43	7.21	1.21	1.22	6.96	0.09	46	187	2126
20	6	2007	20	1	1	3	NT	B	H	I	1.45	1.49	7.11	1.22	1.21	6.97	0.08	41	182	2029
21	6	2007	21	2	1	2	NT	B	L	I	1.49	1.16	8.98	1.24	1.20	7.03	0.08	40	174	2245
22	6	2007	22	2	1	2	CT	B	H	I	0.67	0.74	5.10	1.18	1.15	7.13	0.10	51	209	2282
23	6	2007	23	3	1	3	NT	B	L	I	1.45	0.97	5.43	1.22	1.25	7.28	0.10	43	178	2122
24	6	2007	24	3	1	3	CT	B	H	I	1.71	1.15	5.59	1.22	1.26	7.34	0.09	46	165	2033
25	6	2007	25	1	2	1	CT	B	H	NI	2.61	1.52	6.42	1.22	1.22	7.50	0.07	33	132	1720

obs #	yr	actual yr	plot	T block	B block	rep	till	burn	Nrate	Irr	Soy Yld	Wht Yld	Res Level	Spring BD	Summer BD	pH	EC	P	K	Ca
26	6	2007	26	1	2	1	NT	B	H	NI	2.46	2.54	8.07	1.22	1.05	7.44	0.08	29	115	1767
27	6	2007	27	2	2	2	NT	B	H	NI	2.44	2.7	8.09	1.28	1.15	7.40	0.07	31	127	1940
28	6	2007	28	2	2	1	CT	B	L	NI	2.32	2.18	9.61	1.21	1.25	7.58	0.08	28	115	1816
29	6	2007	29	3	2	3	NT	B	H	NI	2.68	1.34	7.06	1.20	1.16	7.50	0.09	34	122	1776
30	6	2007	30	3	2	2	CT	B	L	NI	2.68	0.86	6.37	1.25	1.19	7.52	0.08	32	113	1741
31	6	2007	31	1	2	3	CT	B	L	NI	1.38	1.52	11.79	1.05	1.23	6.85	0.07	37	169	1929
32	6	2007	32	1	2	1	NT	B	L	NI	1.23	1.42	9.89	1.15	1.23	6.97	0.07	35	158	1738
33	6	2007	33	2	2	2	NT	B	L	NI	1.31	2.18	8.90	1.16	1.13	6.92	0.07	36	162	1924
34	6	2007	34	2	2	2	CT	B	H	NI	1.45	0.59	5.01	1.23	1.16	7.14	0.07	46	161	1897
35	6	2007	35	3	2	3	NT	B	L	NI	1.22	0.39	5.82	1.13	1.17	7.18	0.07	40	155	1778
36	6	2007	36	3	2	3	CT	B	H	NI	1.2	0.91	4.64	1.17	1.19	6.97	0.06	36	142	1824
37	6	2007	37	1	2	1	CT	NB	H	NI	2.77	1.5	6.28	1.12	1.21	7.70	0.08	42	122	1471
38	6	2007	38	1	2	1	NT	NB	L	NI	2.68	2.77	10.61	1.25	1.22	7.45	0.08	26	96	1270
39	6	2007	39	2	2	1	NT	NB	H	NI	2.29	1.49	7.32	1.22	1.26	7.45	0.08	26	105	1342
40	6	2007	40	2	2	2	CT	NB	H	NI	2.72	2.18	10.25	1.21	1.22	7.51	0.08	33	77	1285
41	6	2007	41	3	2	2	NT	NB	L	NI	2.72	1.13	6.96	1.22	1.28	7.22	0.07	31	94	1163
42	6	2007	42	3	2	3	CT	NB	H	NI	2.04	2.97	10.00	1.17	1.24	7.38	0.07	26	92	1206
43	6	2007	43	1	2	1	CT	NB	L	NI	1.24	0.4	4.79	1.22	1.18	7.07	0.08	53	187	2039
44	6	2007	44	1	2	2	NT	NB	H	NI	1.66	1.92	9.60	1.26	1.20	6.90	0.07	40	150	2048
45	6	2007	45	2	2	3	NT	NB	L	NI	1.23	0.87	5.98	1.28	1.21	7.08	0.07	42	155	1920
46	6	2007	46	2	2	2	CT	NB	L	NI	2.06	2.42	8.66	1.20	1.22	7.10	0.08	38	153	2149
47	6	2007	47	3	2	3	NT	NB	H	NI	1.61	0.94	5.74	1.21	1.23	7.06	0.09	45	194	2059
48	6	2007	48	3	2	3	CT	NB	L	NI	1.24	3.15	9.88	1.23	1.22	7.05	0.10	34	152	1970
49	7	2008	1	1	1	1	CT	NB	H	I	0.95	1.57	10.84	1.18	1.18	7.47	0.17	51	115	1474
50	7	2008	2	1	1	1	NT	NB	L	I	2.93	1.57	8.84	1.19	1.20	7.58	0.15	38	114	1264
51	7	2008	3	2	1	1	NT	NB	H	I	3.30	2.40	10.91	1.25	1.23	7.01	0.11	27	113	1230
52	7	2008	4	2	1	1	CT	NB	L	I	3.08	0.53	3.56	1.20	1.19	7.20	0.14	30	123	1269
53	7	2008	5	3	1	2	NT	NB	L	I	4.61	0.86	6.61	1.18	1.24	7.40	0.10	27	110	1306
54	7	2008	6	3	1	2	CT	NB	H	I	3.79	1.55	10.01	1.25	1.23	7.40	0.10	23	119	1503

obs #	yr	actual yr	plot	T block	B block	rep	till	burn	Nrate	Irr	Soy Yld	Wht Yld	Res Level	Spring BD	Summer BD	pH	EC	P	K	Ca
55	7	2008	7	1	1	2	CT	NB	L	I	1.60	0.36	7.43	1.20	1.22	7.40	0.13	38	103	1324
56	7	2008	8	1	1	2	NT	NB	H	I	1.68	0.82	9.41	1.24	1.23	7.32	0.10	24	83	1235
57	7	2008	9	2	1	3	NT	NB	L	I	3.91	0.80	5.33	1.21	1.25	7.25	0.09	23	94	1183
58	7	2008	10	2	1	3	CT	NB	H	I	3.60	0.18	9.72	1.21	1.20	7.24	0.12	25	97	1285
59	7	2008	11	3	1	3	NT	NB	H	I	1.06	1.34	11.27	1.17	1.25	7.04	0.12	24	103	1290
60	7	2008	12	3	1	3	CT	NB	L	I	3.75	0.80	9.29	1.21	1.25	7.35	0.12	30	127	1559
61	7	2008	13	1	1	1	CT	B	L	I	4.08	0.91	7.96	1.18	1.23	7.37	0.14	34	128	1485
62	7	2008	14	1	1	1	NT	B	L	I	3.94	1.91	8.62	1.15	1.25	7.47	0.15	29	128	1566
63	7	2008	15	2	1	1	NT	B	H	I	3.74	1.39	12.25	1.19	1.27	7.43	0.12	29	139	1668
64	7	2008	16	2	1	2	CT	B	L	I	3.95	0.45	5.06	1.16	1.24	7.35	0.16	34	128	1553
65	7	2008	17	3	1	2	NT	B	H	I	3.41	1.52	8.59	1.21	1.28	7.40	0.13	27	130	1689
66	7	2008	18	3	1	3	CT	B	L	I	4.03	0.65	3.71	1.20	1.27	7.45	0.12	33	121	1638
67	7	2008	19	1	1	1	CT	B	H	I	3.57	0.87	12.68	1.19	1.23	7.36	0.13	30	119	1385
68	7	2008	20	1	1	3	NT	B	H	I	3.83	1.06	11.75	1.22	1.26	7.35	0.14	31	138	1541
69	7	2008	21	2	1	2	NT	B	L	I	3.79	0.21	8.64	1.23	1.29	7.42	0.12	35	127	1586
70	7	2008	22	2	1	2	CT	B	H	I	3.91	0.65	15.91	1.21	1.22	7.46	0.13	30	124	1547
71	7	2008	23	3	1	3	NT	B	L	I	3.87	0.45	6.57	1.24	1.32	7.37	0.13	32	125	1579
72	7	2008	24	3	1	3	CT	B	H	I	3.96	0.43	8.81	1.22	1.26	7.36	0.13	33	123	1660
73	7	2008	25	1	2	4	CT	B	H	NI	3.72	1.76	11.74	1.23	1.27	6.90	0.13	34	138	1591
74	7	2008	26	1	2	4	NT	B	H	NI	3.01	2.38	8.04	1.21	1.21	6.78	0.12	35	143	1470
75	7	2008	27	2	2	5	NT	B	H	NI	2.75	2.52	9.89	1.24	1.25	6.83	0.12	30	135	1421
76	7	2008	28	2	2	4	CT	B	L	NI	3.29	0.44	7.24	1.19	1.25	6.91	0.13	36	148	1500
77	7	2008	29	3	2	6	NT	B	H	NI	2.67	2.13	10.40	1.20	1.27	6.92	0.12	33	145	1534
78	7	2008	30	3	2	5	CT	B	L	NI	2.92	0.96	6.28	1.24	1.26	7.06	0.11	40	158	1687
79	7	2008	31	1	2	6	CT	B	L	NI	3.98	0.70	5.06	1.16	1.22	7.13	0.12	40	141	1493
80	7	2008	32	1	2	4	NT	B	L	NI	3.43	1.13	10.21	1.19	1.30	7.06	0.13	44	152	1613
81	7	2008	33	2	2	5	NT	B	L	NI	2.78	0.66	6.74	1.19	1.21	6.95	0.14	41	159	1639
82	7	2008	34	2	2	5	CT	B	H	NI	3.10	0.93	7.45	1.21	1.21	7.03	0.10	37	156	1649
83	7	2008	35	3	2	6	NT	B	L	NI	2.23	0.75	8.43	1.17	1.24	6.96	0.11	33	144	1596

obs #	yr	actual yr	plot	T block	B block	rep	till	burn	Nrate	Irr	Soy Yld	Wht Yld	Res Level	Spring BD	Summer BD	pH	EC	P	K	Ca
84	7	2008	36	3	2	6	CT	B	H	NI	2.11	3.81	7.00	1.19	1.26	7.08	0.11	37	153	1695
85	7	2008	37	1	2	4	CT	NB	H	NI	4.08	1.12	12.45	1.16	1.26	7.12	0.13	40	143	1799
86	7	2008	38	1	2	4	NT	NB	L	NI	3.05	1.05	5.02	1.25	1.28	7.27	0.12	52	149	1986
87	7	2008	39	2	2	4	NT	NB	H	NI	1.23	1.36	12.73	1.22	1.32	7.13	0.12	37	145	1854
88	7	2008	40	2	2	5	CT	NB	H	NI	2.18	1.80	11.60	1.24	1.24	7.20	0.11	39	153	1959
89	7	2008	41	3	2	5	NT	NB	L	NI	3.41	1.62	6.01	1.22	1.33	7.20	0.12	39	149	1902
90	7	2008	42	3	2	6	CT	NB	H	NI	1.79	2.35	7.62	1.19	1.28	7.27	0.11	31	137	1923
91	7	2008	43	1	2	4	CT	NB	L	NI	3.47	1.07	8.02	1.23	1.24	7.26	0.13	49	170	1860
92	7	2008	44	1	2	5	NT	NB	H	NI	1.07	1.67	13.05	1.25	1.29	7.33	0.11	35	137	2027
93	7	2008	45	2	2	6	NT	NB	L	NI	1.81	1.07	6.34	1.27	1.28	7.27	0.13	43	172	2110
94	7	2008	46	2	2	5	CT	NB	L	NI	2.55	0.45	5.07	1.22	1.27	7.28	0.12	41	163	1964
95	7	2008	47	3	2	6	NT	NB	H	NI	.	2.49	7.83	1.20	1.29	7.08	0.11	32	144	1869
96	7	2008	48	3	2	6	CT	NB	L	NI	2.88	1.09	7.23	1.20	1.28	7.30	0.11	39	159	1981
97	8	2009	1	1	1	1	CT	NB	H	I	2.64	4.67	5.43	1.16	1.17	7.01	0.11	52	89	1259
98	8	2009	2	1	1	1	NT	NB	L	I	2.72	1.60	2.21	1.17	1.27	7.26	0.11	47	81	1296
99	8	2009	3	2	1	1	NT	NB	H	I	2.68	2.46	6.47	1.22	1.21	6.72	0.08	25	71	1136
100	8	2009	4	2	1	1	CT	NB	L	I	2.78	1.62	4.44	1.18	1.24	7.16	0.09	33	74	1227
101	8	2009	5	3	1	2	NT	NB	L	I	2.76	1.55	3.41	1.20	1.26	7.15	0.09	29	86	1364
102	8	2009	6	3	1	2	CT	NB	H	I	2.54	3.68	5.87	1.23	1.27	7.02	0.10	26	84	1429
103	8	2009	7	1	1	2	CT	NB	L	I	2.48	2.31	4.01	1.18	1.27	7.33	0.09	43	78	1294
104	8	2009	8	1	1	2	NT	NB	H	I	2.79	2.20	8.12	1.23	1.25	7.16	0.13	29	76	1251
105	8	2009	9	2	1	3	NT	NB	L	I	2.20	1.83	4.04	1.22	1.28	6.96	0.09	36	87	1392
106	8	2009	10	2	1	3	CT	NB	H	I	2.21	3.53	4.15	1.19	1.22	7.14	0.12	27	67	1273
107	8	2009	11	3	1	3	NT	NB	H	I	2.88	3.06	4.20	1.19	1.34	7.03	0.10	36	90	1602
108	8	2009	12	3	1	3	CT	NB	L	I	2.29	2.09	2.13	1.23	1.33	7.43	0.10	45	100	1564
109	8	2009	13	1	1	1	CT	B	L	I	3.01	3.04	4.64	1.16	1.27	7.21	0.11	34	96	1460
110	8	2009	14	1	1	1	NT	B	L	I	2.34	2.79	2.87	1.16	1.27	6.94	0.13	26	96	1482
111	8	2009	15	2	1	1	NT	B	H	I	2.15	4.22	7.34	1.19	1.32	6.78	0.12	41	92	1682
112	8	2009	16	2	1	2	CT	B	L	I	1.93	2.74	3.01	1.15	1.28	7.36	0.12	28	87	1492

obs #	yr	actual yr	plot	T block	B block	rep	till	burn	Nrate	Irr	Soy Yld	Wht Yld	Res Level	Spring BD	Summer BD	pH	EC	P	K	Ca
113	8	2009	17	3	1	2	NT	B	H	I	2.10	3.78	4.62	1.24	1.28	7.00	0.10	41	94	1663
114	8	2009	18	3	1	3	CT	B	L	I	2.37	2.67	3.64	1.22	1.26	7.32	0.10	40	92	1442
115	8	2009	19	1	1	1	CT	B	H	I	2.47	4.42	4.87	1.18	1.24	6.86	0.11	39	92	1427
116	8	2009	20	1	1	3	NT	B	H	I	2.31	4.05	4.91	1.23	1.31	7.16	0.11	33	86	1609
117	8	2009	21	2	1	2	NT	B	L	I	2.42	2.93	2.61	1.22	1.38	7.30	0.12	41	91	1738
118	8	2009	22	2	1	2	CT	B	H	I	2.28	4.51	4.16	1.25	1.28	7.20	0.12	37	95	1718
119	8	2009	23	3	1	3	NT	B	L	I	2.25	2.71	2.85	1.27	1.38	7.36	0.10	33	89	1711
120	8	2009	24	3	1	3	CT	B	H	I	2.35	3.82	4.36	1.22	1.25	7.23	0.11	39	94	1746
121	8	2009	25	1	2	4	CT	B	H	NI	2.32	4.46	3.83	1.23	1.33	6.88	0.12	40	104	1719
122	8	2009	26	1	2	4	NT	B	H	NI	2.69	4.05	5.08	1.20	1.37	6.45	0.11	35	97	1501
123	8	2009	27	2	2	5	NT	B	H	NI	2.47	4.29	5.50	1.19	1.35	6.45	0.11	35	105	1516
124	8	2009	28	2	2	4	CT	B	L	NI	2.05	3.16	3.01	1.17	1.26	6.75	0.11	43	119	1642
125	8	2009	29	3	2	6	NT	B	H	NI	2.56	4.00	4.76	1.20	1.39	6.60	0.11	37	100	1545
126	8	2009	30	3	2	5	CT	B	L	NI	2.29	2.60	3.31	1.23	1.32	7.04	0.10	46	120	1744
127	8	2009	31	1	2	6	CT	B	L	NI	2.06	2.90	3.18	1.26	1.22	6.78	0.12	50	129	1780
128	8	2009	32	1	2	4	NT	B	L	NI	2.32	2.44	2.38	1.23	1.37	6.81	0.11	43	104	1688
129	8	2009	33	2	2	5	NT	B	L	NI	2.87	2.65	3.36	1.23	1.29	6.93	0.10	44	132	1844
130	8	2009	34	2	2	5	CT	B	H	NI	1.86	4.07	4.72	1.18	1.27	6.66	0.12	38	110	1627
131	8	2009	35	3	2	6	NT	B	L	NI	2.26	3.31	3.77	1.22	1.31	6.85	0.11	39	143	1871
132	8	2009	36	3	2	6	CT	B	H	NI	2.23	4.07	4.98	1.20	1.33	6.44	0.12	44	124	1724
133	8	2009	37	1	2	4	CT	NB	H	NI	2.19	4.04	5.41	1.20	1.31	6.86	0.12	44	131	1948
134	8	2009	38	1	2	4	NT	NB	L	NI	2.56	2.18	3.03	1.25	1.34	7.15	0.11	53	138	2143
135	8	2009	39	2	2	4	NT	NB	H	NI	2.30	3.60	3.82	1.23	1.39	6.82	0.12	41	115	1979
136	8	2009	40	2	2	5	CT	NB	H	NI	2.69	3.96	5.15	1.27	1.26	7.11	0.14	48	124	2256
137	8	2009	41	3	2	5	NT	NB	L	NI	2.68	2.10	3.25	1.22	1.37	6.88	0.11	45	138	2026
138	8	2009	42	3	2	6	CT	NB	H	NI	2.40	4.05	6.06	1.22	1.33	7.00	0.12	38	103	2111
139	8	2009	43	1	2	4	CT	NB	L	NI	1.89	2.91	5.23	1.24	1.30	6.96	0.13	56	145	2031
140	8	2009	44	1	2	5	NT	NB	H	NI	2.48	4.00	4.72	1.24	1.38	7.14	0.12	44	124	2224
141	8	2009	45	2	2	6	NT	NB	L	NI	2.14	2.55	2.86	1.25	1.36	7.10	0.11	45	128	2161

obs #	yr	actual yr	plot	T block	B block	rep	till	burn	Nrate	Irr	Soy Yld	Wht Yld	Res Level	Spring BD	Summer BD	pH	EC	P	K	Ca
142	8	2009	46	2	2	5	CT	NB	L	NI	2.60	2.36	4.97	1.24	1.33	7.05	0.13	52	133	2210
143	8	2009	47	3	2	6	NT	NB	H	NI	2.34	3.83	7.54	1.20	1.35	6.91	0.12	34	126	2094
144	8	2009	48	3	2	6	CT	NB	L	NI	2.22	2.32	2.22	1.17	1.35	6.92	0.12	46	122	1984
145	9		1	1	1	1	CT	NB	H	I	1.10	5.17	11.32	1.25	1.29	6.90	0.08	37	64	1376
146	9	2010	2	1	1	1	NT	NB	L	I	1.66	2.73	4.52	1.26	1.29	7.28	0.06	40	68	1289
147	9	2010	3	2	1	1	NT	NB	H	I	1.46	3.01	8.57	1.24	.	6.45	0.07	22	67	1085
148	9	2010	4	2	1	1	CT	NB	L	I	1.15	2.59	5.93	1.29	.	7.03	0.08	31	75	1453
149	9	2010	5	3	1	2	NT	NB	L	I	1.17	2.40	6.72	1.26	1.29	6.90	0.06	22	68	1295
150	9	2010	6	3	1	2	CT	NB	H	I	0.82	3.45	6.50	1.31	1.27	6.70	0.07	22	70	1514
151	9	2010	7	1	1	2	CT	NB	L	I	1.76	2.68	9.07	1.29	1.25	7.08	0.07	33	66	1398
152	9	2010	8	1	1	2	NT	NB	H	I	1.73	3.64	13.58	1.20	1.12	6.14	0.07	24	57	946
153	9	2010	9	2	1	3	NT	NB	L	I	1.35	2.49	16.24	1.27	.	6.78	0.07	23	64	1191
154	9	2010	10	2	1	3	CT	NB	H	I	1.35	3.53	7.67	1.28	.	7.06	0.07	22	61	1358
155	9	2010	11	3	1	3	NT	NB	H	I	1.20	3.47	10.78	1.27	1.31	6.43	0.08	20	57	1133
156	9	2010	12	3	1	3	CT	NB	L	I	1.82	2.30	5.44	1.17	1.31	6.94	0.10	25	81	1703
157	9	2010	13	1	1	1	CT	B	L	I	1.85	1.90	4.12	1.28	1.29	6.92	0.07	28	82	1335
158	9	2010	14	1	1	1	NT	B	L	I	0.90	2.70	4.55	1.29	1.36	6.90	0.07	23	79	1590
159	9	2010	15	2	1	1	NT	B	H	I	1.07	3.79	6.86	1.27	.	6.60	0.09	21	78	1725
160	9	2010	16	2	1	2	CT	B	L	I	2.22	1.66	8.96	1.28	.	6.82	0.07	32	95	1541
161	9	2010	17	3	1	2	NT	B	H	I	1.34	3.45	7.18	1.31	1.33	7.04	0.09	31	91	1768
162	9	2010	18	3	1	3	CT	B	L	I	2.15	1.53	6.93	1.28	1.23	6.98	0.08	41	84	1774
163	9	2010	19	1	1	1	CT	B	H	I	1.42	3.40	7.03	1.32	1.23	6.74	0.07	27	68	1437
164	9	2010	20	1	1	3	NT	B	H	I	1.55	3.21	5.32	1.31	1.30	7.12	0.07	23	61	1628
165	9	2010	21	2	1	2	NT	B	L	I	1.50	2.01	3.48	1.29	.	7.12	0.08	32	79	1713
166	9	2010	22	2	1	2	CT	B	H	I	2.08	1.28	4.55	1.29	.	6.74	0.08	33	76	1669
167	9	2010	23	3	1	3	NT	B	L	I	1.67	2.07	3.61	1.34	1.28	7.24	0.09	32	71	1761
168	9	2010	24	3	1	3	CT	B	H	I	2.16	3.07	6.22	1.23	1.22	6.94	0.09	27	70	1607
169	9	2010	25	1	2	4	CT	B	H	NI	0.70	2.62	9.69	1.32	1.24	6.55	0.06	27	93	1687
170	9	2010	26	1	2	4	NT	B	H	NI	0.72	3.57	6.58	1.34	1.33	6.50	0.07	26	97	1633

obs #	yr	actual yr	plot	T block	B block	rep	till	burn	Nrate	Irr	Soy Yld	Wht Yld	Res Level	Spring BD	Summer BD	pH	EC	P	K	Ca
171	9	2010	27	2	2	5	NT	B	H	NI	0.85	3.62	7.76	1.30	.	6.21	0.08	30	94	1580
172	9	2010	28	2	2	4	CT	B	L	NI	0.89	2.29	8.95	1.35	.	6.30	0.08	31	106	1664
173	9	2010	29	3	2	6	NT	B	H	NI	0.78	3.36	10.76	1.31	1.37	6.21	0.09	28	107	1658
174	9	2010	30	3	2	5	CT	B	L	NI	0.60	2.10	5.58	1.29	1.31	6.61	0.09	37	105	1745
175	9	2010	31	1	2	6	CT	B	L	NI	0.84	2.06	8.79	1.32	1.31	6.37	0.06	33	103	1715
176	9	2010	32	1	2	4	NT	B	L	NI	1.01	1.76	15.20	1.32	1.32	6.28	0.07	36	99	1662
177	9	2010	33	2	2	5	NT	B	L	NI	0.81	2.14	6.86	1.29	.	9.32	0.10	40	117	1734
178	9	2010	34	2	2	5	CT	B	H	NI	0.94	2.50	5.71	1.27	.	6.20	0.08	31	102	1584
179	9	2010	35	3	2	6	NT	B	L	NI	0.95	2.20	10.20	1.33	1.20	6.58	0.11	30	112	1996
180	9	2010	36	3	2	6	CT	B	H	NI	0.62	3.09	9.04	1.29	1.30	6.23	0.08	28	106	1767
181	9	2010	37	1	2	4	CT	NB	H	NI	0.67	3.18	6.24	1.30	1.29	6.40	0.07	29	97	1880
182	9	2010	38	1	2	4	NT	NB	L	NI	0.90	1.61	7.96	1.30	1.26	6.51	0.09	44	117	1955
183	9	2010	39	2	2	4	NT	NB	H	NI	0.71	2.97	10.90	1.38	.	6.53	0.13	34	98	2163
184	9	2010	40	2	2	5	CT	NB	H	NI	0.54	3.21	8.80	1.32	.	6.46	0.12	38	110	2264
185	9	2010	41	3	2	5	NT	NB	L	NI	0.55	1.42	7.24	1.35	1.36	6.91	0.08	30	107	2172
186	9	2010	42	3	2	6	CT	NB	H	NI	0.57	3.15	9.91	1.29	1.26	6.70	0.08	47	138	1962
187	9	2010	43	1	2	4	CT	NB	L	NI	0.72	1.67	10.61	1.30	1.25	6.61	0.07	46	138	2003
188	9	2010	44	1	2	5	NT	NB	H	NI	0.69	2.90	7.10	1.35	1.33	6.71	0.08	39	109	2056
189	9	2010	45	2	2	6	NT	NB	L	NI	0.31	1.77	7.51	1.28	.	6.81	0.08	33	133	2100
190	9	2010	46	2	2	5	CT	NB	L	NI	0.46	1.96	4.28	1.31	.	6.74	0.09	38	125	2114
191	9	2010	47	3	2	6	NT	NB	H	NI	0.49	2.69	5.66	1.38	1.28	6.85	0.09	35	118	2314
192	9	2010	48	3	2	6	CT	NB	L	NI	0.81	1.54	5.51	1.36	1.32	7.03	0.09	40	135	2409
193	10	2011	1	1	1	1	CT	NB	H	I	2.89	2.67	5.98	1.29	1.30	6.30	0.20	60	63	1216
194	10	2011	2	1	1	1	NT	NB	L	I	3.21	2.12	5.44	1.29	1.23	6.74	0.20	48	96	1142
195	10	2011	3	2	1	1	NT	NB	H	I	2.67	3.14	7.76	1.27	1.28	6.32	0.23	47	63	1151
196	10	2011	4	2	1	1	CT	NB	L	I	3.04	1.51	2.75	1.26	1.24	6.65	0.20	45	82	1240
197	10	2011	5	3	1	2	NT	NB	L	I	3.43	1.56	2.87	1.32	1.32	6.55	0.16	33	71	1281
198	10	2011	6	3	1	2	CT	NB	H	I	3.27	2.35	7.05	1.35	1.26	6.32	0.26	47	74	1544
199	10	2011	7	1	1	2	CT	NB	L	I	2.66	2.40	2.47	1.28	1.29	6.35	0.21	57	65	1269

obs #	yr	actual yr	plot	T block	B block	rep	till	burn	Nrate	Irr	Soy Yld	Wht Yld	Res Level	Spring BD	Summer BD	pH	EC	P	K	Ca
200	10	2011	8	1	1	2	NT	NB	H	I	2.74	3.50	9.67	1.23	1.27	6.71	0.20	38	51	1200
201	10	2011	9	2	1	3	NT	NB	L	I	3.30	2.45	5.28	1.20	1.29	6.28	0.24	47	76	1203
202	10	2011	10	2	1	3	CT	NB	H	I	2.82	2.67	4.52	1.28	1.25	6.63	0.20	39	60	1280
203	10	2011	11	3	1	3	NT	NB	H	I	2.49	3.31	7.26	1.21	1.27	6.23	0.27	46	60	1333
204	10	2011	12	3	1	3	CT	NB	L	I	2.53	1.59	3.70	1.31	1.26	6.70	0.16	38	75	1470
205	10	2011	13	1	1	1	CT	B	L	I	4.09	2.10	5.43	1.31	1.32	6.81	0.17	42	74	1472
206	10	2011	14	1	1	1	NT	B	L	I	3.13	3.35	4.51	1.27	1.25	6.16	0.21	37	94	1356
207	10	2011	15	2	1	1	NT	B	H	I	3.05	4.46	8.94	1.30	1.28	6.24	0.18	34	80	1527
208	10	2011	16	2	1	2	CT	B	L	I	3.00	2.08	8.87	1.23	1.28	6.58	0.22	48	94	1485
209	10	2011	17	3	1	2	NT	B	H	I	3.18	4.14	8.18	1.32	1.27	6.32	0.17	33	78	1514
210	10	2011	18	3	1	3	CT	B	L	I	2.86	2.47	5.70	1.30	1.30	6.70	0.19	47	78	1649
211	10	2011	19	1	1	1	CT	B	H	I	3.30	2.58	9.81	1.31	1.28	6.68	0.19	38	69	1488
212	10	2011	20	1	1	3	NT	B	H	I	2.73	3.09	14.89	1.33	1.30	6.40	0.22	42	66	1399
213	10	2011	21	2	1	2	NT	B	L	I	2.90	2.27	8.10	1.33	1.29	6.80	0.22	47	86	1734
214	10	2011	22	2	1	2	CT	B	H	I	3.27	2.80	6.86	1.30	1.25	6.66	0.27	43	75	1644
215	10	2011	23	3	1	3	NT	B	L	I	3.06	2.57	3.04	1.25	1.27	6.78	0.24	40	86	1511
216	10	2011	24	3	1	3	CT	B	H	I	2.43	3.10	6.28	1.33	1.29	6.49	0.22	45	79	1632
217	10	2011	25	1	2	4	CT	B	H	NI	2.30	3.50	6.36	1.39	1.27	6.19	0.19	38	89	1717
218	10	2011	26	1	2	4	NT	B	H	NI	0.69	4.66	6.05	1.29	1.33	6.10	0.19	45	92	1685
219	10	2011	27	2	2	5	NT	B	H	NI	0.69	4.83	7.52	1.32	1.36	6.18	0.19	46	90	1632
220	10	2011	28	2	2	4	CT	B	L	NI	1.88	2.90	3.43	1.29	1.31	6.18	0.22	47	88	1591
221	10	2011	29	3	2	6	NT	B	H	NI	1.54	4.73	13.66	1.32	1.33	6.31	0.18	41	84	1502
222	10	2011	30	3	2	5	CT	B	L	NI	1.19	2.88	3.65	1.32	1.30	6.02	0.24	51	93	1618
223	10	2011	31	1	2	6	CT	B	L	NI	2.20	2.66	5.33	1.31	1.24	6.12	0.24	54	102	1615
224	10	2011	32	1	2	4	NT	B	L	NI	1.64	2.36	2.96	1.29	1.33	6.10	0.18	54	91	1534
225	10	2011	33	2	2	5	NT	B	L	NI	1.53	2.14	3.36	1.24	1.28	6.21	0.23	54	103	1591
226	10	2011	34	2	2	5	CT	B	H	NI	2.72	3.50	7.16	1.33	1.32	5.94	0.28	54	103	1582
227	10	2011	35	3	2	6	NT	B	L	NI	1.19	2.52	3.36	1.26	1.25	5.94	0.23	47	100	1450
228	10	2011	36	3	2	6	CT	B	H	NI	1.39	4.25	6.71	1.29	1.28	5.94	0.27	43	91	1524

obs #	yr	actual yr	plot	T block	B block	rep	till	burn	Nrate	Irr	Soy Yld	Wht Yld	Res Level	Spring BD	Summer BD	pH	EC	P	K	Ca
229	10	2011	37	1	2	4	CT	NB	H	NI	1.94	2.55	10.06	1.28	1.20	5.90	0.30	67	107	1777
230	10	2011	38	1	2	4	NT	NB	L	NI	1.79	2.22	3.95	1.30	1.20	6.27	0.18	53	99	1797
231	10	2011	39	2	2	4	NT	NB	H	NI	1.71	3.70	6.46	1.33	1.32	6.13	0.23	47	87	1958
232	10	2011	40	2	2	5	CT	NB	H	NI	1.60	3.94	8.98	1.25	1.27	5.97	0.25	45	90	1702
233	10	2011	41	3	2	5	NT	NB	L	NI	1.78	2.39	4.02	1.33	1.35	6.45	0.23	59	107	1911
234	10	2011	42	3	2	6	CT	NB	H	NI	2.15	2.89	9.75	1.34	1.20	6.23	0.23	44	97	1825
235	10	2011	43	1	2	4	CT	NB	L	NI	2.04	1.92	3.86	1.29	1.27	6.24	0.23	61	116	1828
236	10	2011	44	1	2	5	NT	NB	H	NI	1.52	4.17	9.23	1.29	1.31	6.17	0.27	54	106	1787
237	10	2011	45	2	2	6	NT	NB	L	NI	1.45	3.06	10.01	1.35	1.28	6.46	0.19	56	103	2167
238	10	2011	46	2	2	5	CT	NB	L	NI	1.80	2.98	4.32	1.29	1.24	6.23	0.23	51	110	1790
239	10	2011	47	3	2	6	NT	NB	H	NI	1.25	5.06	9.89	1.19	1.25	5.81	0.22	47	104	1639
240	10	2011	48	3	2	6	CT	NB	L	NI	1.26	2.07	3.07	1.31	1.28	6.50	0.26	56	95	1903
241	11	2012	1	1	1	1	CT	NB	H	I	3.07	1.87	3.12	1.33	1.30	7.36	0.13	34	49	1384
242	11	2012	2	1	1	1	NT	NB	L	I	2.54	1.72	7.04	1.26	1.23	6.83	0.10	24	56	1199
243	11	2012	3	2	1	1	NT	NB	H	I	2.51	1.41	12.13	1.26	1.28	6.40	0.09	18	51	1091
244	11	2012	4	2	1	1	CT	NB	L	I	3.10	0.47	4.46	1.24	1.24	7.18	0.12	27	75	1298
245	11	2012	5	3	1	2	NT	NB	L	I	2.75	1.45	6.83	1.32	1.32	6.86	0.11	22	62	1294
246	11	2012	6	3	1	2	CT	NB	H	I	2.63	2.99	2.98	1.24	1.26	6.90	0.10	21	59	1434
247	11	2012	7	1	1	2	CT	NB	L	I	2.57	0.36	5.37	1.23	1.29	7.26	0.12	35	69	1300
248	11	2012	8	1	1	2	NT	NB	H	I	3.08	3.55	7.13	1.29	1.27	6.75	0.11	21	47	1048
249	11	2012	9	2	1	3	NT	NB	L	I	2.98	1.81	4.96	1.25	1.29	6.71	0.10	21	61	1180
250	11	2012	10	2	1	3	CT	NB	H	I	2.89	2.12	11.57	1.26	1.25	6.90	0.13	20	52	1318
251	11	2012	11	3	1	3	NT	NB	H	I	1.80	3.05	9.89	1.22	1.27	6.10	0.11	18	59	1046
252	11	2012	12	3	1	3	CT	NB	L	I	2.21	1.37	3.94	1.37	1.25	7.30	0.11	25	65	1570
253	11	2012	13	1	1	1	CT	B	L	I	1.77	0.29	3.90	1.23	1.32	7.26	0.12	35	79	1520
254	11	2012	14	1	1	1	NT	B	L	I	0.26	1.92	4.46	1.36	1.25	6.73	0.07	18	71	1466
255	11	2012	15	2	1	1	NT	B	H	I	0.24	3.09	9.13	1.38	1.28	7.37	0.11	24	69	1830
256	11	2012	16	2	1	2	CT	B	L	I	2.71	1.12	2.52	1.30	1.28	7.14	0.12	31	80	1672
257	11	2012	17	3	1	2	NT	B	H	I	2.02	3.15	12.34	1.35	1.27	7.13	0.11	17	62	1641

obs #	yr	actual yr	plot	T block	B block	rep	till	burn	Nrate	Irr	Soy Yld	Wht Yld	Res Level	Spring BD	Summer BD	pH	EC	P	K	Ca
258	11	2012	18	3	1	3	CT	B	L	I	3.09	0.99	2.75	1.28	1.30	7.34	0.12	46	75	1735
259	11	2012	19	1	1	1	CT	B	H	I	2.07	1.76	6.70	1.34	1.28	7.25	0.10	29	68	1499
260	11	2012	20	1	1	3	NT	B	H	I	2.18	2.71	8.75	1.27	1.30	7.36	0.09	18	62	1489
261	11	2012	21	2	1	2	NT	B	L	I	2.53	1.84	6.34	1.34	1.29	7.27	0.11	30	73	1700
262	11	2012	22	2	1	2	CT	B	H	I	2.67	1.36	8.87	1.34	1.25	7.16	0.12	31	78	1596
263	11	2012	23	3	1	3	NT	B	L	I	2.36	1.76	5.62	1.26	1.27	7.27	0.10	23	73	1593
264	11	2012	24	3	1	3	CT	B	H	I	3.13	1.20	4.28	1.29	1.29	7.38	0.10	28	71	1663
265	11	2012	25	1	2	4	CT	B	H	NI	0.13	1.43	8.80	1.25	1.27	5.83	0.22	34	90	1408
266	11	2012	26	1	2	4	NT	B	H	NI	0.01	4.14	8.15	1.30	1.33	5.87	0.15	26	81	1456
267	11	2012	27	2	2	5	NT	B	H	NI	0.01	4.04	6.00	1.26	1.36	6.02	0.08	20	71	1387
268	11	2012	28	2	2	4	CT	B	L	NI	0.03	1.85	2.52	1.29	1.31	6.54	0.08	27	106	1557
269	11	2012	29	3	2	6	NT	B	H	NI	0.01	3.54	6.97	1.29	1.33	6.00	0.12	22	78	1418
270	11	2012	30	3	2	5	CT	B	L	NI	0.34	2.07	2.10	1.31	1.30	6.57	0.06	24	78	1544
271	11	2012	31	1	2	6	CT	B	L	NI	0.11	1.39	3.63	1.29	1.24	6.45	0.09	33	92	1598
272	11	2012	32	1	2	4	NT	B	L	NI	0.14	1.17	4.01	1.31	1.33	6.62	0.07	35	81	1579
273	11	2012	33	2	2	5	NT	B	L	NI	0.11	1.17	3.77	1.28	1.28	6.77	0.09	29	100	1562
274	11	2012	34	2	2	5	CT	B	H	NI	0.07	2.14	7.58	1.25	1.32	6.16	0.14	22	82	1451
275	11	2012	35	3	2	6	NT	B	L	NI	0.02	1.08	2.60	1.25	1.25	6.82	0.04	23	78	1577
276	11	2012	36	3	2	6	CT	B	H	NI	0.01	3.16	5.40	1.26	1.28	6.08	0.11	23	80	1513
277	11	2012	37	1	2	4	CT	NB	H	NI	0.13	1.30	3.47	1.23	1.20	5.54	0.19	22	95	1607
278	11	2012	38	1	2	4	NT	NB	L	NI	0.60	0.39	3.66	1.20	1.20	6.23	0.07	30	104	1611
279	11	2012	39	2	2	4	NT	NB	H	NI	0.34	2.16	5.32	1.27	1.32	6.34	0.06	18	82	1619
280	11	2012	40	2	2	5	CT	NB	H	NI	0.06	0.92	4.19	1.24	1.27	6.40	0.10	26	135	1678
281	11	2012	41	3	2	5	NT	NB	L	NI	0.35	0.65	4.14	1.25	1.35	6.55	0.05	26	99	1667
282	11	2012	42	3	2	6	CT	NB	H	NI	0.04	1.45	3.60	1.21	1.20	6.51	0.07	24	115	1667
283	11	2012	43	1	2	4	CT	NB	L	NI	0.03	0.15	3.41	1.23	1.26	6.62	0.06	29	111	1800
284	11	2012	44	1	2	5	NT	NB	H	NI	0.31	2.58	7.77	1.28	1.31	6.50	0.08	25	79	1774
285	11	2012	45	2	2	6	NT	NB	L	NI	0.24	0.71	7.64	1.28	1.28	6.78	0.05	30	108	1910
286	11	2012	46	2	2	5	CT	NB	L	NI	0.11	0.26	2.13	1.25	1.24	6.80	0.06	28	89	1777

obs #	yr	actual yr	plot	T block	B block	rep	till	burn	Nrate	Irr	Soy Yld	Wht Yld	Res Level	Spring BD	Summer BD	pH	EC	P	K	Ca
287	11	2012	47	3	2	6	NT	NB	H	NI	0.26	2.57	3.73	1.30	1.25	6.10	0.21	29	124	1860
288	11	2012	48	3	2	6	CT	NB	L	NI	0.03	0.40	2.77	1.28	1.28	6.94	0.08	33	116	1872
289	12	2013	1	1	1	1	CT	NB	H	I	2.55	1.64	10.03	1.31	1.24	7.21	0.06	29	60	1324
290	12	2013	2	1	1	1	NT	NB	L	I	1.78	1.52	7.47	1.22	1.23	7.13	0.08	38	114	1438
291	12	2013	3	2	1	1	NT	NB	H	I	1.87	1.82	5.72	1.28	1.24	6.98	0.08	22	67	1294
292	12	2013	4	2	1	1	CT	NB	L	I	2.21	0.96	7.56	1.25	1.27	7.15	0.08	29	91	1439
293	12	2013	5	3	1	2	NT	NB	L	I	1.98	1.78	10.33	1.24	1.30	7.08	0.07	22	93	1298
294	12	2013	6	3	1	2	CT	NB	H	I	2.21	4.28	12.38	1.32	1.24	7.00	0.06	22	76	1541
295	12	2013	7	1	1	2	CT	NB	L	I	0.30	0.35	4.72	1.26	1.26	7.18	0.07	32	81	1420
296	12	2013	8	1	1	2	NT	NB	H	I	0.82	2.27	10.35	1.21	1.26	6.90	0.07	20	64	1402
297	12	2013	9	2	1	3	NT	NB	L	I	1.78	1.10	5.79	1.23	1.27	6.98	0.07	23	81	1240
298	12	2013	10	2	1	3	CT	NB	H	I	2.10	1.91	9.56	1.30	1.21	7.18	0.07	19	75	1525
299	12	2013	11	3	1	3	NT	NB	H	I	2.13	3.18	10.30	1.28	1.22	6.84	0.06	27	74	1484
300	12	2013	12	3	1	3	CT	NB	L	I	3.52	1.44	4.06	1.35	1.31	7.33	0.06	31	108	1659
301	12	2013	13	1	1	1	CT	B	L	I	2.48	0.22	7.63	1.31	1.34	7.21	0.08	36	119	1560
302	12	2013	14	1	1	1	NT	B	L	I	1.86	1.21	3.51	1.32	1.33	7.12	0.06	31	139	1471
303	12	2013	15	2	1	1	NT	B	H	I	2.65	4.15	9.31	1.27	1.36	6.60	0.06	20	79	1543
304	12	2013	16	2	1	2	CT	B	L	I	2.19	0.63	5.84	1.30	1.21	7.31	0.09	42	140	1885
305	12	2013	17	3	1	2	NT	B	H	I	1.15	3.81	5.28	1.32	1.38	7.24	0.06	34	95	1847
306	12	2013	18	3	1	3	CT	B	L	I	2.09	2.76	4.39	1.32	1.29	7.31	0.06	32	115	1773
307	12	2013	19	1	1	1	CT	B	H	I	1.92	3.61	4.45	1.31	1.27	7.14	0.06	28	83	1563
308	12	2013	20	1	1	3	NT	B	H	I	1.67	1.80	6.31	1.34	1.30	7.31	0.06	20	92	1579
309	12	2013	21	2	1	2	NT	B	L	I	2.76	1.10	5.16	1.24	1.25	7.30	0.07	28	149	1653
310	12	2013	22	2	1	2	CT	B	H	I	1.93	1.76	10.76	1.34	1.20	7.31	0.10	28	93	1747
311	12	2013	23	3	1	3	NT	B	L	I	2.31	1.07	7.54	1.37	1.22	7.73	0.06	29	102	1727
312	12	2013	24	3	1	3	CT	B	H	I	1.47	2.92	4.97	1.28	1.28	7.30	0.08	26	77	1794
313	12	2013	25	1	2	4	CT	B	H	NI	0.47	2.46	4.48	1.32	1.28	5.62	0.08	38	143	1486
314	12	2013	26	1	2	4	NT	B	H	NI	0.68	4.01	6.68	1.33	1.28	5.55	0.08	28	88	1459
315	12	2013	27	2	2	5	NT	B	H	NI	1.49	4.36	4.21	1.36	1.34	5.90	0.08	24	140	1568

obs #	yr	actual yr	plot	T block	B block	rep	till	burn	Nrate	Irr	Soy Yld	Wht Yld	Res Level	Spring BD	Summer BD	pH	EC	P	K	Ca
316	12	2013	28	2	2	4	CT	B	L	NI	1.14	2.84	5.29	1.32	1.29	6.30	0.07	35	295	1551
317	12	2013	29	3	2	6	NT	B	H	NI	0.83	3.89	4.86	1.28	1.29	5.91	0.09	32	109	1663
318	12	2013	30	3	2	5	CT	B	L	NI	0.76	1.09	3.56	1.30	1.29	6.51	0.06	36	227	1590
319	12	2013	31	1	2	6	CT	B	L	NI	0.06	2.43	4.31	1.28	1.27	6.15	0.08	38	104	1626
320	12	2013	32	1	2	4	NT	B	L	NI	0.55	1.70	3.37	1.34	1.19	6.52	0.06	39	158	1735
321	12	2013	33	2	2	5	NT	B	L	NI	0.28	1.91	3.30	1.27	1.25	6.12	0.07	39	96	1672
322	12	2013	34	2	2	5	CT	B	H	NI	0.18	1.28	3.51	1.33	1.25	6.07	0.06	38	118	1601
323	12	2013	35	3	2	6	NT	B	L	NI	0.92	2.03	4.82	1.26	1.33	6.55	0.07	33	99	1690
324	12	2013	36	3	2	6	CT	B	H	NI	0.39	4.24	5.79	1.33	1.30	6.16	0.08	37	160	1751
325	12	2013	37	1	2	4	CT	NB	H	NI	0.22	3.78	6.96	1.27	1.31	6.22	0.08	32	110	1712
326	12	2013	38	1	2	4	NT	NB	L	NI	0.63	3.12	6.21	1.36	1.26	6.65	0.05	39	123	1991
327	12	2013	39	2	2	4	NT	NB	H	NI	0.72	1.55	5.19	1.33	1.29	6.38	0.06	29	112	1862
328	12	2013	40	2	2	5	CT	NB	H	NI	0.72	3.63	6.24	1.35	1.23	6.17	0.06	33	107	1786
329	12	2013	41	3	2	5	NT	NB	L	NI	0.35	1.67	4.90	1.37	1.36	6.60	0.06	40	97	2034
330	12	2013	42	3	2	6	CT	NB	H	NI	0.50	3.29	6.71	1.27	1.22	6.30	0.06	33	111	1800
331	12	2013	43	1	2	4	CT	NB	L	NI	0.51	1.78	3.80	1.30	1.27	6.53	0.08	42	118	1963
332	12	2013	44	1	2	5	NT	NB	H	NI	0.35	4.13	6.00	1.33	1.29	6.26	0.05	36	128	1786
333	12	2013	45	2	2	6	NT	NB	L	NI	0.04	1.78	4.83	1.31	1.32	6.15	0.05	35	209	1763
334	12	2013	46	2	2	5	CT	NB	L	NI	0.03	1.55	4.76	1.29	1.31	6.50	0.08	37	149	1866
335	12	2013	47	3	2	6	NT	NB	H	NI	0.54	2.62	7.29	1.27	1.30	6.26	0.07	37	127	1901
336	12	2013	48	3	2	6	CT	NB	L	NI	0.34	1.95	4.04	1.35	1.03	6.82	0.05	35	163	2011
337	13	2014	1	1	1	1	CT	NB	H	I	1.39	0.97	.	1.23	1.07	7.42	0.08	31	53	1476
338	13	2014	2	1	1	1	NT	NB	L	I	1.36	0.26	.	1.25	1.17	7.20	0.07	26	55	1254
339	13	2014	3	2	1	1	NT	NB	H	I	0.53	1.38	.	1.28	1.26	7.21	0.05	15	59	1312
340	13	2014	4	2	1	1	CT	NB	L	I	1.69	0.24	.	1.26	1.19	7.40	0.06	20	77	1469
341	13	2014	5	3	1	2	NT	NB	L	I	2.12	0.71	.	1.24	1.15	6.97	0.11	22	62	1543
342	13	2014	6	3	1	2	CT	NB	H	I	1.83	0.39	.	1.33	1.21	7.41	0.08	19	63	1680
343	13	2014	7	1	1	2	CT	NB	L	I	0.85	0.23	.	1.18	1.24	7.34	0.08	33	60	1446
344	13	2014	8	1	1	2	NT	NB	H	I	1.28	0.52	.	1.19	1.17	7.03	0.09	23	62	1388

obs #	yr	actual yr	plot	T block	B block	rep	till	burn	Nrate	Irr	Soy Yld	Wht Yld	Res Level	Spring BD	Summer BD	pH	EC	P	K	Ca
345	13	2014	9	2	1	3	NT	NB	L	I	1.49	0.63	.	1.23	1.18	7.20	0.08	19	75	1414
346	13	2014	10	2	1	3	CT	NB	H	I	1.42	1.89	.	1.23	1.17	7.33	0.07	18	59	1620
347	13	2014	11	3	1	3	NT	NB	H	I	1.68	0.07	.	1.29	1.13	7.26	0.06	17	46	1445
348	13	2014	12	3	1	3	CT	NB	L	I	1.11	0.03	.	1.30	.	7.37	0.06	24	61	1623
349	13	2014	13	1	1	1	CT	B	L	I	2.21	0.83	2.84	1.25	1.09	7.40	0.08	38	93	1635
350	13	2014	14	1	1	1	NT	B	L	I	1.83	0.64	1.59	1.33	1.27	7.03	0.07	23	96	1549
351	13	2014	15	2	1	1	NT	B	H	I	1.94	2.58	4.24	1.37	1.14	7.12	0.07	16	62	1758
352	13	2014	16	2	1	2	CT	B	L	I	2.11	0.43	4.08	1.29	1.28	7.46	0.09	31	73	1904
353	13	2014	17	3	1	2	NT	B	H	I	1.71	2.29	3.29	1.22	1.15	7.28	0.10	19	59	1786
354	13	2014	18	3	1	3	CT	B	L	I	2.19	0.16	2.91	1.33	.	7.38	0.10	40	95	2036
355	13	2014	19	1	1	1	CT	B	H	I	1.80	1.05	6.02	1.27	1.17	7.42	0.07	21	55	1554
356	13	2014	20	1	1	3	NT	B	H	I	1.80	2.67	5.61	1.28	1.18	7.20	0.08	20	57	1641
357	13	2014	21	2	1	2	NT	B	L	I	1.21	0.57	2.37	1.28	1.21	7.35	0.10	31	88	1938
358	13	2014	22	2	1	2	CT	B	H	I	1.98	0.43	5.71	1.25	1.18	7.27	0.07	25	57	1734
359	13	2014	23	3	1	3	NT	B	L	I	1.76	0.73	3.16	1.27	1.12	7.23	0.08	22	76	1625
360	13	2014	24	3	1	3	CT	B	H	I	2.14	0.45	5.95	1.23	1.16	7.17	0.10	25	52	1817
361	13	2014	25	1	2	4	CT	B	H	NI	1.59	3.32	4.87	1.30	1.25	6.70	0.04	21	77	1624
362	13	2014	26	1	2	4	NT	B	H	NI	2.12	3.61	5.30	1.32	1.06	6.47	0.05	19	92	1486
363	13	2014	27	2	2	5	NT	B	H	NI	1.73	3.63	4.91	1.32	1.34	6.30	0.05	18	71	1467
364	13	2014	28	2	2	4	CT	B	L	NI	2.25	1.72	2.98	1.24	1.21	6.30	0.10	30	78	1502
365	13	2014	29	3	2	6	NT	B	H	NI	1.96	3.47	4.59	1.31	1.26	6.47	0.06	21	78	1490
366	13	2014	30	3	2	5	CT	B	L	NI	1.90	0.68	2.28	1.30	1.30	6.58	0.06	27	201	1568
367	13	2014	31	1	2	6	CT	B	L	NI	1.97	1.61	2.53	1.27	1.27	6.82	0.06	31	108	1639
368	13	2014	32	1	2	4	NT	B	L	NI	2.16	1.18	2.56	1.27	1.35	6.74	0.06	35	98	1575
369	13	2014	33	2	2	5	NT	B	L	NI	3.69	1.52	2.98	1.31	1.24	6.60	0.06	33	79	1713
370	13	2014	34	2	2	5	CT	B	H	NI	2.58	2.72	4.10	1.23	1.18	6.56	0.06	29	94	1552
371	13	2014	35	3	2	6	NT	B	L	NI	2.48	1.01	2.07	1.32	1.34	6.43	0.05	24	72	1557
372	13	2014	36	3	2	6	CT	B	H	NI	2.15	3.77	4.74	1.28	1.34	6.55	0.06	25	96	1649
373	13	2014	37	1	2	4	CT	NB	H	NI	1.48	2.49	7.60	1.34	1.21	6.44	0.06	35	98	1822

obs #	yr	actual yr	plot	T block	B block	rep	till	burn	Nrate	Irr	Soy Yld	Wht Yld	Res Level	Spring BD	Summer BD	pH	EC	P	K	Ca
374	13	2014	38	1	2	4	NT	NB	L	NI	1.36	0.81	2.54	1.28	1.23	6.84	0.08	43	141	1906
375	13	2014	39	2	2	4	NT	NB	H	NI	1.95	1.75	3.31	1.26	1.29	6.44	0.10	29	113	1823
376	13	2014	40	2	2	5	CT	NB	H	NI	1.66	2.48	5.28	1.27	1.30	6.38	0.09	25	76	1781
377	13	2014	41	3	2	5	NT	NB	L	NI	1.35	0.60	2.57	1.28	1.21	6.56	0.09	35	110	1961
378	13	2014	42	3	2	6	CT	NB	H	NI	1.48	3.21	6.68	1.35	1.29	6.82	0.08	25	64	2060
379	13	2014	43	1	2	4	CT	NB	L	NI	1.71	1.90	4.27	1.23	1.26	6.63	0.09	35	102	1832
380	13	2014	44	1	2	5	NT	NB	H	NI	1.29	2.79	3.46	1.26	1.23	6.50	0.08	22	142	1744
381	13	2014	45	2	2	6	NT	NB	L	NI	2.27	0.92	3.43	1.28	1.16	6.76	0.08	31	131	1989
382	13	2014	46	2	2	5	CT	NB	L	NI	1.98	0.94	3.06	1.28	1.29	6.70	0.11	40	151	1901
383	13	2014	47	3	2	6	NT	NB	H	NI	2.43	1.39	3.29	1.22	1.11	6.17	0.09	32	100	1688
384	13	2014	48	3	2	6	CT	NB	L	NI	1.72	1.26	1.77	1.36	1.23	7.06	0.07	33	83	1969

Magnesium (Mg; kg ha^{-1}), sulfur (S; kg ha^{-1}), iron (Fe; kg ha^{-1}), manganese (Mn; kg ha^{-1}), zinc (Zn; kg ha^{-1}), and copper (Cu; kg ha^{-1}).

obs #	yr	actual yr	plot	Tblock	Bblock	rep	till	burn	Nrate	Irr	Mg	S	Na	Fe	Mn	Zn	Cu
1	6	2007	1	1	1	1	CT	NB	H	I	386	9.1	20.0	204.3	184.1	1.5	2.6
2	6	2007	2	1	1	1	NT	NB	L	I	422	8.7	27.5	200.2	150.3	1.1	2.2
3	6	2007	3	2	1	1	NT	NB	H	I	445	8.3	27.3	202.9	146.3	1.1	2.4
4	6	2007	4	2	1	1	CT	NB	L	I	403	8.5	20.1	213.9	176.1	1.5	2.5
5	6	2007	5	3	1	2	NT	NB	L	I	477	9.5	23.8	214.2	172.1	1.3	2.5
6	6	2007	6	3	1	2	CT	NB	H	I	467	8.4	20.5	199.2	153.4	1.1	2.4
7	6	2007	7	1	1	2	CT	NB	L	I	408	10.3	19.1	197.6	154.0	1.7	2.5
8	6	2007	8	1	1	2	NT	NB	H	I	401	9.8	20.5	193.2	166.6	1.7	2.8
9	6	2007	9	2	1	3	NT	NB	L	I	434	9.6	25.5	195.0	174.3	1.7	2.6
10	6	2007	10	2	1	3	CT	NB	H	I	387	9.8	23.2	196.2	140.9	1.7	2.5
11	6	2007	11	3	1	3	NT	NB	H	I	369	9.2	20.8	177.0	153.2	1.5	2.3
12	6	2007	12	3	1	3	CT	NB	L	I	412	7.6	19.5	177.9	153.9	1.5	2.4
13	6	2007	13	1	1	1	CT	B	L	I	336	9.9	19.5	186.0	231.7	2.3	2.3
14	6	2007	14	1	1	1	NT	B	L	I	343	10.1	22.0	171.0	227.4	1.8	2.4
15	6	2007	15	2	1	1	NT	B	H	I	414	9.1	23.7	181.5	176.6	1.3	2.2
16	6	2007	16	2	1	2	CT	B	L	I	287	9.3	16.8	173.0	231.6	2.1	2.3
17	6	2007	17	3	1	2	NT	B	H	I	312	8.9	18.7	160.6	208.2	1.3	2.1
18	6	2007	18	3	1	3	CT	B	L	I	430	9.2	25.2	181.6	160.1	1.2	2.3
19	6	2007	19	1	1	1	CT	B	H	I	418	10.0	17.5	231.3	171.3	1.9	2.9
20	6	2007	20	1	1	3	NT	B	H	I	417	9.7	15.2	177.0	185.0	2.1	2.6
21	6	2007	21	2	1	2	NT	B	L	I	418	9.8	21.4	179.5	186.3	2.3	2.7
22	6	2007	22	2	1	2	CT	B	H	I	416	10.5	22.4	227.2	158.6	2.1	3.1
23	6	2007	23	3	1	3	NT	B	L	I	371	12.4	17.8	168.8	168.5	2.0	2.7
24	6	2007	24	3	1	3	CT	B	H	I	357	9.5	23.1	174.9	174.6	2.2	2.6
25	6	2007	25	1	2	1	CT	B	H	NI	381	8.5	23.3	172.6	151.7	1.5	2.4
26	6	2007	26	1	2	1	NT	B	H	NI	434	8.3	23.5	174.9	136.1	1.3	2.3
27	6	2007	27	2	2	2	NT	B	H	NI	485	8.2	27.5	191.8	133.2	1.2	2.4
28	6	2007	28	2	2	1	CT	B	L	NI	435	9.4	26.8	177.4	177.8	1.4	2.3

obs #	yr	actual yr	plot	Tblock	Bblock	rep	till	burn	Nrate	Irr	Mg	S	Na	Fe	Mn	Zn	Cu
29	6	2007	29	3	2	3	NT	B	H	NI	437	8.4	23.8	194.7	165.8	1.4	2.4
30	6	2007	30	3	2	2	CT	B	L	NI	403	7.4	25.4	191.7	137.2	1.1	2.3
31	6	2007	31	1	2	3	CT	B	L	NI	405	10.0	21.5	190.1	136.9	1.9	2.6
32	6	2007	32	1	2	1	NT	B	L	NI	373	9.7	15.6	184.3	147.4	2.1	2.6
33	6	2007	33	2	2	2	NT	B	L	NI	427	10.2	29.9	195.4	165.7	2.1	3.0
34	6	2007	34	2	2	2	CT	B	H	NI	388	9.2	21.3	187.2	137.2	1.9	2.7
35	6	2007	35	3	2	3	NT	B	L	NI	387	8.8	19.3	175.7	128.8	1.8	2.4
36	6	2007	36	3	2	3	CT	B	H	NI	384	7.2	20.2	171.5	136.2	1.5	2.4
37	6	2007	37	1	2	1	CT	NB	H	NI	349	10.6	22.0	175.5	229.6	2.0	2.3
38	6	2007	38	1	2	1	NT	NB	L	NI	286	9.5	18.0	153.7	195.2	1.6	2.1
39	6	2007	39	2	2	1	NT	NB	H	NI	319	8.4	18.5	135.1	161.9	1.2	1.9
40	6	2007	40	2	2	2	CT	NB	H	NI	282	9.1	19.0	161.4	215.5	2.0	2.2
41	6	2007	41	3	2	2	NT	NB	L	NI	263	7.8	17.4	158.8	179.0	1.4	1.9
42	6	2007	42	3	2	3	CT	NB	H	NI	307	7.5	15.7	155.9	149.5	1.1	2.0
43	6	2007	43	1	2	1	CT	NB	L	NI	405	8.6	16.1	187.3	149.2	2.2	2.7
44	6	2007	44	1	2	2	NT	NB	H	NI	413	9.7	16.7	186.9	145.1	2.0	2.7
45	6	2007	45	2	2	3	NT	NB	L	NI	343	7.3	17.0	165.2	134.9	1.8	2.3
46	6	2007	46	2	2	2	CT	NB	L	NI	381	9.1	19.6	181.1	137.5	2.0	2.8
47	6	2007	47	3	2	3	NT	NB	H	NI	349	9.1	19.4	161.3	133.0	2.1	2.3
48	6	2007	48	3	2	3	CT	NB	L	NI	332	8.6	20.6	150.0	138.1	1.9	2.4
49	7	2008	1	1	1	1	CT	NB	H	I	310	12.4	58.4	173.3	252.1	2.3	1.8
50	7	2008	2	1	1	1	NT	NB	L	I	301	12.6	40.7	144.0	244.0	2.1	1.6
51	7	2008	3	2	1	1	NT	NB	H	I	259	10.4	34.2	133.5	200.3	1.8	1.5
52	7	2008	4	2	1	1	CT	NB	L	I	300	12.1	44.3	130.4	233.7	1.8	1.5
53	7	2008	5	3	1	2	NT	NB	L	I	310	9.9	41.3	112.9	166.0	1.5	1.5
54	7	2008	6	3	1	2	CT	NB	H	I	390	9.9	39.6	130.6	174.9	1.4	1.6
55	7	2008	7	1	1	2	CT	NB	L	I	298	11.5	41.3	164.4	246.6	2.4	1.8
56	7	2008	8	1	1	2	NT	NB	H	I	283	10.0	41.8	119.9	200.0	1.9	1.5
57	7	2008	9	2	1	3	NT	NB	L	I	231	9.3	37.7	111.5	169.1	1.5	1.5

obs #	yr	actual yr	plot	Tblock	Bblock	rep	till	burn	Nrate	Irr	Mg	S	Na	Fe	Mn	Zn	Cu
58	7	2008	10	2	1	3	CT	NB	H	I	311	9.7	38.9	129.1	211.0	1.6	1.7
59	7	2008	11	3	1	3	NT	NB	H	I	283	10.7	36.7	115.6	168.4	1.4	1.5
60	7	2008	12	3	1	3	CT	NB	L	I	387	9.9	41.8	130.7	161.5	1.4	1.7
61	7	2008	13	1	1	1	CT	B	L	I	367	10.1	37.1	160.2	185.9	1.5	1.7
62	7	2008	14	1	1	1	NT	B	L	I	359	9.7	41.9	121.3	151.4	1.5	1.5
63	7	2008	15	2	1	1	NT	B	H	I	409	10.9	43.5	124.1	146.3	1.5	1.6
64	7	2008	16	2	1	2	CT	B	L	I	389	11.2	41.2	148.0	172.9	1.4	1.7
65	7	2008	17	3	1	2	NT	B	H	I	412	9.6	40.9	140.5	119.8	1.3	1.6
66	7	2008	18	3	1	3	CT	B	L	I	432	8.7	41.5	158.4	155.5	1.2	1.6
67	7	2008	19	1	1	1	CT	B	H	I	369	10.9	39.8	158.9	191.9	1.5	1.6
68	7	2008	20	1	1	3	NT	B	H	I	374	11.7	39.8	136.7	181.7	1.8	1.6
69	7	2008	21	2	1	2	NT	B	L	I	401	9.4	43.7	147.3	157.0	1.5	1.8
70	7	2008	22	2	1	2	CT	B	H	I	405	10.8	45.9	150.6	172.2	1.2	1.7
71	7	2008	23	3	1	3	NT	B	L	I	393	10.2	41.0	130.2	142.5	1.4	1.6
72	7	2008	24	3	1	3	CT	B	H	I	467	11.3	41.9	167.2	177.9	1.3	1.6
73	7	2008	25	1	2	4	CT	B	H	NI	379	13.5	41.2	150.9	165.9	1.7	1.8
74	7	2008	26	1	2	4	NT	B	H	NI	321	12.3	36.5	144.2	146.6	1.9	1.7
75	7	2008	27	2	2	5	NT	B	H	NI	310	12.3	35.3	136.8	144.7	1.9	1.7
76	7	2008	28	2	2	4	CT	B	L	NI	362	11.6	33.8	142.5	172.3	1.7	1.7
77	7	2008	29	3	2	6	NT	B	H	NI	368	13.5	24.6	160.5	203.7	2.1	1.5
78	7	2008	30	3	2	5	CT	B	L	NI	410	10.6	29.0	170.4	220.2	1.7	1.6
79	7	2008	31	1	2	6	CT	B	L	NI	350	10.1	25.8	160.2	171.5	1.6	1.6
80	7	2008	32	1	2	4	NT	B	L	NI	381	10.6	24.2	157.9	165.0	1.9	1.6
81	7	2008	33	2	2	5	NT	B	L	NI	380	10.5	25.7	155.1	159.5	1.7	1.6
82	7	2008	34	2	2	5	CT	B	H	NI	385	10.9	26.3	163.1	192.6	1.6	1.6
83	7	2008	35	3	2	6	NT	B	L	NI	388	10.7	28.1	144.5	164.5	1.7	1.5
84	7	2008	36	3	2	6	CT	B	H	NI	414	11.5	25.0	162.4	210.5	1.7	1.5
85	7	2008	37	1	2	4	CT	NB	H	NI	387	10.8	28.5	197.2	223.4	1.9	1.8
86	7	2008	38	1	2	4	NT	NB	L	NI	412	9.7	26.5	171.8	204.2	2.2	1.8

obs #	yr	actual yr	plot	Tblock	Bblock	rep	till	burn	Nrate	Irr	Mg	S	Na	Fe	Mn	Zn	Cu
87	7	2008	39	2	2	4	NT	NB	H	NI	393	10.4	27.7	159.6	192.0	1.9	1.6
88	7	2008	40	2	2	5	CT	NB	H	NI	415	11.3	26.8	158.7	213.1	2.0	1.6
89	7	2008	41	3	2	5	NT	NB	L	NI	383	9.1	25.0	151.7	185.8	1.9	1.6
90	7	2008	42	3	2	6	CT	NB	H	NI	375	8.7	25.3	154.4	205.3	1.9	1.6
91	7	2008	43	1	2	4	CT	NB	L	NI	411	9.7	26.3	206.4	215.7	2.0	1.8
92	7	2008	44	1	2	5	NT	NB	H	NI	395	8.4	26.7	158.1	196.6	2.0	1.8
93	7	2008	45	2	2	6	NT	NB	L	NI	399	10.2	21.6	155.3	192.1	2.4	1.9
94	7	2008	46	2	2	5	CT	NB	L	NI	379	9.0	19.6	159.3	216.9	2.2	1.7
95	7	2008	47	3	2	6	NT	NB	H	NI	341	8.6	19.3	144.6	185.4	2.1	1.6
96	7	2008	48	3	2	6	CT	NB	L	NI	392	8.3	22.8	162.4	232.9	2.1	1.7
97	8	2009	1	1	1	1	CT	NB	H	I	314	29.3	14.3	196.9	308.9	2.6	1.8
98	8	2009	2	1	1	1	NT	NB	L	I	304	29.7	16.8	189.2	306.0	2.6	1.9
99	8	2009	3	2	1	1	NT	NB	H	I	233	26.0	18.4	163.6	259.9	1.9	1.8
100	8	2009	4	2	1	1	CT	NB	L	I	296	26.9	12.9	180.5	314.6	1.8	1.7
101	8	2009	5	3	1	2	NT	NB	L	I	297	29.1	14.3	155.6	228.9	1.5	1.6
102	8	2009	6	3	1	2	CT	NB	H	I	364	31.1	18.9	166.4	206.0	1.5	1.8
103	8	2009	7	1	1	2	CT	NB	L	I	302	29.5	17.2	200.3	307.4	2.4	1.8
104	8	2009	8	1	1	2	NT	NB	H	I	303	28.5	14.8	172.0	337.4	2.2	1.8
105	8	2009	9	2	1	3	NT	NB	L	I	351	31.2	16.4	187.0	291.5	2.2	1.8
106	8	2009	10	2	1	3	CT	NB	H	I	349	28.7	19.5	152.9	185.6	1.7	1.5
107	8	2009	11	3	1	3	NT	NB	H	I	403	34.1	21.5	169.4	199.8	1.7	1.8
108	8	2009	12	3	1	3	CT	NB	L	I	414	34.4	19.0	223.9	255.9	2.0	2.2
109	8	2009	13	1	1	1	CT	B	L	I	297	32.1	16.6	150.3	163.9	1.9	1.6
110	8	2009	14	1	1	1	NT	B	L	I	364	32.4	19.5	147.9	163.8	1.7	1.6
111	8	2009	15	2	1	1	NT	B	H	I	426	35.9	21.6	205.1	215.9	1.8	1.8
112	8	2009	16	2	1	2	CT	B	L	I	377	31.9	21.2	162.4	153.4	1.7	1.6
113	8	2009	17	3	1	2	NT	B	H	I	446	35.4	21.9	206.5	204.5	1.7	1.8
114	8	2009	18	3	1	3	CT	B	L	I	370	32.9	17.8	233.1	271.0	2.2	1.9
115	8	2009	19	1	1	1	CT	B	H	I	365	32.2	16.6	230.2	275.2	2.0	1.8

obs #	yr	actual yr	plot	Tblock	Bblock	rep	till	burn	Nrate	Irr	Mg	S	Na	Fe	Mn	Zn	Cu
116	8	2009	20	1	1	3	NT	B	H	I	412	35.1	21.7	186.0	229.3	2.0	1.8
117	8	2009	21	2	1	2	NT	B	L	I	474	37.9	27.0	217.7	237.8	1.9	2.0
118	8	2009	22	2	1	2	CT	B	H	I	449	36.6	22.8	216.4	238.2	1.7	2.0
119	8	2009	23	3	1	3	NT	B	L	I	388	36.5	31.0	173.3	180.4	1.7	1.9
120	8	2009	24	3	1	3	CT	B	H	I	509	37.7	21.6	214.4	218.2	1.8	1.8
121	8	2009	25	1	2	4	CT	B	H	NI	391	37.5	20.3	211.8	215.9	2.3	2.1
122	8	2009	26	1	2	4	NT	B	H	NI	326	34.1	19.5	176.3	146.9	2.1	1.9
123	8	2009	27	2	2	5	NT	B	H	NI	336	34.4	17.3	178.2	179.3	2.4	1.9
124	8	2009	28	2	2	4	CT	B	L	NI	382	36.2	19.5	193.6	227.9	2.3	1.9
125	8	2009	29	3	2	6	NT	B	H	NI	342	34.4	19.7	185.8	188.2	2.5	2.0
126	8	2009	30	3	2	5	CT	B	L	NI	407	38.0	20.4	201.8	256.1	2.2	2.1
127	8	2009	31	1	2	6	CT	B	L	NI	383	38.9	18.6	213.2	202.5	2.1	2.2
128	8	2009	32	1	2	4	NT	B	L	NI	349	36.8	19.8	186.3	150.0	2.2	2.2
129	8	2009	33	2	2	5	NT	B	L	NI	385	39.4	19.5	189.4	183.2	2.3	2.2
130	8	2009	34	2	2	5	CT	B	H	NI	379	35.7	16.9	187.8	201.9	2.1	2.0
131	8	2009	35	3	2	6	NT	B	L	NI	428	40.9	19.8	192.2	224.6	2.4	2.2
132	8	2009	36	3	2	6	CT	B	H	NI	397	38.7	20.9	191.9	205.0	2.3	2.2
133	8	2009	37	1	2	4	CT	NB	H	NI	380	41.9	16.5	222.3	237.3	2.2	2.2
134	8	2009	38	1	2	4	NT	NB	L	NI	377	44.7	22.4	219.4	217.3	2.5	2.5
135	8	2009	39	2	2	4	NT	NB	H	NI	365	42.2	20.4	191.2	211.8	2.3	2.1
136	8	2009	40	2	2	5	CT	NB	H	NI	416	47.6	21.2	224.1	253.6	2.6	2.1
137	8	2009	41	3	2	5	NT	NB	L	NI	366	42.9	17.9	182.3	208.8	2.4	2.0
138	8	2009	42	3	2	6	CT	NB	H	NI	370	44.2	21.5	185.0	209.1	2.4	2.1
139	8	2009	43	1	2	4	CT	NB	L	NI	390	43.4	15.5	242.5	230.4	2.6	2.3
140	8	2009	44	1	2	5	NT	NB	H	NI	385	46.9	18.5	199.9	214.0	2.7	2.2
141	8	2009	45	2	2	6	NT	NB	L	NI	366	45.7	19.6	178.5	176.0	2.7	2.4
142	8	2009	46	2	2	5	CT	NB	L	NI	412	46.8	16.9	205.5	259.6	2.8	2.3
143	8	2009	47	3	2	6	NT	NB	H	NI	339	44.6	16.4	172.7	197.1	2.5	2.1
144	8	2009	48	3	2	6	CT	NB	L	NI	380	42.4	16.8	201.5	246.4	2.6	2.1

obs #	yr	actual yr	plot	Tblock	Bblock	rep	till	burn	Nrate	Irr	Mg	S	Na	Fe	Mn	Zn	Cu
145	9		1	1	1	1	CT	NB	H	I	307	8.6	17.5	264.1	326.4	2.6	2.4
146	9	2010	2	1	1	1	NT	NB	L	I	295	7.4	17.9	228.7	342.8	2.5	2.4
147	9	2010	3	2	1	1	NT	NB	H	I	225	8.1	15.3	212.9	263.1	2.2	2.1
148	9	2010	4	2	1	1	CT	NB	L	I	337	8.9	19.3	246.4	363.6	2.3	2.6
149	9	2010	5	3	1	2	NT	NB	L	I	289	7.7	19.5	188.7	232.9	2.1	2.2
150	9	2010	6	3	1	2	CT	NB	H	I	364	7.8	22.0	206.8	239.6	1.5	2.5
151	9	2010	7	1	1	2	CT	NB	L	I	295	7.7	18.2	266.6	383.5	2.6	2.6
152	9	2010	8	1	1	2	NT	NB	H	I	209	9.5	15.1	216.3	291.6	2.1	2.0
153	9	2010	9	2	1	3	NT	NB	L	I	209	7.7	19.7	204.1	291.3	1.7	2.0
154	9	2010	10	2	1	3	CT	NB	H	I	337	8.0	19.8	218.7	328.9	1.9	1.9
155	9	2010	11	3	1	3	NT	NB	H	I	259	8.4	24.8	190.8	219.0	1.3	2.0
156	9	2010	12	3	1	3	CT	NB	L	I	351	7.3	18.1	183.7	205.4	1.4	2.1
157	9	2010	13	1	1	1	CT	B	L	I	312	7.9	17.3	234.9	265.8	1.4	2.4
158	9	2010	14	1	1	1	NT	B	L	I	311	7.3	20.3	194.2	187.5	1.6	2.4
159	9	2010	15	2	1	1	NT	B	H	I	436	9.0	22.8	219.3	171.0	1.8	2.4
160	9	2010	16	2	1	2	CT	B	L	I	387	7.3	16.5	272.0	265.4	1.5	2.4
161	9	2010	17	3	1	2	NT	B	H	I	471	7.8	24.6	227.5	189.0	1.5	2.4
162	9	2010	18	3	1	3	CT	B	L	I	484	8.6	24.0	309.8	255.7	1.7	2.6
163	9	2010	19	1	1	1	CT	B	H	I	356	7.3	17.2	252.6	267.8	1.8	2.4
164	9	2010	20	1	1	3	NT	B	H	I	369	6.3	21.8	227.7	293.1	1.6	2.7
165	9	2010	21	2	1	2	NT	B	L	I	444	6.6	20.7	269.4	263.8	1.6	2.2
166	9	2010	22	2	1	2	CT	B	H	I	426	7.9	20.6	352.9	267.6	1.5	2.3
167	9	2010	23	3	1	3	NT	B	L	I	423	8.2	29.8	246.2	197.7	1.4	1.8
168	9	2010	24	3	1	3	CT	B	H	I	440	7.0	19.7	252.8	230.4	1.3	1.9
169	9	2010	25	1	2	4	CT	B	H	NI	350	6.8	20.0	282.8	226.6	1.6	2.2
170	9	2010	26	1	2	4	NT	B	H	NI	359	7.0	13.0	241.3	169.4	1.9	2.3
171	9	2010	27	2	2	5	NT	B	H	NI	341	8.3	16.2	251.4	175.9	2.2	2.1
172	9	2010	28	2	2	4	CT	B	L	NI	370	8.7	19.1	298.6	256.6	2.2	2.3
173	9	2010	29	3	2	6	NT	B	H	NI	366	9.1	19.7	266.0	226.5	2.2	2.0

obs #	yr	actual yr	plot	Tblock	Bblock	rep	till	burn	Nrate	Irr	Mg	S	Na	Fe	Mn	Zn	Cu
174	9	2010	30	3	2	5	CT	B	L	NI	403	7.4	16.3	270.4	260.4	2.1	2.5
175	9	2010	31	1	2	6	CT	B	L	NI	350	6.7	16.8	266.0	217.3	1.6	2.3
176	9	2010	32	1	2	4	NT	B	L	NI	343	8.0	20.6	231.4	159.0	1.9	2.5
177	9	2010	33	2	2	5	NT	B	L	NI	380	9.4	18.5	238.4	176.3	2.3	2.1
178	9	2010	34	2	2	5	CT	B	H	NI	329	7.9	18.3	294.6	272.8	1.6	2.1
179	9	2010	35	3	2	6	NT	B	L	NI	392	8.9	18.6	231.5	203.1	2.1	2.3
180	9	2010	36	3	2	6	CT	B	H	NI	391	8.5	17.3	268.2	239.6	2.2	2.3
181	9	2010	37	1	2	4	CT	NB	H	NI	337	8.2	15.4	268.9	233.9	2.0	2.3
182	9	2010	38	1	2	4	NT	NB	L	NI	373	8.9	18.3	272.9	231.8	2.5	2.4
183	9	2010	39	2	2	4	NT	NB	H	NI	397	8.4	21.2	271.9	239.1	2.2	2.4
184	9	2010	40	2	2	5	CT	NB	H	NI	342	7.3	22.4	237.7	231.7	2.3	2.6
185	9	2010	41	3	2	5	NT	NB	L	NI	357	7.1	21.5	238.5	216.0	1.8	2.3
186	9	2010	42	3	2	6	CT	NB	H	NI	366	7.4	14.8	288.3	216.1	2.4	2.5
187	9	2010	43	1	2	4	CT	NB	L	NI	374	7.8	14.8	296.8	221.9	2.4	2.6
188	9	2010	44	1	2	5	NT	NB	H	NI	373	6.9	15.6	262.8	201.4	2.4	2.3
189	9	2010	45	2	2	6	NT	NB	L	NI	341	9.4	15.6	211.2	220.1	2.2	2.6
190	9	2010	46	2	2	5	CT	NB	L	NI	355	9.6	19.0	240.1	242.1	2.3	2.7
191	9	2010	47	3	2	6	NT	NB	H	NI	357	9.7	20.7	235.7	223.3	2.2	2.7
192	9	2010	48	3	2	6	CT	NB	L	NI	407	9.5	22.2	277.0	320.3	2.2	2.9
193	10	2011	1	1	1	1	CT	NB	H	I	260	32.1	20.7	219.9	346.0	2.4	1.2
194	10	2011	2	1	1	1	NT	NB	L	I	292	23.2	13.0	186.2	334.5	2.1	1.2
195	10	2011	3	2	1	1	NT	NB	H	I	231	32.9	19.9	180.7	288.3	1.7	1.0
196	10	2011	4	2	1	1	CT	NB	L	I	285	25.6	16.5	187.9	311.9	1.9	1.2
197	10	2011	5	3	1	2	NT	NB	L	I	255	24.4	20.3	160.5	228.1	1.3	1.0
198	10	2011	6	3	1	2	CT	NB	H	I	335	36.7	27.9	189.4	245.3	1.4	1.2
199	10	2011	7	1	1	2	CT	NB	L	I	261	32.0	20.5	215.4	327.3	2.4	1.2
200	10	2011	8	1	1	2	NT	NB	H	I	275	27.4	21.0	174.1	297.7	1.8	1.0
201	10	2011	9	2	1	3	NT	NB	L	I	238	34.4	21.1	167.0	260.5	1.8	0.9
202	10	2011	10	2	1	3	CT	NB	H	I	298	26.3	19.0	181.8	292.9	1.6	1.1

obs #	yr	actual yr	plot	Tblock	Bblock	rep	till	burn	Nrate	Irr	Mg	S	Na	Fe	Mn	Zn	Cu
203	10	2011	11	3	1	3	NT	NB	H	I	296	37.6	16.6	172.2	209.2	1.3	0.9
204	10	2011	12	3	1	3	CT	NB	L	I	341	20.8	23.8	167.3	194.3	1.2	1.2
205	10	2011	13	1	1	1	CT	B	L	I	355	19.7	19.3	208.9	237.4	1.4	1.3
206	10	2011	14	1	1	1	NT	B	L	I	296	28.3	16.8	161.0	182.4	1.6	1.1
207	10	2011	15	2	1	1	NT	B	H	I	337	26.1	21.7	171.2	173.7	1.4	1.0
208	10	2011	16	2	1	2	CT	B	L	I	372	23.3	13.0	218.6	226.8	1.5	1.2
209	10	2011	17	3	1	2	NT	B	H	I	354	22.0	28.5	167.9	131.1	1.0	0.9
210	10	2011	18	3	1	3	CT	B	L	I	423	20.2	26.3	214.8	217.7	1.3	1.3
211	10	2011	19	1	1	1	CT	B	H	I	363	23.9	25.6	200.2	250.2	1.5	1.3
212	10	2011	20	1	1	3	NT	B	H	I	320	32.0	26.4	195.7	245.0	1.4	1.2
213	10	2011	21	2	1	2	NT	B	L	I	407	26.5	24.2	214.9	233.4	1.4	1.3
214	10	2011	22	2	1	2	CT	B	H	I	404	26.5	28.4	229.1	233.6	1.3	1.3
215	10	2011	23	3	1	3	NT	B	L	I	414	20.7	16.2	172.4	179.4	1.4	1.1
216	10	2011	24	3	1	3	CT	B	H	I	413	30.8	26.3	214.4	216.5	1.1	1.2
217	10	2011	25	1	2	4	CT	B	H	NI	319	23.3	23.7	208.2	191.5	1.3	1.3
218	10	2011	26	1	2	4	NT	B	H	NI	341	27.2	19.6	190.1	178.9	1.7	1.2
219	10	2011	27	2	2	5	NT	B	H	NI	311	32.4	22.4	192.1	187.8	1.9	1.3
220	10	2011	28	2	2	4	CT	B	L	NI	345	28.3	21.8	199.8	229.1	1.7	1.3
221	10	2011	29	3	2	6	NT	B	H	NI	305	25.8	19.4	192.4	242.5	2.2	1.7
222	10	2011	30	3	2	5	CT	B	L	NI	298	32.9	25.8	207.7	229.8	1.5	1.2
223	10	2011	31	1	2	6	CT	B	L	NI	335	30.0	20.5	224.7	206.4	1.6	1.4
224	10	2011	32	1	2	4	NT	B	L	NI	330	25.8	17.6	185.8	178.5	1.9	1.3
225	10	2011	33	2	2	5	NT	B	L	NI	339	27.0	17.0	178.0	176.9	2.1	1.2
226	10	2011	34	2	2	5	CT	B	H	NI	331	34.4	20.0	223.7	246.4	1.6	1.2
227	10	2011	35	3	2	6	NT	B	L	NI	326	31.6	18.3	177.9	191.3	2.0	1.2
228	10	2011	36	3	2	6	CT	B	H	NI	309	28.5	19.3	191.4	214.5	1.5	1.2
229	10	2011	37	1	2	4	CT	NB	H	NI	320	45.0	20.2	235.6	235.2	2.0	1.5
230	10	2011	38	1	2	4	NT	NB	L	NI	296	21.1	15.1	187.3	195.7	2.0	1.4
231	10	2011	39	2	2	4	NT	NB	H	NI	299	28.3	24.7	187.2	215.0	1.7	1.4

obs #	yr	actual yr	plot	Tblock	Bblock	rep	till	burn	Nrate	Irr	Mg	S	Na	Fe	Mn	Zn	Cu
232	10	2011	40	2	2	5	CT	NB	H	NI	304	27.6	14.3	183.1	236.4	2.0	1.3
233	10	2011	41	3	2	5	NT	NB	L	NI	275	24.6	19.8	206.9	207.3	1.8	1.5
234	10	2011	42	3	2	6	CT	NB	H	NI	318	27.0	20.1	185.6	211.4	1.5	1.3
235	10	2011	43	1	2	4	CT	NB	L	NI	328	28.8	18.1	220.9	226.4	2.2	1.6
236	10	2011	44	1	2	5	NT	NB	H	NI	279	32.4	16.3	189.6	195.2	1.9	1.5
237	10	2011	45	2	2	6	NT	NB	L	NI	323	25.8	17.4	198.8	218.1	2.4	1.7
238	10	2011	46	2	2	5	CT	NB	L	NI	303	23.6	14.1	185.8	225.8	1.9	1.4
239	10	2011	47	3	2	6	NT	NB	H	NI	260	28.6	11.5	170.6	228.9	2.6	1.2
240	10	2011	48	3	2	6	CT	NB	L	NI	367	30.2	26.0	203.3	265.0	2.2	1.6
241	11	2012	1	1	1	1	CT	NB	H	I	314	16.7	21.8	200.0	284.4	2.1	1.7
242	11	2012	2	1	1	1	NT	NB	L	I	292	15.7	19.5	152.9	244.5	2.1	1.2
243	11	2012	3	2	1	1	NT	NB	H	I	223	13.9	22.5	139.6	194.8	1.5	1.0
244	11	2012	4	2	1	1	CT	NB	L	I	355	15.8	19.5	157.4	229.4	1.8	1.9
245	11	2012	5	3	1	2	NT	NB	L	I	301	15.8	22.5	134.0	172.2	1.4	1.4
246	11	2012	6	3	1	2	CT	NB	H	I	367	14.6	21.3	141.8	156.5	1.3	1.5
247	11	2012	7	1	1	2	CT	NB	L	I	328	15.0	17.3	159.1	249.6	2.2	1.4
248	11	2012	8	1	1	2	NT	NB	H	I	266	14.5	18.7	136.7	215.6	1.8	1.3
249	11	2012	9	2	1	3	NT	NB	L	I	254	12.9	17.2	123.1	171.5	1.4	0.9
250	11	2012	10	2	1	3	CT	NB	H	I	338	17.3	22.0	164.6	215.8	1.4	1.1
251	11	2012	11	3	1	3	NT	NB	H	I	282	16.4	18.7	124.3	137.5	1.1	0.8
252	11	2012	12	3	1	3	CT	NB	L	I	388	13.6	29.7	146.3	171.1	1.3	1.3
253	11	2012	13	1	1	1	CT	B	L	I	375	9.6	20.8	186.3	216.5	1.8	1.4
254	11	2012	14	1	1	1	NT	B	L	I	305	7.6	20.1	130.2	139.3	1.2	1.2
255	11	2012	15	2	1	1	NT	B	H	I	435	6.8	28.6	157.0	168.9	1.4	1.3
256	11	2012	16	2	1	2	CT	B	L	I	451	15.3	24.1	175.3	188.8	1.3	1.3
257	11	2012	17	3	1	2	NT	B	H	I	401	11.7	33.3	138.1	102.3	1.0	1.1
258	11	2012	18	3	1	3	CT	B	L	I	479	15.7	35.0	180.0	165.5	1.3	1.4
259	11	2012	19	1	1	1	CT	B	H	I	394	17.7	21.0	174.6	221.1	1.6	1.7
260	11	2012	20	1	1	3	NT	B	H	I	378	6.0	20.6	150.7	180.1	1.4	1.3

obs #	yr	actual yr	plot	Tblock	Bblock	rep	till	burn	Nrate	Irr	Mg	S	Na	Fe	Mn	Zn	Cu
261	11	2012	21	2	1	2	NT	B	L	I	445	8.9	23.0	178.2	163.3	1.6	1.6
262	11	2012	22	2	1	2	CT	B	H	I	442	20.9	26.4	202.4	202.0	1.2	1.6
263	11	2012	23	3	1	3	NT	B	L	I	425	7.6	21.6	133.9	136.4	1.3	1.3
264	11	2012	24	3	1	3	CT	B	H	I	469	15.3	29.0	171.6	171.1	1.1	1.3
265	11	2012	25	1	2	4	CT	B	H	NI	345	12.1	14.7	177.9	167.7	2.1	1.7
266	11	2012	26	1	2	4	NT	B	H	NI	339	8.4	16.0	157.1	130.6	1.9	1.3
267	11	2012	27	2	2	5	NT	B	H	NI	289	8.0	15.2	142.4	110.1	1.9	2.1
268	11	2012	28	2	2	4	CT	B	L	NI	356	6.4	29.5	159.2	151.9	1.6	2.1
269	11	2012	29	3	2	6	NT	B	H	NI	337	6.9	11.6	156.1	142.0	1.8	2.0
270	11	2012	30	3	2	5	CT	B	L	NI	339	5.1	12.9	155.6	147.7	1.4	2.2
271	11	2012	31	1	2	6	CT	B	L	NI	354	8.1	11.9	164.2	151.4	1.6	2.3
272	11	2012	32	1	2	4	NT	B	L	NI	342	7.5	13.0	153.2	130.4	2.1	2.2
273	11	2012	33	2	2	5	NT	B	L	NI	356	7.0	12.3	132.9	107.7	1.7	2.1
274	11	2012	34	2	2	5	CT	B	H	NI	360	6.7	7.8	164.7	176.6	1.4	1.8
275	11	2012	35	3	2	6	NT	B	L	NI	365	5.7	9.8	123.1	109.8	1.5	1.9
276	11	2012	36	3	2	6	CT	B	H	NI	354	6.3	13.5	139.6	132.4	1.5	2.1
277	11	2012	37	1	2	4	CT	NB	H	NI	306	7.7	8.3	152.9	135.3	1.8	2.0
278	11	2012	38	1	2	4	NT	NB	L	NI	308	7.8	7.9	144.2	127.0	1.9	1.9
279	11	2012	39	2	2	4	NT	NB	H	NI	310	6.4	10.1	138.5	131.5	1.5	2.0
280	11	2012	40	2	2	5	CT	NB	H	NI	344	8.8	9.8	144.3	158.0	1.8	2.0
281	11	2012	41	3	2	5	NT	NB	L	NI	303	7.0	8.4	139.1	135.1	2.0	2.0
282	11	2012	42	3	2	6	CT	NB	H	NI	305	6.7	14.0	131.5	129.7	2.0	2.0
283	11	2012	43	1	2	4	CT	NB	L	NI	349	6.4	11.4	164.6	137.3	2.0	2.5
284	11	2012	44	1	2	5	NT	NB	H	NI	318	5.5	9.1	141.4	117.4	1.9	2.4
285	11	2012	45	2	2	6	NT	NB	L	NI	354	5.7	8.5	131.4	132.9	2.3	2.3
286	11	2012	46	2	2	5	CT	NB	L	NI	323	5.2	8.6	142.3	156.7	2.1	2.3
287	11	2012	47	3	2	6	NT	NB	H	NI	321	6.1	7.8	144.7	155.6	2.1	2.1
288	11	2012	48	3	2	6	CT	NB	L	NI	364	6.8	14.8	155.6	174.0	2.1	2.4
289	12	2013	1	1	1	1	CT	NB	H	I	317	9.2	21.0	230.6	379.4	2.3	2.9

obs #	yr	actual yr	plot	Tblock	Bblock	rep	till	burn	Nrate	Irr	Mg	S	Na	Fe	Mn	Zn	Cu
290	12	2013	2	1	1	1	NT	NB	L	I	364	10.6	18.6	207.8	320.8	2.8	2.5
291	12	2013	3	2	1	1	NT	NB	H	I	298	11.5	27.0	201.1	276.3	2.2	2.6
292	12	2013	4	2	1	1	CT	NB	L	I	371	11.1	17.7	213.5	328.8	2.1	2.3
293	12	2013	5	3	1	2	NT	NB	L	I	322	8.8	18.0	185.0	204.7	1.3	2.2
294	12	2013	6	3	1	2	CT	NB	H	I	389	9.0	20.8	194.8	238.0	1.3	2.5
295	12	2013	7	1	1	2	CT	NB	L	I	324	9.2	17.7	211.2	355.7	2.5	2.2
296	12	2013	8	1	1	2	NT	NB	H	I	318	12.5	23.7	184.4	261.3	2.3	2.3
297	12	2013	9	2	1	3	NT	NB	L	I	302	9.1	17.2	163.6	232.7	1.7	1.9
298	12	2013	10	2	1	3	CT	NB	H	I	378	11.0	22.1	209.6	317.8	1.7	2.6
299	12	2013	11	3	1	3	NT	NB	H	I	329	10.1	21.9	186.5	222.6	1.9	2.3
300	12	2013	12	3	1	3	CT	NB	L	I	418	8.9	20.7	188.5	215.8	1.6	2.5
301	12	2013	13	1	1	1	CT	B	L	I	408	10.5	22.6	224.8	266.2	1.9	2.5
302	12	2013	14	1	1	1	NT	B	L	I	361	9.2	15.4	179.8	202.0	1.9	2.5
303	12	2013	15	2	1	1	NT	B	H	I	370	9.0	20.7	183.1	148.6	1.6	1.9
304	12	2013	16	2	1	2	CT	B	L	I	490	14.7	26.3	248.7	243.7	2.2	2.7
305	12	2013	17	3	1	2	NT	B	H	I	475	9.8	20.9	226.9	191.2	1.7	2.0
306	12	2013	18	3	1	3	CT	B	L	I	481	7.8	15.4	240.7	233.5	1.3	2.4
307	12	2013	19	1	1	1	CT	B	H	I	420	10.1	17.8	223.5	257.4	1.7	2.4
308	12	2013	20	1	1	3	NT	B	H	I	419	10.6	19.4	194.5	211.0	1.4	2.8
309	12	2013	21	2	1	2	NT	B	L	I	440	9.4	16.0	215.5	218.0	1.5	2.3
310	12	2013	22	2	1	2	CT	B	H	I	470	12.1	27.8	247.0	248.7	1.2	2.9
311	12	2013	23	3	1	3	NT	B	L	I	437	9.9	31.3	200.5	193.4	1.1	2.2
312	12	2013	24	3	1	3	CT	B	H	I	506	9.7	26.4	235.9	229.3	1.2	2.6
313	12	2013	25	1	2	4	CT	B	H	NI	316	11.7	13.0	259.2	199.8	1.8	2.4
314	12	2013	26	1	2	4	NT	B	H	NI	305	15.7	21.5	199.4	146.2	1.6	2.8
315	12	2013	27	2	2	5	NT	B	H	NI	303	10.7	24.3	210.6	189.2	1.8	2.3
316	12	2013	28	2	2	4	CT	B	L	NI	322	8.0	12.1	243.9	239.3	1.9	2.7
317	12	2013	29	3	2	6	NT	B	H	NI	341	12.9	20.0	214.7	188.2	2.3	2.1
318	12	2013	30	3	2	5	CT	B	L	NI	343	8.6	16.2	215.3	231.4	1.7	2.3

obs #	yr	actual yr	plot	Tblock	Bblock	rep	till	burn	Nrate	Irr	Mg	S	Na	Fe	Mn	Zn	Cu
319	12	2013	31	1	2	6	CT	B	L	NI	324	10.4	14.1	222.3	191.6	1.8	2.3
320	12	2013	32	1	2	4	NT	B	L	NI	327	8.6	18.0	210.0	162.7	2.1	2.6
321	12	2013	33	2	2	5	NT	B	L	NI	342	12.0	14.5	214.8	176.1	2.4	2.3
322	12	2013	34	2	2	5	CT	B	H	NI	329	11.4	13.7	229.6	208.7	2.0	2.3
323	12	2013	35	3	2	6	NT	B	L	NI	371	9.8	15.1	202.5	202.2	2.1	2.3
324	12	2013	36	3	2	6	CT	B	H	NI	370	12.1	15.0	254.6	195.3	2.3	3.0
325	12	2013	37	1	2	4	CT	NB	H	NI	322	11.6	14.3	212.1	197.4	2.2	2.3
326	12	2013	38	1	2	4	NT	NB	L	NI	346	9.8	13.0	211.4	213.9	2.3	3.0
327	12	2013	39	2	2	4	NT	NB	H	NI	296	10.6	18.3	191.6	152.1	2.2	2.3
328	12	2013	40	2	2	5	CT	NB	H	NI	321	10.1	13.1	232.1	225.0	1.9	2.7
329	12	2013	41	3	2	5	NT	NB	L	NI	342	9.3	16.1	224.2	225.3	2.4	2.5
330	12	2013	42	3	2	6	CT	NB	H	NI	327	10.3	11.7	201.5	218.8	2.2	2.1
331	12	2013	43	1	2	4	CT	NB	L	NI	339	14.1	17.2	255.4	217.9	3.1	2.8
332	12	2013	44	1	2	5	NT	NB	H	NI	290	9.4	9.7	210.4	185.7	2.4	2.3
333	12	2013	45	2	2	6	NT	NB	L	NI	278	11.2	13.2	186.9	168.2	2.7	2.5
334	12	2013	46	2	2	5	CT	NB	L	NI	308	9.9	11.6	204.5	234.8	2.3	2.4
335	12	2013	47	3	2	6	NT	NB	H	NI	325	11.3	10.6	221.0	240.2	2.6	2.8
336	12	2013	48	3	2	6	CT	NB	L	NI	341	6.5	14.5	209.8	231.6	1.8	2.3
337	13	2014	1	1	1	1	CT	NB	H	I	397	8.9	18.5	214.6	355.5	2.5	1.6
338	13	2014	2	1	1	1	NT	NB	L	I	331	7.5	13.4	186.2	320.5	2.3	1.4
339	13	2014	3	2	1	1	NT	NB	H	I	363	6.4	12.1	180.6	277.8	1.6	1.3
340	13	2014	4	2	1	1	CT	NB	L	I	416	6.9	13.5	184.3	302.0	1.8	1.5
341	13	2014	5	3	1	2	NT	NB	L	I	401	9.3	15.5	173.7	205.7	1.4	1.1
342	13	2014	6	3	1	2	CT	NB	H	I	468	7.4	20.4	178.9	227.4	1.2	1.5
343	13	2014	7	1	1	2	CT	NB	L	I	371	8.3	12.1	179.6	294.2	2.4	1.4
344	13	2014	8	1	1	2	NT	NB	H	I	347	9.1	14.0	186.0	256.2	2.1	1.1
345	13	2014	9	2	1	3	NT	NB	L	I	382	8.8	12.8	149.1	219.2	1.8	1.2
346	13	2014	10	2	1	3	CT	NB	H	I	451	8.2	15.4	185.9	286.3	1.6	1.4
347	13	2014	11	3	1	3	NT	NB	H	I	390	7.7	17.6	181.2	248.2	1.5	1.3

obs #	yr	actual yr	plot	Tblock	Bblock	rep	till	burn	Nrate	Irr	Mg	S	Na	Fe	Mn	Zn	Cu
348	13	2014	12	3	1	3	CT	NB	L	I	478	6.5	17.9	176.6	220.6	1.4	1.4
349	13	2014	13	1	1	1	CT	B	L	I	454	8.2	18.4	223.9	268.5	2.0	1.6
350	13	2014	14	1	1	1	NT	B	L	I	313	7.1	21.2	170.1	166.9	1.4	1.4
351	13	2014	15	2	1	1	NT	B	H	I	464	7.6	26.7	178.5	166.5	1.3	1.3
352	13	2014	16	2	1	2	CT	B	L	I	541	7.5	26.7	237.7	256.5	1.2	1.7
353	13	2014	17	3	1	2	NT	B	H	I	499	7.8	23.2	179.1	160.9	1.1	1.3
354	13	2014	18	3	1	3	CT	B	L	I	574	10.1	34.5	248.2	251.5	1.6	1.7
355	13	2014	19	1	1	1	CT	B	H	I	454	6.8	16.7	204.1	252.4	1.5	1.6
356	13	2014	20	1	1	3	NT	B	H	I	452	8.0	18.2	180.1	206.1	1.4	1.4
357	13	2014	21	2	1	2	NT	B	L	I	528	8.8	26.2	214.4	230.3	1.7	1.7
358	13	2014	22	2	1	2	CT	B	H	I	532	7.5	17.5	235.9	265.2	1.5	1.6
359	13	2014	23	3	1	3	NT	B	L	I	466	6.2	16.5	200.5	158.5	1.1	1.3
360	13	2014	24	3	1	3	CT	B	H	I	527	8.0	19.2	213.7	237.4	1.3	1.5
361	13	2014	25	1	2	4	CT	B	H	NI	375	6.4	12.2	202.5	179.8	1.3	1.5
362	13	2014	26	1	2	4	NT	B	H	NI	310	7.0	16.6	187.6	151.3	1.6	1.4
363	13	2014	27	2	2	5	NT	B	H	NI	324	6.8	16.1	183.0	134.9	1.4	1.5
364	13	2014	28	2	2	4	CT	B	L	NI	344	10.9	18.6	194.3	220.5	1.8	1.5
365	13	2014	29	3	2	6	NT	B	H	NI	334	7.5	16.1	199.7	223.8	1.9	1.5
366	13	2014	30	3	2	5	CT	B	L	NI	362	6.5	14.5	200.1	220.5	1.9	1.5
367	13	2014	31	1	2	6	CT	B	L	NI	405	6.6	12.2	198.4	178.9	1.5	1.6
368	13	2014	32	1	2	4	NT	B	L	NI	380	6.4	12.3	188.4	146.7	1.9	1.6
369	13	2014	33	2	2	5	NT	B	L	NI	399	7.7	15.9	187.7	151.2	2.1	1.5
370	13	2014	34	2	2	5	CT	B	H	NI	402	8.1	12.7	232.2	225.2	1.9	1.5
371	13	2014	35	3	2	6	NT	B	L	NI	352	7.6	21.1	193.1	159.2	1.8	1.5
372	13	2014	36	3	2	6	CT	B	H	NI	401	7.4	14.5	193.5	217.3	2.0	1.5
373	13	2014	37	1	2	4	CT	NB	H	NI	357	9.2	16.1	217.1	195.6	2.2	1.7
374	13	2014	38	1	2	4	NT	NB	L	NI	366	7.9	12.1	199.3	195.7	2.0	1.6
375	13	2014	39	2	2	4	NT	NB	H	NI	385	11.2	13.6	190.4	185.1	2.4	1.5
376	13	2014	40	2	2	5	CT	NB	H	NI	363	9.8	14.3	196.6	221.9	2.1	1.6

obs #	yr	actual yr	plot	Tblock	Bblock	rep	till	burn	Nrate	Irr	Mg	S	Na	Fe	Mn	Zn	Cu
377	13	2014	41	3	2	5	NT	NB	L	NI	356	9.6	16.2	195.8	212.9	2.3	1.7
378	13	2014	42	3	2	6	CT	NB	H	NI	374	8.1	21.5	224.2	235.0	2.0	1.8
379	13	2014	43	1	2	4	CT	NB	L	NI	349	8.5	16.9	225.9	195.5	2.5	1.8
380	13	2014	44	1	2	5	NT	NB	H	NI	307	8.4	11.7	176.7	173.2	2.3	1.6
381	13	2014	45	2	2	6	NT	NB	L	NI	348	7.9	11.3	168.8	159.3	1.8	1.6
382	13	2014	46	2	2	5	CT	NB	L	NI	357	10.0	12.6	205.0	264.6	2.5	1.8
383	13	2014	47	3	2	6	NT	NB	H	NI	328	9.7	10.4	205.5	192.3	2.7	1.5
384	13	2014	48	3	2	6	CT	NB	L	NI	417	6.9	16.7	220.5	281.2	2.3	2.0

Soil organic matter concentration (OMconc), total soil nitrogen concentration (Nconc), total soil carbon concentration (Cconc), carbon-to-nitrogen ratio (C:N), soil organic matter content (OMcontent; kg m^{-2}), soil nitrogen content (Ncontent; kg m^{-2}), soil carbon content (Ccontent; kg m^{-2}), carbon fraction of soil organic matter (Cfraction), and nitrogen fraction of soil organic matter (Nfraction).

obs #	yr	actual yr	plot	T block	B block	rep	till	burn	Nrate	Irr	OM conc	N conc	C conc	C:N	OM content	N content	C content	C fraction	N fraction
1	6	2007	1	1	1	1	CT	NB	H	I	2.18	0.11	0.98	8.86	2.60	0.13	1.17	0.45	0.05
2	6	2007	2	1	1	1	NT	NB	L	I	2.22	0.10	0.90	8.98	2.68	0.12	1.08	0.40	0.04
3	6	2007	3	2	1	1	NT	NB	H	I	1.91	0.10	0.88	8.77	2.46	0.13	1.13	0.46	0.05
4	6	2007	4	2	1	1	CT	NB	L	I	1.95	0.10	0.97	9.85	2.39	0.12	1.19	0.50	0.05
5	6	2007	5	3	1	2	NT	NB	L	I	2.22	0.10	0.99	9.44	2.55	0.12	1.14	0.45	0.05
6	6	2007	6	3	1	2	CT	NB	H	I	2.36	0.10	0.93	9.69	2.98	0.12	1.18	0.40	0.04
7	6	2007	7	1	1	2	CT	NB	L	I	2.50	0.12	1.13	9.24	3.05	0.15	1.38	0.45	0.05
8	6	2007	8	1	1	2	NT	NB	H	I	2.39	0.11	1.02	9.44	2.98	0.13	1.27	0.43	0.05
9	6	2007	9	2	1	3	NT	NB	L	I	2.34	0.10	0.96	9.24	2.79	0.12	1.15	0.41	0.04
10	6	2007	10	2	1	3	CT	NB	H	I	2.55	0.10	1.00	9.86	3.13	0.12	1.23	0.39	0.04
11	6	2007	11	3	1	3	NT	NB	H	I	2.39	0.10	1.02	10.01	2.77	0.12	1.18	0.43	0.04
12	6	2007	12	3	1	3	CT	NB	L	I	2.22	0.11	1.05	9.45	2.64	0.13	1.24	0.47	0.05
13	6	2007	13	1	1	1	CT	B	L	I	2.57	0.11	1.16	10.10	3.06	0.14	1.38	0.45	0.04
14	6	2007	14	1	1	1	NT	B	L	I	2.13	0.11	0.97	8.53	2.43	0.13	1.10	0.45	0.05
15	6	2007	15	2	1	1	NT	B	H	I	2.34	0.13	1.08	8.46	2.80	0.15	1.30	0.46	0.05
16	6	2007	16	2	1	2	CT	B	L	I	1.82	0.11	0.90	8.45	2.14	0.13	1.06	0.50	0.06
17	6	2007	17	3	1	2	NT	B	H	I	1.95	0.11	0.86	8.08	2.28	0.12	1.01	0.44	0.05
18	6	2007	18	3	1	3	CT	B	L	I	2.35	0.11	0.93	8.21	2.77	0.13	1.09	0.39	0.05
19	6	2007	19	1	1	1	CT	B	H	I	2.84	0.12	1.21	9.92	3.42	0.15	1.46	0.43	0.04
20	6	2007	20	1	1	3	NT	B	H	I	2.88	0.13	1.37	10.27	3.51	0.16	1.67	0.48	0.05
21	6	2007	21	2	1	2	NT	B	L	I	2.67	0.12	1.21	10.25	3.31	0.15	1.50	0.45	0.04
22	6	2007	22	2	1	2	CT	B	H	I	2.25	0.12	1.15	9.66	2.66	0.14	1.36	0.51	0.05
23	6	2007	23	3	1	3	NT	B	L	I	2.28	0.11	1.09	9.70	2.78	0.14	1.33	0.48	0.05
24	6	2007	24	3	1	3	CT	B	H	I	2.45	0.11	1.03	9.35	2.98	0.13	1.25	0.42	0.04
25	6	2007	25	1	2	1	CT	B	H	NI	1.80	0.10	0.89	8.59	2.20	0.13	1.09	0.50	0.06
26	6	2007	26	1	2	1	NT	B	H	NI	2.41	0.11	1.01	9.03	2.94	0.14	1.24	0.42	0.05

obs #	yr	actual yr	plot	T block	B block	rep	till	burn	Nrate	Irr	OM conc	N conc	C conc	C:N	OM content	N content	C content	C fraction	N fraction
27	6	2007	27	2	2	2	NT	B	H	NI	2.40	0.10	0.96	9.20	3.08	0.13	1.24	0.40	0.04
28	6	2007	28	2	2	1	CT	B	L	NI	1.95	0.09	0.86	9.61	2.36	0.11	1.04	0.44	0.05
29	6	2007	29	3	2	3	NT	B	H	NI	2.13	0.10	0.96	9.74	2.56	0.12	1.15	0.45	0.05
30	6	2007	30	3	2	2	CT	B	L	NI	2.03	0.09	0.84	9.75	2.54	0.11	1.05	0.41	0.04
31	6	2007	31	1	2	3	CT	B	L	NI	2.60	0.11	1.11	10.20	2.74	0.11	1.17	0.43	0.04
32	6	2007	32	1	2	1	NT	B	L	NI	2.28	0.11	1.10	9.74	2.62	0.13	1.26	0.48	0.05
33	6	2007	33	2	2	2	NT	B	L	NI	2.29	0.10	0.98	9.57	2.65	0.12	1.13	0.43	0.04
34	6	2007	34	2	2	2	CT	B	H	NI	2.51	0.10	0.93	9.24	3.10	0.12	1.15	0.37	0.04
35	6	2007	35	3	2	3	NT	B	L	NI	2.59	0.11	1.03	9.59	2.92	0.12	1.16	0.40	0.04
36	6	2007	36	3	2	3	CT	B	H	NI	2.02	0.09	0.87	9.63	2.37	0.11	1.02	0.43	0.04
37	6	2007	37	1	2	1	CT	NB	H	NI	2.11	0.11	0.93	8.34	2.37	0.12	1.04	0.44	0.05
38	6	2007	38	1	2	1	NT	NB	L	NI	2.34	0.13	1.15	8.77	2.94	0.16	1.44	0.49	0.06
39	6	2007	39	2	2	1	NT	NB	H	NI	2.41	0.11	1.04	9.02	2.93	0.14	1.26	0.43	0.05
40	6	2007	40	2	2	2	CT	NB	H	NI	1.98	0.11	0.91	8.64	2.40	0.13	1.11	0.46	0.05
41	6	2007	41	3	2	2	NT	NB	L	NI	1.78	0.09	0.77	8.69	2.17	0.11	0.94	0.43	0.05
42	6	2007	42	3	2	3	CT	NB	H	NI	1.88	0.09	0.77	8.28	2.19	0.11	0.90	0.41	0.05
43	6	2007	43	1	2	1	CT	NB	L	NI	2.78	0.12	1.16	9.80	3.38	0.14	1.42	0.42	0.04
44	6	2007	44	1	2	2	NT	NB	H	NI	3.01	0.12	1.22	10.03	3.79	0.15	1.54	0.41	0.04
45	6	2007	45	2	2	3	NT	NB	L	NI	2.28	0.10	1.02	10.21	2.92	0.13	1.31	0.45	0.04
46	6	2007	46	2	2	2	CT	NB	L	NI	2.39	0.11	1.09	9.96	2.86	0.13	1.31	0.46	0.05
47	6	2007	47	3	2	3	NT	NB	H	NI	2.35	0.11	1.13	10.24	2.84	0.13	1.36	0.48	0.05
48	6	2007	48	3	2	3	CT	NB	L	NI	2.59	0.12	1.10	9.10	3.17	0.15	1.35	0.43	0.05
49	7	2008	1	1	1	1	CT	NB	H	I	2.44	0.13	1.06	8.28	2.87	0.15	1.25	0.44	0.05
50	7	2008	2	1	1	1	NT	NB	L	I	2.38	0.12	1.12	9.23	2.83	0.14	1.33	0.47	0.05
51	7	2008	3	2	1	1	NT	NB	H	I	2.43	0.13	1.11	8.66	3.05	0.16	1.39	0.46	0.05
52	7	2008	4	2	1	1	CT	NB	L	I	2.14	0.12	1.05	9.11	2.57	0.14	1.26	0.49	0.05
53	7	2008	5	3	1	2	NT	NB	L	I	2.45	0.12	0.97	8.29	2.88	0.14	1.14	0.40	0.05
54	7	2008	6	3	1	2	CT	NB	H	I	2.78	0.13	1.11	8.77	3.47	0.16	1.38	0.40	0.05
55	7	2008	7	1	1	2	CT	NB	L	I	2.19	0.11	1.03	9.28	2.63	0.13	1.23	0.47	0.05

obs #	yr	actual yr	plot	T block	B block	rep	till	burn	Nrate	Irr	OM conc	N conc	C conc	C:N	OM content	N content	C content	C fraction	N fraction
56	7	2008	8	1	1	2	NT	NB	H	I	2.13	0.11	0.98	8.58	2.64	0.14	1.21	0.46	0.05
57	7	2008	9	2	1	3	NT	NB	L	I	2.22	0.11	0.99	8.82	2.68	0.14	1.19	0.45	0.05
58	7	2008	10	2	1	3	CT	NB	H	I	2.55	0.12	1.05	8.58	3.08	0.15	1.26	0.41	0.05
59	7	2008	11	3	1	3	NT	NB	H	I	2.62	0.12	1.05	8.48	3.08	0.15	1.24	0.40	0.05
60	7	2008	12	3	1	3	CT	NB	L	I	2.33	0.13	1.06	8.45	2.81	0.15	1.28	0.45	0.05
61	7	2008	13	1	1	1	CT	B	L	I	2.58	0.12	1.08	9.12	3.03	0.14	1.27	0.42	0.05
62	7	2008	14	1	1	1	NT	B	L	I	2.66	0.12	1.04	8.80	3.06	0.14	1.20	0.39	0.04
63	7	2008	15	2	1	1	NT	B	H	I	2.41	0.13	1.19	8.94	2.87	0.16	1.41	0.49	0.06
64	7	2008	16	2	1	2	CT	B	L	I	2.85	0.11	1.01	9.37	3.32	0.13	1.17	0.35	0.04
65	7	2008	17	3	1	2	NT	B	H	I	2.65	0.12	1.24	10.50	3.20	0.14	1.50	0.47	0.04
66	7	2008	18	3	1	3	CT	B	L	I	2.95	0.11	1.10	9.81	3.54	0.13	1.32	0.37	0.04
67	7	2008	19	1	1	1	CT	B	H	I	3.18	0.14	1.17	8.40	3.79	0.17	1.40	0.37	0.04
68	7	2008	20	1	1	3	NT	B	H	I	2.81	0.14	1.33	9.55	3.44	0.17	1.62	0.47	0.05
69	7	2008	21	2	1	2	NT	B	L	I	2.54	0.12	1.09	9.05	3.12	0.15	1.33	0.43	0.05
70	7	2008	22	2	1	2	CT	B	H	I	2.46	0.11	1.06	9.26	2.99	0.14	1.29	0.43	0.05
71	7	2008	23	3	1	3	NT	B	L	I	2.88	0.13	1.12	8.62	3.58	0.16	1.39	0.39	0.04
72	7	2008	24	3	1	3	CT	B	H	I	2.79	0.14	1.27	9.24	3.40	0.17	1.55	0.46	0.05
73	7	2008	25	1	2	4	CT	B	H	NI	2.79	0.14	1.18	8.43	3.42	0.17	1.45	0.42	0.05
74	7	2008	26	1	2	4	NT	B	H	NI	2.80	0.14	1.17	8.50	3.39	0.17	1.41	0.42	0.05
75	7	2008	27	2	2	5	NT	B	H	NI	2.77	0.12	1.16	9.74	3.43	0.15	1.44	0.42	0.04
76	7	2008	28	2	2	4	CT	B	L	NI	2.99	0.13	1.16	9.19	3.56	0.15	1.38	0.39	0.04
77	7	2008	29	3	2	6	NT	B	H	NI	3.07	0.13	1.24	9.32	3.69	0.16	1.48	0.40	0.04
78	7	2008	30	3	2	5	CT	B	L	NI	2.62	0.12	1.14	9.44	3.25	0.15	1.42	0.44	0.05
79	7	2008	31	1	2	6	CT	B	L	NI	2.42	0.11	1.19	10.75	2.80	0.13	1.37	0.49	0.05
80	7	2008	32	1	2	4	NT	B	L	NI	2.62	0.13	1.16	9.00	3.11	0.15	1.37	0.44	0.05
81	7	2008	33	2	2	5	NT	B	L	NI	2.77	0.12	1.05	8.67	3.31	0.14	1.26	0.38	0.04
82	7	2008	34	2	2	5	CT	B	H	NI	2.69	0.11	1.02	9.13	3.25	0.14	1.24	0.38	0.04
83	7	2008	35	3	2	6	NT	B	L	NI	2.72	0.11	1.02	9.55	3.19	0.13	1.20	0.37	0.04
84	7	2008	36	3	2	6	CT	B	H	NI	2.96	0.12	1.23	10.07	3.51	0.14	1.45	0.41	0.04

obs #	yr	actual yr	plot	T block	B block	rep	till	burn	Nrate	Irr	OM conc	N conc	C conc	C:N	OM content	N content	C content	C fraction	N fraction
85	7	2008	37	1	2	4	CT	NB	H	NI	3.24	0.13	1.26	9.60	3.76	0.15	1.47	0.39	0.04
86	7	2008	38	1	2	4	NT	NB	L	NI	2.82	0.11	1.11	9.95	3.53	0.14	1.39	0.40	0.04
87	7	2008	39	2	2	4	NT	NB	H	NI	3.04	0.12	1.08	9.24	3.72	0.14	1.32	0.36	0.04
88	7	2008	40	2	2	5	CT	NB	H	NI	3.27	0.14	1.38	9.88	4.06	0.17	1.71	0.42	0.04
89	7	2008	41	3	2	5	NT	NB	L	NI	3.03	0.11	1.06	9.26	3.69	0.14	1.29	0.35	0.04
90	7	2008	42	3	2	6	CT	NB	H	NI	2.81	0.12	1.15	9.75	3.36	0.14	1.38	0.41	0.04
91	7	2008	43	1	2	4	CT	NB	L	NI	3.09	0.12	1.11	9.20	3.80	0.15	1.36	0.36	0.04
92	7	2008	44	1	2	5	NT	NB	H	NI	2.59	0.12	1.03	8.72	3.24	0.15	1.29	0.40	0.05
93	7	2008	45	2	2	6	NT	NB	L	NI	2.89	0.13	1.27	9.51	3.66	0.17	1.60	0.44	0.05
94	7	2008	46	2	2	5	CT	NB	L	NI	2.71	0.13	1.24	9.55	3.31	0.16	1.51	0.46	0.05
95	7	2008	47	3	2	6	NT	NB	H	NI	3.12	0.12	1.14	9.23	3.75	0.15	1.37	0.37	0.04
96	7	2008	48	3	2	6	CT	NB	L	NI	2.93	0.12	1.21	10.22	3.51	0.14	1.45	0.41	0.04
97	8	2009	1	1	1	1	CT	NB	H	I	2.53	0.13	1.13	8.83	2.93	0.15	1.31	0.45	0.05
98	8	2009	2	1	1	1	NT	NB	L	I	2.19	0.14	1.09	7.98	2.57	0.16	1.27	0.50	0.06
99	8	2009	3	2	1	1	NT	NB	H	I	1.79	0.12	0.82	6.89	2.18	0.14	1.00	0.46	0.07
100	8	2009	4	2	1	1	CT	NB	L	I	2.09	0.14	1.00	7.17	2.47	0.16	1.18	0.48	0.07
101	8	2009	5	3	1	2	NT	NB	L	I	2.41	0.14	1.01	7.35	2.89	0.17	1.22	0.42	0.06
102	8	2009	6	3	1	2	CT	NB	H	I	2.54	0.16	1.13	7.26	3.13	0.19	1.39	0.44	0.06
103	8	2009	7	1	1	2	CT	NB	L	I	2.28	0.14	1.02	7.44	2.70	0.16	1.21	0.45	0.06
104	8	2009	8	1	1	2	NT	NB	H	I	2.25	0.13	0.91	7.15	2.77	0.16	1.12	0.40	0.06
105	8	2009	9	2	1	3	NT	NB	L	I	2.45	0.14	1.03	7.48	2.99	0.17	1.25	0.42	0.06
106	8	2009	10	2	1	3	CT	NB	H	I	2.61	0.15	1.18	8.08	3.11	0.17	1.40	0.45	0.06
107	8	2009	11	3	1	3	NT	NB	H	I	2.49	0.14	1.10	7.62	2.96	0.17	1.31	0.44	0.06
108	8	2009	12	3	1	3	CT	NB	L	I	2.36	0.13	0.92	7.06	2.90	0.16	1.13	0.39	0.05
109	8	2009	13	1	1	1	CT	B	L	I	2.66	0.14	1.12	7.99	3.09	0.16	1.30	0.42	0.05
110	8	2009	14	1	1	1	NT	B	L	I	2.82	0.15	1.18	8.02	3.27	0.17	1.36	0.42	0.05
111	8	2009	15	2	1	1	NT	B	H	I	2.57	0.14	1.11	7.99	3.06	0.17	1.32	0.43	0.05
112	8	2009	16	2	1	2	CT	B	L	I	2.44	0.13	1.04	8.02	2.81	0.15	1.20	0.43	0.05
113	8	2009	17	3	1	2	NT	B	H	I	2.26	0.11	0.98	9.00	2.81	0.14	1.22	0.43	0.05

obs #	yr	actual yr	plot	T block	B block	rep	till	burn	Nrate	Irr	OM conc	N conc	C conc	C:N	OM content	N content	C content	C fraction	N fraction
114	8	2009	18	3	1	3	CT	B	L	I	2.45	0.12	0.99	8.51	2.99	0.14	1.21	0.40	0.05
115	8	2009	19	1	1	1	CT	B	H	I	2.52	0.13	1.08	8.27	2.97	0.15	1.27	0.43	0.05
116	8	2009	20	1	1	3	NT	B	H	I	2.31	0.13	1.10	8.57	2.84	0.16	1.36	0.48	0.06
117	8	2009	21	2	1	2	NT	B	L	I	2.48	0.14	1.30	9.48	3.02	0.17	1.59	0.53	0.06
118	8	2009	22	2	1	2	CT	B	H	I	2.28	0.12	0.85	7.42	2.85	0.14	1.07	0.38	0.05
119	8	2009	23	3	1	3	NT	B	L	I	2.13	0.11	0.95	8.80	2.71	0.14	1.21	0.45	0.05
120	8	2009	24	3	1	3	CT	B	H	I	2.15	0.13	1.05	8.06	2.62	0.16	1.29	0.49	0.06
121	8	2009	25	1	2	4	CT	B	H	NI	2.43	0.12	1.00	8.17	2.99	0.15	1.23	0.41	0.05
122	8	2009	26	1	2	4	NT	B	H	NI	2.42	0.12	1.02	8.21	2.90	0.15	1.23	0.42	0.05
123	8	2009	27	2	2	5	NT	B	H	NI	2.22	0.12	1.05	8.46	2.64	0.15	1.25	0.47	0.06
124	8	2009	28	2	2	4	CT	B	L	NI	2.42	0.13	1.13	8.55	2.83	0.15	1.32	0.47	0.05
125	8	2009	29	3	2	6	NT	B	H	NI	2.60	0.14	1.16	8.49	3.13	0.16	1.39	0.44	0.05
126	8	2009	30	3	2	5	CT	B	L	NI	2.43	0.12	0.98	8.01	2.98	0.15	1.20	0.40	0.05
127	8	2009	31	1	2	6	CT	B	L	NI	2.39	0.12	0.98	8.34	3.02	0.15	1.24	0.41	0.05
128	8	2009	32	1	2	4	NT	B	L	NI	2.33	0.12	0.90	7.84	2.87	0.14	1.11	0.39	0.05
129	8	2009	33	2	2	5	NT	B	L	NI	2.45	0.12	1.02	8.19	3.01	0.15	1.25	0.42	0.05
130	8	2009	34	2	2	5	CT	B	H	NI	2.42	0.13	1.04	8.25	2.86	0.15	1.23	0.43	0.05
131	8	2009	35	3	2	6	NT	B	L	NI	2.54	0.13	1.03	8.15	3.10	0.15	1.26	0.41	0.05
132	8	2009	36	3	2	6	CT	B	H	NI	2.58	0.13	1.12	8.72	3.09	0.15	1.34	0.43	0.05
133	8	2009	37	1	2	4	CT	NB	H	NI	2.44	0.14	1.14	8.36	2.93	0.16	1.37	0.47	0.06
134	8	2009	38	1	2	4	NT	NB	L	NI	2.02	0.11	0.82	7.68	2.52	0.13	1.02	0.41	0.05
135	8	2009	39	2	2	4	NT	NB	H	NI	2.50	0.13	1.08	8.52	3.07	0.16	1.33	0.43	0.05
136	8	2009	40	2	2	5	CT	NB	H	NI	2.74	0.13	1.06	8.09	3.48	0.17	1.34	0.39	0.05
137	8	2009	41	3	2	5	NT	NB	L	NI	2.78	0.13	1.10	8.34	3.39	0.16	1.34	0.39	0.05
138	8	2009	42	3	2	6	CT	NB	H	NI	2.76	0.13	1.04	8.12	3.37	0.16	1.27	0.38	0.05
139	8	2009	43	1	2	4	CT	NB	L	NI	2.51	0.10	1.00	9.62	3.11	0.13	1.24	0.40	0.04
140	8	2009	44	1	2	5	NT	NB	H	NI	2.43	0.11	1.10	9.67	3.02	0.14	1.37	0.45	0.05
141	8	2009	45	2	2	6	NT	NB	L	NI	2.20	0.10	0.92	9.11	2.75	0.13	1.15	0.42	0.05
142	8	2009	46	2	2	5	CT	NB	L	NI	2.45	0.10	1.02	9.68	3.04	0.13	1.26	0.41	0.04

obs #	yr	actual yr	plot	T block	B block	rep	till	burn	Nrate	Irr	OM conc	N conc	C conc	C:N	OM content	N content	C content	C fraction	N fraction
143	8	2009	47	3	2	6	NT	NB	H	NI	2.89	0.12	1.17	9.66	3.47	0.15	1.40	0.40	0.04
144	8	2009	48	3	2	6	CT	NB	L	NI	2.76	0.12	1.12	9.32	3.23	0.14	1.31	0.40	0.04
145	9		1	1	1	1	CT	NB	H	I	2.68	0.11	1.16	10.13	3.35	0.14	1.45	0.43	0.04
146	9	2010	2	1	1	1	NT	NB	L	I	1.93	0.08	0.84	10.14	2.43	0.10	1.06	0.44	0.04
147	9	2010	3	2	1	1	NT	NB	H	I	1.95	0.09	0.88	9.33	2.42	0.12	1.09	0.45	0.05
148	9	2010	4	2	1	1	CT	NB	L	I	2.15	0.10	0.92	9.55	2.77	0.12	1.18	0.43	0.04
149	9	2010	5	3	1	2	NT	NB	L	I	2.02	0.09	0.86	9.87	2.55	0.11	1.08	0.43	0.04
150	9	2010	6	3	1	2	CT	NB	H	I	2.34	0.11	0.96	9.08	3.07	0.14	1.26	0.41	0.05
151	9	2010	7	1	1	2	CT	NB	L	I	2.12	0.10	0.92	9.52	2.73	0.12	1.18	0.43	0.05
152	9	2010	8	1	1	2	NT	NB	H	I	1.97	0.09	0.84	9.54	2.36	0.11	1.01	0.43	0.04
153	9	2010	9	2	1	3	NT	NB	L	I	1.69	0.07	0.66	9.56	2.15	0.09	0.84	0.39	0.04
154	9	2010	10	2	1	3	CT	NB	H	I	2.08	0.09	0.86	9.14	2.66	0.12	1.10	0.41	0.05
155	9	2010	11	3	1	3	NT	NB	H	I	1.96	0.09	0.77	8.92	2.49	0.11	0.98	0.39	0.04
156	9	2010	12	3	1	3	CT	NB	L	I	2.35	0.11	1.09	10.03	2.75	0.13	1.28	0.46	0.05
157	9	2010	13	1	1	1	CT	B	L	I	1.70	0.07	0.72	9.72	2.18	0.10	0.92	0.42	0.04
158	9	2010	14	1	1	1	NT	B	L	I	2.20	0.09	0.87	9.44	2.84	0.12	1.12	0.39	0.04
159	9	2010	15	2	1	1	NT	B	H	I	2.78	0.13	1.20	9.56	3.53	0.16	1.53	0.43	0.05
160	9	2010	16	2	1	2	CT	B	L	I	2.22	0.09	0.83	8.78	2.84	0.12	1.06	0.37	0.04
161	9	2010	17	3	1	2	NT	B	H	I	2.34	0.10	0.92	9.23	3.07	0.13	1.21	0.40	0.04
162	9	2010	18	3	1	3	CT	B	L	I	2.73	0.12	1.10	9.19	3.49	0.15	1.41	0.40	0.04
163	9	2010	19	1	1	1	CT	B	H	I	2.18	0.10	0.86	8.45	2.88	0.13	1.13	0.39	0.05
164	9	2010	20	1	1	3	NT	B	H	I	1.92	0.08	0.74	9.17	2.52	0.11	0.97	0.38	0.04
165	9	2010	21	2	1	2	NT	B	L	I	2.01	0.09	0.85	9.37	2.59	0.12	1.09	0.42	0.04
166	9	2010	22	2	1	2	CT	B	H	I	2.34	0.10	0.96	9.17	3.02	0.13	1.23	0.41	0.04
167	9	2010	23	3	1	3	NT	B	L	I	2.26	0.10	0.92	9.63	3.03	0.13	1.24	0.41	0.04
168	9	2010	24	3	1	3	CT	B	H	I	2.46	0.10	0.96	9.36	3.03	0.13	1.18	0.39	0.04
169	9	2010	25	1	2	4	CT	B	H	NI	2.28	0.09	0.80	8.78	3.01	0.12	1.05	0.35	0.04
170	9	2010	26	1	2	4	NT	B	H	NI	2.55	0.10	1.01	9.88	3.42	0.14	1.35	0.39	0.04
171	9	2010	27	2	2	5	NT	B	H	NI	2.71	0.11	1.06	10.08	3.52	0.14	1.38	0.39	0.04

obs #	yr	actual yr	plot	T block	B block	rep	till	burn	Nrate	Irr	OM conc	N conc	C conc	C:N	OM content	N content	C content	C fraction	N fraction
172	9	2010	28	2	2	4	CT	B	L	NI	2.14	0.10	0.93	9.08	2.89	0.14	1.25	0.43	0.05
173	9	2010	29	3	2	6	NT	B	H	NI	3.49	0.12	1.22	10.61	4.57	0.15	1.60	0.35	0.03
174	9	2010	30	3	2	5	CT	B	L	NI	2.53	0.11	1.04	9.49	3.26	0.14	1.34	0.41	0.04
175	9	2010	31	1	2	6	CT	B	L	NI	2.00	0.09	0.80	9.14	2.64	0.12	1.06	0.40	0.04
176	9	2010	32	1	2	4	NT	B	L	NI	2.07	0.10	0.82	8.01	2.73	0.14	1.09	0.40	0.05
177	9	2010	33	2	2	5	NT	B	L	NI	2.66	0.11	1.11	9.78	3.43	0.15	1.43	0.42	0.04
178	9	2010	34	2	2	5	CT	B	H	NI	2.26	0.10	0.81	8.36	2.87	0.12	1.03	0.36	0.04
179	9	2010	35	3	2	6	NT	B	L	NI	2.60	0.12	1.08	9.27	3.46	0.16	1.44	0.42	0.04
180	9	2010	36	3	2	6	CT	B	H	NI	2.64	0.13	1.20	8.99	3.41	0.17	1.55	0.46	0.05
181	9	2010	37	1	2	4	CT	NB	H	NI	2.51	0.12	1.05	8.92	3.26	0.15	1.37	0.42	0.05
182	9	2010	38	1	2	4	NT	NB	L	NI	2.33	0.11	0.95	8.30	3.03	0.15	1.23	0.41	0.05
183	9	2010	39	2	2	4	NT	NB	H	NI	2.47	0.12	1.02	8.81	3.41	0.16	1.41	0.41	0.05
184	9	2010	40	2	2	5	CT	NB	H	NI	2.95	0.14	1.25	9.01	3.89	0.18	1.65	0.42	0.05
185	9	2010	41	3	2	5	NT	NB	L	NI	2.16	0.10	0.80	7.84	2.92	0.14	1.08	0.37	0.05
186	9	2010	42	3	2	6	CT	NB	H	NI	2.17	0.10	0.76	7.36	2.80	0.13	0.98	0.35	0.05
187	9	2010	43	1	2	4	CT	NB	L	NI	2.66	0.13	1.11	8.57	3.46	0.17	1.44	0.42	0.05
188	9	2010	44	1	2	5	NT	NB	H	NI	2.74	0.13	1.10	8.54	3.70	0.17	1.49	0.40	0.05
189	9	2010	45	2	2	6	NT	NB	L	NI	2.24	0.12	0.97	7.93	2.87	0.16	1.25	0.43	0.05
190	9	2010	46	2	2	5	CT	NB	L	NI	2.28	0.12	0.97	8.05	2.99	0.16	1.27	0.43	0.05
191	9	2010	47	3	2	6	NT	NB	H	NI	2.25	0.12	0.92	7.45	3.11	0.17	1.27	0.41	0.05
192	9	2010	48	3	2	6	CT	NB	L	NI	2.24	0.12	0.87	7.57	3.05	0.16	1.18	0.39	0.05
193	10	2011	1	1	1	1	CT	NB	H	I	2.31	0.11	0.92	8.76	2.98	0.14	1.19	0.40	0.05
194	10	2011	2	1	1	1	NT	NB	L	I	1.93	0.09	0.78	8.39	2.49	0.12	1.01	0.41	0.05
195	10	2011	3	2	1	1	NT	NB	H	I	2.35	0.11	1.00	8.82	2.98	0.14	1.27	0.43	0.05
196	10	2011	4	2	1	1	CT	NB	L	I	2.29	0.10	0.94	9.30	2.88	0.13	1.18	0.41	0.04
197	10	2011	5	3	1	2	NT	NB	L	I	1.87	0.08	0.67	8.33	2.46	0.11	0.88	0.36	0.04
198	10	2011	6	3	1	2	CT	NB	H	I	2.64	0.11	0.96	8.60	3.56	0.15	1.29	0.36	0.04
199	10	2011	7	1	1	2	CT	NB	L	I	2.48	0.12	1.07	9.24	3.17	0.15	1.37	0.43	0.05
200	10	2011	8	1	1	2	NT	NB	H	I	2.19	0.11	1.00	8.88	2.69	0.14	1.23	0.46	0.05

obs #	yr	actual yr	plot	T block	B block	rep	till	burn	Nrate	Irr	OM conc	N conc	C conc	C:N	OM content	N content	C content	C fraction	N fraction
201	10	2011	9	2	1	3	NT	NB	L	I	2.87	0.13	1.11	8.70	3.45	0.15	1.33	0.39	0.04
202	10	2011	10	2	1	3	CT	NB	H	I	2.35	0.11	0.94	8.66	3.00	0.14	1.21	0.40	0.05
203	10	2011	11	3	1	3	NT	NB	H	I	3.30	0.13	1.22	9.15	3.99	0.16	1.48	0.37	0.04
204	10	2011	12	3	1	3	CT	NB	L	I	2.04	0.10	0.76	7.83	2.68	0.13	1.00	0.37	0.05
205	10	2011	13	1	1	1	CT	B	L	I	2.16	0.10	0.82	8.12	2.82	0.13	1.08	0.38	0.05
206	10	2011	14	1	1	1	NT	B	L	I	2.35	0.12	0.95	7.96	2.98	0.15	1.21	0.40	0.05
207	10	2011	15	2	1	1	NT	B	H	I	2.60	0.13	1.00	7.67	3.38	0.17	1.29	0.38	0.05
208	10	2011	16	2	1	2	CT	B	L	I	2.57	0.13	0.98	7.47	3.17	0.16	1.21	0.38	0.05
209	10	2011	17	3	1	2	NT	B	H	I	1.82	0.12	0.77	6.41	2.41	0.16	1.01	0.42	0.07
210	10	2011	18	3	1	3	CT	B	L	I	2.44	0.15	1.03	7.02	3.17	0.19	1.34	0.42	0.06
211	10	2011	19	1	1	1	CT	B	H	I	2.27	0.14	0.92	6.60	2.98	0.18	1.21	0.41	0.06
212	10	2011	20	1	1	3	NT	B	H	I	2.15	0.10	0.89	8.94	2.86	0.13	1.18	0.41	0.05
213	10	2011	21	2	1	2	NT	B	L	I	2.23	0.11	0.91	7.99	2.96	0.15	1.21	0.41	0.05
214	10	2011	22	2	1	2	CT	B	H	I	2.47	0.10	0.93	9.11	3.21	0.13	1.21	0.38	0.04
215	10	2011	23	3	1	3	NT	B	L	I	2.79	0.11	1.06	9.44	3.49	0.14	1.32	0.38	0.04
216	10	2011	24	3	1	3	CT	B	H	I	2.28	0.10	0.87	8.88	3.04	0.13	1.16	0.38	0.04
217	10	2011	25	1	2	4	CT	B	H	NI	2.14	0.09	0.77	8.73	2.98	0.12	1.08	0.36	0.04
218	10	2011	26	1	2	4	NT	B	H	NI	2.56	0.12	1.14	9.87	3.31	0.15	1.47	0.45	0.05
219	10	2011	27	2	2	5	NT	B	H	NI	2.12	0.10	0.89	8.99	2.80	0.13	1.17	0.42	0.05
220	10	2011	28	2	2	4	CT	B	L	NI	2.47	0.12	1.10	8.80	3.19	0.16	1.42	0.45	0.05
221	10	2011	29	3	2	6	NT	B	H	NI	2.20	0.10	0.89	8.91	2.90	0.13	1.17	0.40	0.05
222	10	2011	30	3	2	5	CT	B	L	NI	2.25	0.10	0.88	8.65	2.97	0.13	1.16	0.39	0.05
223	10	2011	31	1	2	6	CT	B	L	NI	2.43	0.12	1.05	8.91	3.19	0.15	1.37	0.43	0.05
224	10	2011	32	1	2	4	NT	B	L	NI	2.47	0.10	0.98	9.57	3.19	0.13	1.26	0.40	0.04
225	10	2011	33	2	2	5	NT	B	L	NI	2.85	0.12	1.14	9.53	3.54	0.15	1.41	0.40	0.04
226	10	2011	34	2	2	5	CT	B	H	NI	2.32	0.10	0.86	8.63	3.09	0.13	1.15	0.37	0.04
227	10	2011	35	3	2	6	NT	B	L	NI	2.38	0.11	0.95	8.72	3.00	0.14	1.20	0.40	0.05
228	10	2011	36	3	2	6	CT	B	H	NI	2.16	0.10	0.85	8.50	2.78	0.13	1.10	0.40	0.05
229	10	2011	37	1	2	4	CT	NB	H	NI	3.12	0.14	1.28	9.25	3.99	0.18	1.63	0.41	0.04

obs #	yr	actual yr	plot	T block	B block	rep	till	burn	Nrate	Irr	OM conc	N conc	C conc	C:N	OM content	N content	C content	C fraction	N fraction
230	10	2011	38	1	2	4	NT	NB	L	NI	2.69	0.11	1.01	9.27	3.49	0.14	1.32	0.38	0.04
231	10	2011	39	2	2	4	NT	NB	H	NI	2.47	0.10	0.92	8.84	3.29	0.14	1.22	0.37	0.04
232	10	2011	40	2	2	5	CT	NB	H	NI	2.99	0.13	1.21	9.52	3.74	0.16	1.51	0.40	0.04
233	10	2011	41	3	2	5	NT	NB	L	NI	2.17	0.08	0.74	9.03	2.89	0.11	0.99	0.34	0.04
234	10	2011	42	3	2	6	CT	NB	H	NI	2.33	0.10	0.81	8.51	3.12	0.13	1.09	0.35	0.04
235	10	2011	43	1	2	4	CT	NB	L	NI	2.99	0.13	1.15	9.12	3.85	0.16	1.48	0.38	0.04
236	10	2011	44	1	2	5	NT	NB	H	NI	2.66	0.11	0.96	8.84	3.43	0.14	1.24	0.36	0.04
237	10	2011	45	2	2	6	NT	NB	L	NI	2.83	0.12	1.07	9.01	3.81	0.16	1.45	0.38	0.04
238	10	2011	46	2	2	5	CT	NB	L	NI	2.84	0.11	1.05	9.16	3.67	0.15	1.36	0.37	0.04
239	10	2011	47	3	2	6	NT	NB	H	NI	3.76	0.15	1.44	9.41	4.48	0.18	1.71	0.38	0.04
240	10	2011	48	3	2	6	CT	NB	L	NI	3.11	0.12	1.11	8.94	4.07	0.16	1.45	0.36	0.04
241	11	2012	1	1	1	1	CT	NB	H	I	1.80	0.10	0.89	9.09	2.40	0.13	1.19	0.50	0.05
242	11	2012	2	1	1	1	NT	NB	L	I	1.89	0.11	0.98	9.24	2.39	0.13	1.23	0.52	0.06
243	11	2012	3	2	1	1	NT	NB	H	I	1.95	0.10	0.99	9.71	2.46	0.13	1.25	0.51	0.05
244	11	2012	4	2	1	1	CT	NB	L	I	2.15	0.12	1.11	9.26	2.66	0.15	1.37	0.52	0.06
245	11	2012	5	3	1	2	NT	NB	L	I	1.72	0.09	0.81	9.22	2.28	0.12	1.07	0.47	0.05
246	11	2012	6	3	1	2	CT	NB	H	I	2.13	0.12	1.04	8.95	2.64	0.14	1.29	0.49	0.05
247	11	2012	7	1	1	2	CT	NB	L	I	2.15	0.12	1.23	10.01	2.65	0.15	1.51	0.57	0.06
248	11	2012	8	1	1	2	NT	NB	H	I	1.74	0.10	0.90	9.39	2.24	0.12	1.17	0.52	0.06
249	11	2012	9	2	1	3	NT	NB	L	I	2.18	0.11	1.07	9.58	2.73	0.14	1.34	0.49	0.05
250	11	2012	10	2	1	3	CT	NB	H	I	2.27	0.12	1.12	9.55	2.86	0.15	1.41	0.49	0.05
251	11	2012	11	3	1	3	NT	NB	H	I	2.10	0.11	0.98	8.62	2.57	0.14	1.19	0.46	0.05
252	11	2012	12	3	1	3	CT	NB	L	I	2.16	0.10	0.94	9.06	2.96	0.14	1.28	0.43	0.05
253	11	2012	13	1	1	1	CT	B	L	I	2.72	0.13	1.25	9.68	3.35	0.16	1.53	0.46	0.05
254	11	2012	14	1	1	1	NT	B	L	I	1.80	0.09	0.80	9.19	2.45	0.12	1.09	0.45	0.05
255	11	2012	15	2	1	1	NT	B	H	I	2.12	0.10	0.97	9.87	2.93	0.14	1.35	0.46	0.05
256	11	2012	16	2	1	2	CT	B	L	I	2.13	0.11	1.04	9.52	2.77	0.14	1.35	0.49	0.05
257	11	2012	17	3	1	2	NT	B	H	I	1.98	0.09	0.89	9.42	2.67	0.13	1.20	0.45	0.05
258	11	2012	18	3	1	3	CT	B	L	I	2.61	0.12	1.19	9.70	3.34	0.16	1.52	0.46	0.05

obs #	yr	actual yr	plot	T block	B block	rep	till	burn	Nrate	Irr	OM conc	N conc	C conc	C:N	OM content	N content	C content	C fraction	N fraction
259	11	2012	19	1	1	1	CT	B	H	I	2.22	0.11	1.03	9.70	2.97	0.14	1.39	0.47	0.05
260	11	2012	20	1	1	3	NT	B	H	I	2.25	0.11	1.06	9.93	2.86	0.14	1.34	0.47	0.05
261	11	2012	21	2	1	2	NT	B	L	I	2.20	0.12	1.13	9.67	2.95	0.16	1.51	0.51	0.05
262	11	2012	22	2	1	2	CT	B	H	I	2.08	0.10	0.90	9.20	2.78	0.13	1.21	0.43	0.05
263	11	2012	23	3	1	3	NT	B	L	I	2.43	0.12	1.16	10.06	3.06	0.15	1.46	0.48	0.05
264	11	2012	24	3	1	3	CT	B	H	I	1.98	0.10	0.91	9.49	2.56	0.12	1.18	0.46	0.05
265	11	2012	25	1	2	4	CT	B	H	NI	2.87	0.15	1.45	9.61	3.59	0.19	1.82	0.51	0.05
266	11	2012	26	1	2	4	NT	B	H	NI	2.17	0.11	1.09	9.56	2.83	0.15	1.41	0.50	0.05
267	11	2012	27	2	2	5	NT	B	H	NI	2.28	0.12	1.21	10.14	2.87	0.15	1.52	0.53	0.05
268	11	2012	28	2	2	4	CT	B	L	NI	2.28	0.11	1.00	9.46	2.94	0.14	1.29	0.44	0.05
269	11	2012	29	3	2	6	NT	B	H	NI	2.17	0.11	1.01	9.12	2.80	0.14	1.30	0.46	0.05
270	11	2012	30	3	2	5	CT	B	L	NI	1.85	0.09	0.82	8.96	2.42	0.12	1.07	0.44	0.05
271	11	2012	31	1	2	6	CT	B	L	NI	2.36	0.11	0.99	9.12	3.04	0.14	1.28	0.42	0.05
272	11	2012	32	1	2	4	NT	B	L	NI	2.07	0.11	1.02	9.27	2.71	0.14	1.34	0.49	0.05
273	11	2012	33	2	2	5	NT	B	L	NI	2.18	0.10	0.94	8.97	2.79	0.13	1.20	0.43	0.05
274	11	2012	34	2	2	5	CT	B	H	NI	2.82	0.13	1.21	9.54	3.52	0.16	1.52	0.43	0.05
275	11	2012	35	3	2	6	NT	B	L	NI	2.23	0.10	0.93	9.38	2.78	0.12	1.16	0.42	0.04
276	11	2012	36	3	2	6	CT	B	H	NI	2.47	0.12	1.11	9.13	3.12	0.15	1.40	0.45	0.05
277	11	2012	37	1	2	4	CT	NB	H	NI	3.04	0.15	1.38	9.28	3.74	0.18	1.69	0.45	0.05
278	11	2012	38	1	2	4	NT	NB	L	NI	2.89	0.15	1.45	10.01	3.47	0.17	1.74	0.50	0.05
279	11	2012	39	2	2	4	NT	NB	H	NI	2.50	0.12	1.08	9.14	3.18	0.15	1.37	0.43	0.05
280	11	2012	40	2	2	5	CT	NB	H	NI	2.77	0.14	1.33	9.69	3.44	0.17	1.65	0.48	0.05
281	11	2012	41	3	2	5	NT	NB	L	NI	2.33	0.12	1.09	9.20	2.92	0.15	1.36	0.47	0.05
282	11	2012	42	3	2	6	CT	NB	H	NI	2.67	0.13	1.32	9.95	3.23	0.16	1.60	0.49	0.05
283	11	2012	43	1	2	4	CT	NB	L	NI	2.91	0.14	1.39	9.93	3.57	0.17	1.71	0.48	0.05
284	11	2012	44	1	2	5	NT	NB	H	NI	2.64	0.12	1.15	9.74	3.38	0.15	1.47	0.43	0.04
285	11	2012	45	2	2	6	NT	NB	L	NI	2.52	0.12	1.17	10.09	3.23	0.15	1.50	0.46	0.05
286	11	2012	46	2	2	5	CT	NB	L	NI	2.39	0.12	1.16	9.75	2.99	0.15	1.44	0.48	0.05
287	11	2012	47	3	2	6	NT	NB	H	NI	2.56	0.13	1.19	9.31	3.32	0.17	1.55	0.47	0.05

obs #	yr	actual yr	plot	T block	B block	rep	till	burn	Nrate	Irr	OM conc	N conc	C conc	C:N	OM content	N content	C content	C fraction	N fraction
288	11	2012	48	3	2	6	CT	NB	L	NI	2.50	0.12	1.15	9.68	3.20	0.15	1.48	0.46	0.05
289	12	2013	1	1	1	1	CT	NB	H	I	1.73	0.09	0.84	9.32	2.26	0.12	1.10	0.48	0.05
290	12	2013	2	1	1	1	NT	NB	L	I	2.82	0.15	1.37	9.37	3.44	0.18	1.67	0.49	0.05
291	12	2013	3	2	1	1	NT	NB	H	I	1.92	0.10	0.84	8.52	2.46	0.13	1.07	0.44	0.05
292	12	2013	4	2	1	1	CT	NB	L	I	2.28	0.12	1.07	9.18	2.84	0.15	1.34	0.47	0.05
293	12	2013	5	3	1	2	NT	NB	L	I	1.93	0.11	0.90	8.24	2.39	0.14	1.12	0.47	0.06
294	12	2013	6	3	1	2	CT	NB	H	I	2.00	0.10	0.87	8.85	2.64	0.13	1.15	0.43	0.05
295	12	2013	7	1	1	2	CT	NB	L	I	2.14	0.10	0.95	9.11	2.70	0.13	1.19	0.44	0.05
296	12	2013	8	1	1	2	NT	NB	H	I	2.70	0.15	1.31	8.97	3.27	0.18	1.59	0.49	0.05
297	12	2013	9	2	1	3	NT	NB	L	I	2.14	0.11	0.99	9.18	2.63	0.13	1.21	0.46	0.05
298	12	2013	10	2	1	3	CT	NB	H	I	2.20	0.12	1.01	8.62	2.87	0.15	1.32	0.46	0.05
299	12	2013	11	3	1	3	NT	NB	H	I	2.41	0.11	0.97	8.65	3.08	0.14	1.24	0.40	0.05
300	12	2013	12	3	1	3	CT	NB	L	I	2.02	0.10	0.87	8.55	2.73	0.14	1.17	0.43	0.05
301	12	2013	13	1	1	1	CT	B	L	I	2.06	0.10	0.94	9.42	2.70	0.13	1.23	0.46	0.05
302	12	2013	14	1	1	1	NT	B	L	I	2.00	0.10	0.87	8.89	2.64	0.13	1.15	0.44	0.05
303	12	2013	15	2	1	1	NT	B	H	I	2.41	0.12	1.08	9.19	3.07	0.15	1.37	0.45	0.05
304	12	2013	16	2	1	2	CT	B	L	I	2.55	0.13	1.26	9.53	3.30	0.17	1.63	0.49	0.05
305	12	2013	17	3	1	2	NT	B	H	I	2.50	0.12	1.05	8.98	3.30	0.15	1.38	0.42	0.05
306	12	2013	18	3	1	3	CT	B	L	I	2.12	0.10	0.90	8.82	2.79	0.13	1.18	0.42	0.05
307	12	2013	19	1	1	1	CT	B	H	I	2.12	0.11	1.00	8.71	2.78	0.15	1.31	0.47	0.05
308	12	2013	20	1	1	3	NT	B	H	I	1.92	0.10	0.94	9.44	2.56	0.13	1.25	0.49	0.05
309	12	2013	21	2	1	2	NT	B	L	I	2.57	0.12	1.17	9.56	3.20	0.15	1.45	0.45	0.05
310	12	2013	22	2	1	2	CT	B	H	I	2.16	0.10	0.90	8.61	2.90	0.14	1.20	0.41	0.05
311	12	2013	23	3	1	3	NT	B	L	I	1.71	0.08	0.64	8.16	2.34	0.11	0.88	0.37	0.05
312	12	2013	24	3	1	3	CT	B	H	I	2.58	0.11	1.00	8.87	3.31	0.14	1.28	0.39	0.04
313	12	2013	25	1	2	4	CT	B	H	NI	2.25	0.11	0.98	8.58	2.96	0.15	1.29	0.44	0.05
314	12	2013	26	1	2	4	NT	B	H	NI	1.87	0.10	0.79	8.27	2.48	0.13	1.05	0.42	0.05
315	12	2013	27	2	2	5	NT	B	H	NI	2.19	0.11	0.92	8.71	2.98	0.14	1.25	0.42	0.05
316	12	2013	28	2	2	4	CT	B	L	NI	2.15	0.11	0.90	8.41	2.85	0.14	1.19	0.42	0.05

obs #	yr	actual yr	plot	T block	B block	rep	till	burn	Nrate	Irr	OM conc	N conc	C conc	C:N	OM content	N content	C content	C fraction	N fraction
317	12	2013	29	3	2	6	NT	B	H	NI	2.63	0.13	1.19	8.84	3.36	0.17	1.52	0.45	0.05
318	12	2013	30	3	2	5	CT	B	L	NI	2.11	0.10	0.81	8.22	2.74	0.13	1.05	0.38	0.05
319	12	2013	31	1	2	6	CT	B	L	NI	2.31	0.11	1.03	9.37	2.96	0.14	1.31	0.44	0.05
320	12	2013	32	1	2	4	NT	B	L	NI	2.23	0.10	0.93	8.91	2.99	0.14	1.25	0.42	0.05
321	12	2013	33	2	2	5	NT	B	L	NI	2.74	0.13	1.25	9.70	3.49	0.16	1.59	0.46	0.05
322	12	2013	34	2	2	5	CT	B	H	NI	2.20	0.11	0.90	8.53	2.93	0.14	1.20	0.41	0.05
323	12	2013	35	3	2	6	NT	B	L	NI	2.56	0.13	1.15	9.06	3.24	0.16	1.45	0.45	0.05
324	12	2013	36	3	2	6	CT	B	H	NI	2.66	0.13	1.15	9.12	3.53	0.17	1.53	0.43	0.05
325	12	2013	37	1	2	4	CT	NB	H	NI	2.69	0.13	1.16	8.94	3.40	0.16	1.46	0.43	0.05
326	12	2013	38	1	2	4	NT	NB	L	NI	2.38	0.10	0.91	8.86	3.24	0.14	1.24	0.38	0.04
327	12	2013	39	2	2	4	NT	NB	H	NI	2.37	0.10	0.91	8.72	3.14	0.14	1.20	0.38	0.04
328	12	2013	40	2	2	5	CT	NB	H	NI	2.21	0.11	0.90	8.32	2.98	0.15	1.21	0.41	0.05
329	12	2013	41	3	2	5	NT	NB	L	NI	2.44	0.11	1.00	8.86	3.33	0.15	1.37	0.41	0.05
330	12	2013	42	3	2	6	CT	NB	H	NI	2.45	0.12	1.01	8.39	3.12	0.15	1.29	0.41	0.05
331	12	2013	43	1	2	4	CT	NB	L	NI	2.79	0.13	1.23	9.30	3.64	0.17	1.60	0.44	0.05
332	12	2013	44	1	2	5	NT	NB	H	NI	2.60	0.12	1.00	8.55	3.45	0.16	1.33	0.39	0.05
333	12	2013	45	2	2	6	NT	NB	L	NI	2.47	0.12	1.03	8.71	3.24	0.15	1.35	0.42	0.05
334	12	2013	46	2	2	5	CT	NB	L	NI	2.41	0.11	0.97	8.75	3.10	0.14	1.25	0.40	0.05
335	12	2013	47	3	2	6	NT	NB	H	NI	3.27	0.15	1.42	9.47	4.17	0.19	1.81	0.43	0.05
336	12	2013	48	3	2	6	CT	NB	L	NI	1.96	0.09	0.74	8.45	2.64	0.12	0.99	0.37	0.04
337	13	2014	1	1	1	1	CT	NB	H	I	2.27	0.12	1.16	9.76	2.79	0.15	1.43	0.51	0.05
338	13	2014	2	1	1	1	NT	NB	L	I	1.94	0.09	0.88	10.15	2.42	0.11	1.10	0.45	0.04
339	13	2014	3	2	1	1	NT	NB	H	I	1.93	0.10	0.90	9.28	2.47	0.12	1.15	0.47	0.05
340	13	2014	4	2	1	1	CT	NB	L	I	2.29	0.10	1.10	10.67	2.89	0.13	1.39	0.48	0.05
341	13	2014	5	3	1	2	NT	NB	L	I	2.51	0.11	1.17	10.41	3.11	0.14	1.44	0.46	0.04
342	13	2014	6	3	1	2	CT	NB	H	I	2.27	0.09	0.98	10.38	3.02	0.13	1.30	0.43	0.04
343	13	2014	7	1	1	2	CT	NB	L	I	2.32	0.12	1.44	11.61	2.75	0.15	1.70	0.62	0.05
344	13	2014	8	1	1	2	NT	NB	H	I	2.94	0.15	1.59	10.35	3.49	0.18	1.89	0.54	0.05
345	13	2014	9	2	1	3	NT	NB	L	I	2.89	0.14	1.48	10.54	3.55	0.17	1.81	0.51	0.05

obs #	yr	actual yr	plot	T block	B block	rep	till	burn	Nrate	Irr	OM conc	N conc	C conc	C:N	OM content	N content	C content	C fraction	N fraction
346	13	2014	10	2	1	3	CT	NB	H	I	2.69	0.13	1.30	10.18	3.32	0.16	1.61	0.48	0.05
347	13	2014	11	3	1	3	NT	NB	H	I	2.17	0.10	1.09	11.39	2.81	0.12	1.41	0.50	0.04
348	13	2014	12	3	1	3	CT	NB	L	I	2.23	0.10	1.05	10.26	2.90	0.13	1.36	0.47	0.05
349	13	2014	13	1	1	1	CT	B	L	I	2.30	0.10	1.15	11.57	2.87	0.12	1.43	0.50	0.04
350	13	2014	14	1	1	1	NT	B	L	I	1.58	0.06	0.71	11.80	2.09	0.08	0.94	0.45	0.04
351	13	2014	15	2	1	1	NT	B	H	I	2.03	0.10	0.93	9.67	2.78	0.13	1.27	0.46	0.05
352	13	2014	16	2	1	2	CT	B	L	I	2.12	0.11	1.12	10.42	2.72	0.14	1.43	0.53	0.05
353	13	2014	17	3	1	2	NT	B	H	I	2.48	0.13	1.17	8.86	3.03	0.16	1.43	0.47	0.05
354	13	2014	18	3	1	3	CT	B	L	I	2.39	0.12	1.05	9.10	3.19	0.15	1.40	0.44	0.05
355	13	2014	19	1	1	1	CT	B	H	I	1.98	0.12	0.93	7.95	2.52	0.15	1.19	0.47	0.06
356	13	2014	20	1	1	3	NT	B	H	I	2.20	0.11	0.98	8.83	2.82	0.14	1.26	0.45	0.05
357	13	2014	21	2	1	2	NT	B	L	I	2.26	0.12	1.09	9.34	2.89	0.15	1.40	0.48	0.05
358	13	2014	22	2	1	2	CT	B	H	I	2.33	0.12	1.14	9.33	2.91	0.15	1.42	0.49	0.05
359	13	2014	23	3	1	3	NT	B	L	I	1.86	0.10	0.83	8.28	2.36	0.13	1.05	0.44	0.05
360	13	2014	24	3	1	3	CT	B	H	I	2.35	0.13	1.12	8.95	2.90	0.15	1.38	0.48	0.05
361	13	2014	25	1	2	4	CT	B	H	NI	2.55	0.10	0.70	7.25	3.31	0.12	0.90	0.27	0.04
362	13	2014	26	1	2	4	NT	B	H	NI	1.89	0.11	0.83	7.53	2.49	0.15	1.09	0.44	0.06
363	13	2014	27	2	2	5	NT	B	H	NI	1.77	0.09	0.72	8.29	2.33	0.11	0.95	0.41	0.05
364	13	2014	28	2	2	4	CT	B	L	NI	2.02	0.11	0.92	8.63	2.50	0.13	1.14	0.45	0.05
365	13	2014	29	3	2	6	NT	B	H	NI	2.03	0.10	0.89	8.78	2.65	0.13	1.16	0.44	0.05
366	13	2014	30	3	2	5	CT	B	L	NI	2.09	0.10	0.94	9.46	2.72	0.13	1.21	0.45	0.05
367	13	2014	31	1	2	6	CT	B	L	NI	1.87	0.09	0.79	9.03	2.38	0.11	1.00	0.42	0.05
368	13	2014	32	1	2	4	NT	B	L	NI	1.92	0.10	0.86	9.09	2.43	0.12	1.09	0.45	0.05
369	13	2014	33	2	2	5	NT	B	L	NI	2.42	0.10	1.03	10.61	3.16	0.13	1.34	0.43	0.04
370	13	2014	34	2	2	5	CT	B	H	NI	2.32	0.10	1.09	10.96	2.85	0.12	1.33	0.47	0.04
371	13	2014	35	3	2	6	NT	B	L	NI	1.89	0.09	0.77	8.32	2.49	0.12	1.01	0.40	0.05
372	13	2014	36	3	2	6	CT	B	H	NI	2.50	0.11	1.06	9.57	3.20	0.14	1.36	0.42	0.04
373	13	2014	37	1	2	4	CT	NB	H	NI	2.57	0.11	1.07	9.42	3.44	0.15	1.43	0.42	0.04
374	13	2014	38	1	2	4	NT	NB	L	NI	2.14	0.08	0.88	11.36	2.73	0.10	1.12	0.41	0.04

obs #	yr	actual yr	plot	T block	B block	rep	till	burn	Nrate	Irr	OM conc	N conc	C conc	C:N	OM content	N content	C content	C fraction	N fraction
375	13	2014	39	2	2	4	NT	NB	H	NI	3.03	0.14	1.39	9.84	3.82	0.18	1.75	0.46	0.05
376	13	2014	40	2	2	5	CT	NB	H	NI	2.56	0.12	1.16	9.95	3.25	0.15	1.48	0.45	0.05
377	13	2014	41	3	2	5	NT	NB	L	NI	2.19	0.10	0.94	9.77	2.81	0.12	1.20	0.43	0.04
378	13	2014	42	3	2	6	CT	NB	H	NI	2.34	0.10	0.95	10.04	3.15	0.13	1.29	0.41	0.04
379	13	2014	43	1	2	4	CT	NB	L	NI	2.81	0.13	1.28	10.04	3.46	0.16	1.57	0.45	0.05
380	13	2014	44	1	2	5	NT	NB	H	NI	2.80	0.12	1.15	9.75	3.54	0.15	1.45	0.41	0.04
381	13	2014	45	2	2	6	NT	NB	L	NI	1.99	0.09	0.75	8.56	2.56	0.11	0.97	0.38	0.04
382	13	2014	46	2	2	5	CT	NB	L	NI	2.42	0.09	1.05	11.31	3.10	0.12	1.35	0.43	0.04
383	13	2014	47	3	2	6	NT	NB	H	NI	2.81	0.13	1.27	10.11	3.44	0.15	1.56	0.45	0.04
384	13	2014	48	3	2	6	CT	NB	L	NI	2.21	0.09	0.91	10.45	3.00	0.12	1.23	0.41	0.04

Appendix E

This appendix contains an example of the SAS program used for the ANCOVA of the relationship between soil water potential (-MPa) and water content (g/g) as affected by residue level [Nrate; high (H) and low (L)], burning [burn (B) and no-burn (NB)], tillage [conventional tillage (CT) and no-tillage (NT)], and irrigation [irrigated (I) and non-irrigated (NI)].

```
Title 'Ryan, N: Analysis of Co variance with all trt combn';
Data asa;
* length trtcode1 trtcode2 trtcode3 trtcode4 $16;
infile 'water_potential_sas_data_2015.csv' firstobs=2 delimiter= ","
lrecl=400;
input obs watercontent plot tblock bblock rep T $ B $  N $ I $
      lnwaterpotential ;

label obs='observation #'
      watercontent='Water Content (g)'
      plot='plot #'
      tblock='tillage block'
      bblock='burning block'
      rep='replication'
      T='Tillage'
      B='Burning'
      N='NRate level'
      I='Irrigation'
      lnwaterpotential='Natural Log of Water Potential (Mpa)';
run;

proc sort data=asa;
by T B N I watercontent ;
quit;

proc print data=asa ;
run;

ods rtf file='Water_Potential_complete_final.rtf' style=journal bodytitle;
title3 'P<.05';
proc mixed data=asa method=type3 ;
class T B N I rep;
model lnwaterpotential=
                 N
                 watercontent
                 watercontent*N

                / ddfm=kr ;

random rep(T B N I) ;
id T B N I;

estimate 'Intercept H' intercept 1 n 1 0 ;
estimate 'Intercept L' intercept 1 n 0 1 ;
estimate 'Slope H' watercontent 1 watercontent*n 1 0 ;
estimate 'Slope L' watercontent 1 watercontent*n 0 1 ;

run;
Quit;
ods rtf close;
```

Appendix F.

This appendix contains the raw data used for the ANCOVA of the relationship between soil water potential (-MPa) and water content (g/g).

obsv #	watercontent	plot	tblock	bblock	rep	Tillage	Burning	N Rate	Irrigation	lnwaterpotential
1	0.030	1	1	1	1	CT	NB	H	I	2.681
2	0.020	1	1	1	1	CT	NB	H	I	1.732
3	0.036	1	1	1	1	CT	NB	H	I	0.673
4	0.066	1	1	1	1	CT	NB	H	I	-0.301
5	0.058	1	1	1	1	CT	NB	H	I	-0.117
6	0.080	1	1	1	1	CT	NB	H	I	-0.713
7	0.110	1	1	1	1	CT	NB	H	I	-1.139
8	0.014	2	1	1	1	NT	NB	L	I	2.754
9	0.030	2	1	1	1	NT	NB	L	I	1.037
10	0.042	2	1	1	1	NT	NB	L	I	0.174
11	0.072	2	1	1	1	NT	NB	L	I	-1.109
12	0.095	2	1	1	1	NT	NB	L	I	-0.916
13	0.100	2	1	1	1	NT	NB	L	I	-1.273
14	0.118	2	1	1	1	NT	NB	L	I	-1.715
15	0.029	3	2	1	1	NT	NB	H	I	2.991
16	0.037	3	2	1	1	NT	NB	H	I	2.370
17	0.049	3	2	1	1	NT	NB	H	I	1.394
18	0.073	3	2	1	1	NT	NB	H	I	0.140
19	0.090	3	2	1	1	NT	NB	H	I	-0.357
20	0.104	3	2	1	1	NT	NB	H	I	-0.968
21	0.159	3	2	1	1	NT	NB	H	I	-2.659
22	0.020	4	2	1	1	CT	NB	L	I	3.025
23	0.036	4	2	1	1	CT	NB	L	I	1.452
24	0.056	4	2	1	1	CT	NB	L	I	1.105
25	0.067	4	2	1	1	CT	NB	L	I	-0.062
26	0.075	4	2	1	1	CT	NB	L	I	-0.416
27	0.085	4	2	1	1	CT	NB	L	I	-0.261
28	0.135	4	2	1	1	CT	NB	L	I	-1.347

obsv #	watercontent	plot	tblock	bblock	rep	Tillage	Burning	N Rate	Irrigation	lnwaterpotential
29	0.033	5	3	1	2	NT	NB	L	I	2.965
30	0.043	5	3	1	2	NT	NB	L	I	1.472
31	0.049	5	3	1	2	NT	NB	L	I	0.863
32	0.075	5	3	1	2	NT	NB	L	I	0.030
33	0.091	5	3	1	2	NT	NB	L	I	-0.799
34	0.104	5	3	1	2	NT	NB	L	I	-1.273
35	0.139	5	3	1	2	NT	NB	L	I	-1.427
36	0.018	6	3	1	2	CT	NB	H	I	3.469
37	0.028	6	3	1	2	CT	NB	H	I	2.148
38	0.039	6	3	1	2	CT	NB	H	I	1.384
39	0.071	6	3	1	2	CT	NB	H	I	-0.128
40	0.077	6	3	1	2	CT	NB	H	I	-0.010
41	0.107	6	3	1	2	CT	NB	H	I	-0.713
42	0.130	6	3	1	2	CT	NB	H	I	-1.772
43	0.022	7	1	1	2	CT	NB	L	I	2.701
44	0.034	7	1	1	2	CT	NB	L	I	1.482
45	0.043	7	1	1	2	CT	NB	L	I	0.863
46	0.065	7	1	1	2	CT	NB	L	I	-0.400
47	0.087	7	1	1	2	CT	NB	L	I	-0.892
48	0.116	7	1	1	2	CT	NB	L	I	-0.051
49	0.128	7	1	1	2	CT	NB	L	I	-1.386
50	0.026	8	1	1	2	NT	NB	H	I	2.425
51	0.043	8	1	1	2	NT	NB	H	I	1.454
52	0.059	8	1	1	2	NT	NB	H	I	-0.211
53	0.083	8	1	1	2	NT	NB	H	I	-1.772
54	0.102	8	1	1	2	NT	NB	H	I	-1.661
55	0.124	8	1	1	2	NT	NB	H	I	-1.715
56	0.170	8	1	1	2	NT	NB	H	I	-2.526
57	0.031	9	2	1	3	NT	NB	L	I	2.791
58	0.047	9	2	1	3	NT	NB	L	I	0.554

obsv #	watercontent	plot	tblock	bblock	rep	Tillage	Burning	N Rate	Irrigation	lnwaterpotential
59	0.053	9	2	1	3	NT	NB	L	I	0.122
60	0.088	9	2	1	3	NT	NB	L	I	-1.514
61	0.106	9	2	1	3	NT	NB	L	I	-2.408
62	0.118	9	2	1	3	NT	NB	L	I	-2.526
63	0.166	9	2	1	3	NT	NB	L	I	.
64	0.026	10	2	1	3	CT	NB	H	I	2.827
65	0.043	10	2	1	3	CT	NB	H	I	1.552
66	0.061	10	2	1	3	CT	NB	H	I	0.049
67	0.098	10	2	1	3	CT	NB	H	I	-1.514
68	0.112	10	2	1	3	CT	NB	H	I	-2.207
69	0.123	10	2	1	3	CT	NB	H	I	-2.996
70	0.164	10	2	1	3	CT	NB	H	I	.
71	0.024	11	3	1	3	NT	NB	H	I	2.845
72	0.032	11	3	1	3	NT	NB	H	I	1.898
73	0.045	11	3	1	3	NT	NB	H	I	1.078
74	0.075	11	3	1	3	NT	NB	H	I	-0.186
75	0.077	11	3	1	3	NT	NB	H	I	-0.821
76	0.100	11	3	1	3	NT	NB	H	I	-1.661
77	0.128	11	3	1	3	NT	NB	H	I	-1.514
78	0.022	12	3	1	3	CT	NB	L	I	3.030
79	0.036	12	3	1	3	CT	NB	L	I	1.645
80	0.050	12	3	1	3	CT	NB	L	I	0.182
81	0.085	12	3	1	3	CT	NB	L	I	-1.966
82	0.101	12	3	1	3	CT	NB	L	I	-3.219
83	0.119	12	3	1	3	CT	NB	L	I	.
84	0.157	12	3	1	3	CT	NB	L	I	.
85	0.026	13	1	1	1	CT	B	L	I	2.557
86	0.045	13	1	1	1	CT	B	L	I	1.564
87	0.042	13	1	1	1	CT	B	L	I	0.802
88	0.072	13	1	1	1	CT	B	L	I	-0.528

obsv #	watercontent	plot	tblock	bblock	rep	Tillage	Burning	N Rate	Irrigation	lnwaterpotential
89	0.081	13	1	1	1	CT	B	L	I	-0.635
90	0.101	13	1	1	1	CT	B	L	I	-0.968
91	0.134	13	1	1	1	CT	B	L	I	-2.120
92	0.033	14	1	1	1	NT	B	L	I	2.632
93	0.043	14	1	1	1	NT	B	L	I	1.406
94	0.055	14	1	1	1	NT	B	L	I	0.519
95	0.084	14	1	1	1	NT	B	L	I	-0.528
96	0.096	14	1	1	1	NT	B	L	I	-1.386
97	0.110	14	1	1	1	NT	B	L	I	-1.715
98	0.141	14	1	1	1	NT	B	L	I	-1.470
99	0.027	15	2	1	1	NT	B	H	I	2.773
100	0.047	15	2	1	1	NT	B	H	I	0.993
101	0.049	15	2	1	1	NT	B	H	I	0.793
102	0.078	15	2	1	1	NT	B	H	I	-0.511
103	0.091	15	2	1	1	NT	B	H	I	-1.238
104	0.108	15	2	1	1	NT	B	H	I	-1.386
105	0.135	15	2	1	1	NT	B	H	I	-1.833
106	0.030	16	2	1	2	CT	B	L	I	2.477
107	0.039	16	2	1	2	CT	B	L	I	1.805
108	0.049	16	2	1	2	CT	B	L	I	0.837
109	0.071	16	2	1	2	CT	B	L	I	-0.174
110	0.081	16	2	1	2	CT	B	L	I	-0.713
111	0.092	16	2	1	2	CT	B	L	I	-0.777
112	0.118	16	2	1	2	CT	B	L	I	-1.772
113	0.027	17	3	1	2	NT	B	H	I	2.797
114	0.038	17	3	1	2	NT	B	H	I	1.839
115	0.052	17	3	1	2	NT	B	H	I	0.908
116	0.071	17	3	1	2	NT	B	H	I	0.399
117	0.088	17	3	1	2	NT	B	H	I	-0.105
118	0.127	17	3	1	2	NT	B	H	I	-1.470

obsv #	watercontent	plot	tblock	bblock	rep	Tillage	Burning	N Rate	Irrigation	lnwaterpotential
119	0.175	17	3	1	2	NT	B	H	I	-2.040
120	0.018	18	3	1	3	CT	B	L	I	3.450
121	0.037	18	3	1	3	CT	B	L	I	1.780
122	0.053	18	3	1	3	CT	B	L	I	1.082
123	0.074	18	3	1	3	CT	B	L	I	-0.478
124	0.084	18	3	1	3	CT	B	L	I	-0.494
125	0.107	18	3	1	3	CT	B	L	I	-0.868
126	0.144	18	3	1	3	CT	B	L	I	-2.303
127	0.031	19	1	1	1	CT	B	H	I	2.501
128	0.045	19	1	1	1	CT	B	H	I	0.944
129	0.061	19	1	1	1	CT	B	H	I	-0.274
130	0.088	19	1	1	1	CT	B	H	I	-2.120
131	0.098	19	1	1	1	CT	B	H	I	-1.609
132	0.112	19	1	1	1	CT	B	H	I	-1.386
133	0.157	19	1	1	1	CT	B	H	I	-3.507
134	0.022	20	1	1	3	NT	B	H	I	2.815
135	0.035	20	1	1	3	NT	B	H	I	1.761
136	0.026	20	1	1	3	NT	B	H	I	0.615
137	0.067	20	1	1	3	NT	B	H	I	-0.713
138	0.083	20	1	1	3	NT	B	H	I	-1.273
139	0.100	20	1	1	3	NT	B	H	I	-1.273
140	0.143	20	1	1	3	NT	B	H	I	-3.912
141	0.033	21	2	1	2	NT	B	L	I	2.779
142	0.035	21	2	1	2	NT	B	L	I	1.699
143	0.049	21	2	1	2	NT	B	L	I	0.824
144	0.071	21	2	1	2	NT	B	L	I	-0.598
145	0.086	21	2	1	2	NT	B	L	I	-1.347
146	0.100	21	2	1	2	NT	B	L	I	-1.386
147	0.136	21	2	1	2	NT	B	L	I	-2.659
148	0.029	22	2	1	2	CT	B	H	I	3.063

obsv #	watercontent	plot	tblock	bblock	rep	Tillage	Burning	N Rate	Irrigation	lnwaterpotential
149	0.041	22	2	1	2	CT	B	H	I	1.803
150	0.049	22	2	1	2	CT	B	H	I	1.166
151	0.073	22	2	1	2	CT	B	H	I	-0.051
152	0.084	22	2	1	2	CT	B	H	I	-0.400
153	0.103	22	2	1	2	CT	B	H	I	-0.821
154	0.130	22	2	1	2	CT	B	H	I	-1.171
155	0.020	23	3	1	3	NT	B	L	I	3.203
156	0.041	23	3	1	3	NT	B	L	I	1.468
157	0.049	23	3	1	3	NT	B	L	I	0.815
158	0.073	23	3	1	3	NT	B	L	I	-0.598
159	0.088	23	3	1	3	NT	B	L	I	-1.204
160	0.097	23	3	1	3	NT	B	L	I	-1.079
161	0.141	23	3	1	3	NT	B	L	I	-2.120
162	0.029	24	3	1	3	CT	B	H	I	2.868
163	0.043	24	3	1	3	CT	B	H	I	1.879
164	0.059	24	3	1	3	CT	B	H	I	0.548
165	0.076	24	3	1	3	CT	B	H	I	-0.198
166	0.098	24	3	1	3	CT	B	H	I	-0.799
167	0.111	24	3	1	3	CT	B	H	I	-1.022
168	0.132	24	3	1	3	CT	B	H	I	-1.079
169	0.026	25	1	2	1	CT	B	H	NI	2.632
170	0.037	25	1	2	1	CT	B	H	NI	1.777
171	0.049	25	1	2	1	CT	B	H	NI	0.647
172	0.069	25	1	2	1	CT	B	H	NI	-0.198
173	0.078	25	1	2	1	CT	B	H	NI	-0.844
174	0.106	25	1	2	1	CT	B	H	NI	-1.273
175	0.169	25	1	2	1	CT	B	H	NI	-2.996
176	0.022	26	1	2	1	NT	B	H	NI	3.001
177	0.034	26	1	2	1	NT	B	H	NI	1.500
178	0.051	26	1	2	1	NT	B	H	NI	0.610

obsv #	watercontent	plot	tblock	bblock	rep	Tillage	Burning	N Rate	Irrigation	lnwaterpotential
179	0.073	26	1	2	1	NT	B	H	NI	-0.673
180	0.081	26	1	2	1	NT	B	H	NI	-1.309
181	0.100	26	1	2	1	NT	B	H	NI	-1.273
182	0.134	26	1	2	1	NT	B	H	NI	-1.609
183	0.024	27	2	2	2	NT	B	H	NI	2.734
184	0.037	27	2	2	2	NT	B	H	NI	1.506
185	0.053	27	2	2	2	NT	B	H	NI	0.476
186	0.071	27	2	2	2	NT	B	H	NI	-0.616
187	0.093	27	2	2	2	NT	B	H	NI	-0.916
188	0.113	27	2	2	2	NT	B	H	NI	-1.609
189	0.136	27	2	2	2	NT	B	H	NI	-1.561
190	0.030	28	2	2	1	CT	B	L	NI	2.728
191	0.039	28	2	2	1	CT	B	L	NI	1.662
192	0.053	28	2	2	1	CT	B	L	NI	0.626
193	0.078	28	2	2	1	CT	B	L	NI	-0.371
194	0.094	28	2	2	1	CT	B	L	NI	-1.171
195	0.113	28	2	2	1	CT	B	L	NI	-1.050
196	0.136	28	2	2	1	CT	B	L	NI	-2.996
197	0.026	29	3	2	3	NT	B	H	NI	2.773
198	0.032	29	3	2	3	NT	B	H	NI	2.010
199	0.049	29	3	2	3	NT	B	H	NI	0.713
200	0.073	29	3	2	3	NT	B	H	NI	-0.598
201	0.092	29	3	2	3	NT	B	H	NI	-1.273
202	0.099	29	3	2	3	NT	B	H	NI	-1.079
203	0.138	29	3	2	3	NT	B	H	NI	-2.040
204	0.028	30	3	2	2	CT	B	L	NI	2.760
205	0.041	30	3	2	2	CT	B	L	NI	1.454
206	0.057	30	3	2	2	CT	B	L	NI	0.385
207	0.069	30	3	2	2	CT	B	L	NI	-0.274
208	0.096	30	3	2	2	CT	B	L	NI	-1.514

obsv #	watercontent	plot	tblock	bblock	rep	Tillage	Burning	N Rate	Irrigation	lnwaterpotential
209	0.106	30	3	2	2	CT	B	L	NI	-1.109
210	0.134	30	3	2	2	CT	B	L	NI	-2.207
211	0.027	31	1	2	3	CT	B	L	NI	2.918
212	0.043	31	1	2	3	CT	B	L	NI	1.562
213	0.055	31	1	2	3	CT	B	L	NI	0.751
214	0.078	31	1	2	3	CT	B	L	NI	-0.734
215	0.092	31	1	2	3	CT	B	L	NI	-0.942
216	0.108	31	1	2	3	CT	B	L	NI	-1.514
217	0.143	31	1	2	3	CT	B	L	NI	-2.813
218	0.027	32	1	2	1	NT	B	L	NI	2.785
219	0.035	32	1	2	1	NT	B	L	NI	2.162
220	0.051	32	1	2	1	NT	B	L	NI	0.761
221	0.075	32	1	2	1	NT	B	L	NI	-0.734
222	0.115	32	1	2	1	NT	B	L	NI	-2.040
223	0.133	32	1	2	1	NT	B	L	NI	-2.207
224	0.165	32	1	2	1	NT	B	L	NI	-3.912
225	0.035	33	2	2	2	NT	B	L	NI	2.667
226	0.043	33	2	2	2	NT	B	L	NI	1.775
227	0.058	33	2	2	2	NT	B	L	NI	0.875
228	0.079	33	2	2	2	NT	B	L	NI	-0.635
229	0.084	33	2	2	2	NT	B	L	NI	-1.109
230	0.092	33	2	2	2	NT	B	L	NI	-1.273
231	0.121	33	2	2	2	NT	B	L	NI	-1.561
232	0.018	34	2	2	2	CT	B	H	NI	3.440
233	0.038	34	2	2	2	CT	B	H	NI	0.571
234	0.054	34	2	2	2	CT	B	H	NI	0.815
235	0.093	34	2	2	2	CT	B	H	NI	-1.050
236	0.090	34	2	2	2	CT	B	H	NI	-1.386
237	0.117	34	2	2	2	CT	B	H	NI	-1.966
238	0.153	34	2	2	2	CT	B	H	NI	-3.912

obsv #	watercontent	plot	tblock	bblock	rep	Tillage	Burning	N Rate	Irrigation	lnwaterpotential
239	0.018	35	3	2	3	NT	B	L	NI	3.487
240	0.036	35	3	2	3	NT	B	L	NI	1.699
241	0.050	35	3	2	3	NT	B	L	NI	0.708
242	0.090	35	3	2	3	NT	B	L	NI	-1.833
243	0.091	35	3	2	3	NT	B	L	NI	-1.309
244	0.115	35	3	2	3	NT	B	L	NI	-2.659
245	0.157	35	3	2	3	NT	B	L	NI	.
246	0.031	36	3	2	3	CT	B	H	NI	3.073
247	0.047	36	3	2	3	CT	B	H	NI	1.303
248	0.063	36	3	2	3	CT	B	H	NI	-0.083
249	0.092	36	3	2	3	CT	B	H	NI	-0.916
250	0.112	36	3	2	3	CT	B	H	NI	-1.897
251	0.138	36	3	2	3	CT	B	H	NI	-3.219
252	0.179	36	3	2	3	CT	B	H	NI	-3.219
253	0.031	37	1	2	1	CT	NB	H	NI	2.896
254	0.047	37	1	2	1	CT	NB	H	NI	1.381
255	0.059	37	1	2	1	CT	NB	H	NI	0.642
256	0.090	37	1	2	1	CT	NB	H	NI	-0.734
257	0.110	37	1	2	1	CT	NB	H	NI	-1.347
258	0.127	37	1	2	1	CT	NB	H	NI	-1.715
259	0.166	37	1	2	1	CT	NB	H	NI	-1.897
260	0.033	38	1	2	1	NT	NB	L	NI	2.939
261	0.047	38	1	2	1	NT	NB	L	NI	1.805
262	0.057	38	1	2	1	NT	NB	L	NI	0.892
263	0.084	38	1	2	1	NT	NB	L	NI	-0.315
264	0.105	38	1	2	1	NT	NB	L	NI	-0.755
265	0.112	38	1	2	1	NT	NB	L	NI	-0.777
266	0.138	38	1	2	1	NT	NB	L	NI	-1.514
267	0.031	39	2	2	1	NT	NB	H	NI	2.573
268	0.045	39	2	2	1	NT	NB	H	NI	1.585

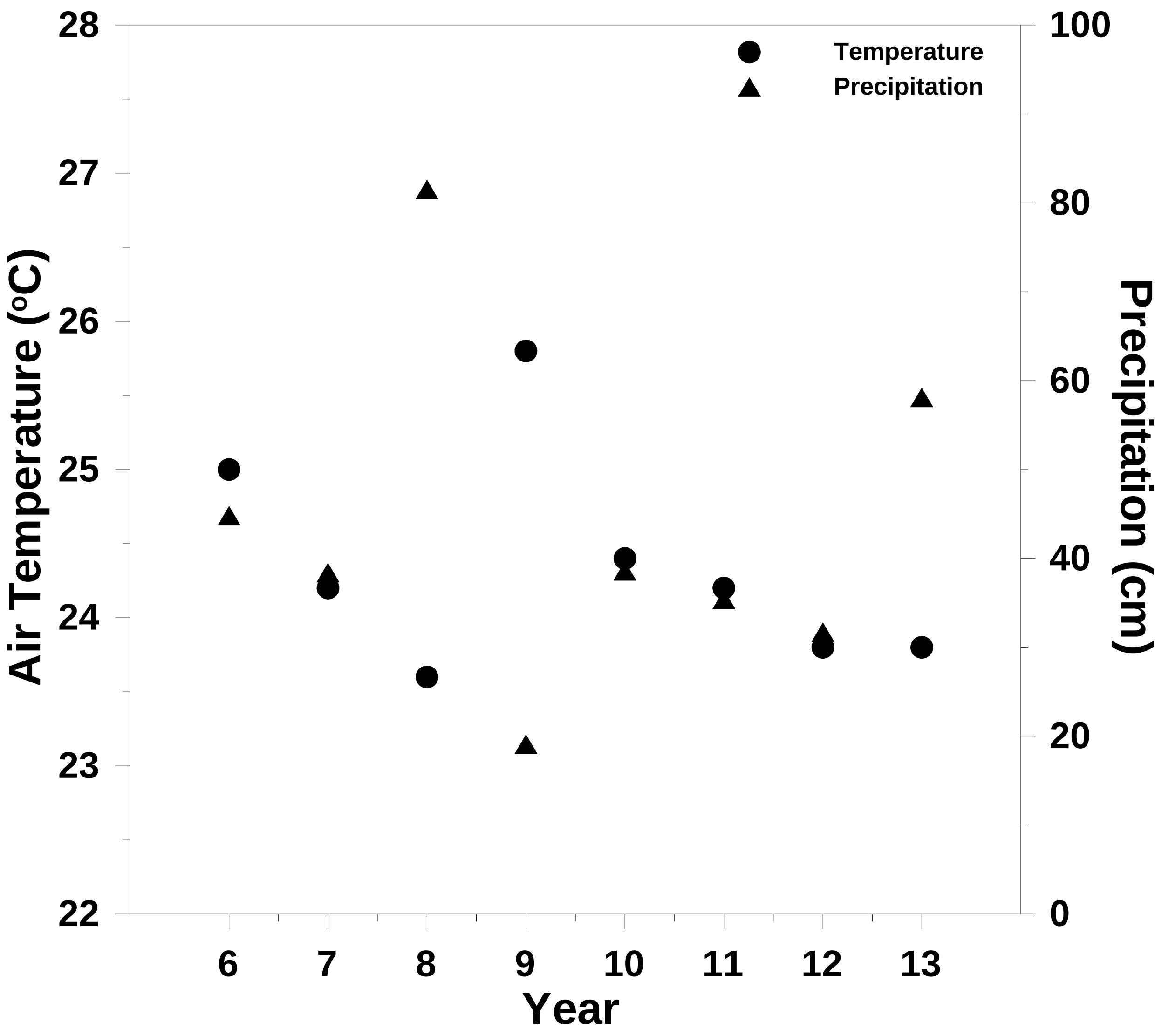
obsv #	watercontent	plot	tblock	bblock	rep	Tillage	Burning	N Rate	Irrigation	lnwaterpotential
269	0.063	39	2	2	1	NT	NB	H	NI	0.501
270	0.117	39	2	2	1	NT	NB	H	NI	-3.912
271	0.116	39	2	2	1	NT	NB	H	NI	-1.966
272	0.139	39	2	2	1	NT	NB	H	NI	-2.526
273	0.170	39	2	2	1	NT	NB	H	NI	-4.605
274	0.029	40	2	2	2	CT	NB	H	NI	3.182
275	0.039	40	2	2	2	CT	NB	H	NI	1.800
276	0.049	40	2	2	2	CT	NB	H	NI	1.169
277	0.077	40	2	2	2	CT	NB	H	NI	-0.654
278	0.081	40	2	2	2	CT	NB	H	NI	-0.511
279	0.110	40	2	2	2	CT	NB	H	NI	-2.120
280	0.145	40	2	2	2	CT	NB	H	NI	-1.772
281	0.031	41	3	2	2	NT	NB	L	NI	2.510
282	0.045	41	3	2	2	NT	NB	L	NI	1.147
283	0.063	41	3	2	2	NT	NB	L	NI	-0.288
284	0.096	41	3	2	2	NT	NB	L	NI	-2.659
285	0.102	41	3	2	2	NT	NB	L	NI	-1.561
286	0.129	41	3	2	2	NT	NB	L	NI	-4.605
287	0.166	41	3	2	2	NT	NB	L	NI	.
288	0.031	42	3	2	3	CT	NB	H	NI	3.068
289	0.049	42	3	2	3	CT	NB	H	NI	1.303
290	0.061	42	3	2	3	CT	NB	H	NI	0.358
291	0.098	42	3	2	3	CT	NB	H	NI	-0.916
292	0.110	42	3	2	3	CT	NB	H	NI	-1.273
293	0.136	42	3	2	3	CT	NB	H	NI	-1.833
294	0.173	42	3	2	3	CT	NB	H	NI	-2.408
295	0.029	43	1	2	1	CT	NB	L	NI	2.510
296	0.047	43	1	2	1	CT	NB	L	NI	1.197
297	0.061	43	1	2	1	CT	NB	L	NI	0.000
298	0.096	43	1	2	1	CT	NB	L	NI	-1.171

obsv #	watercontent	plot	tblock	bblock	rep	Tillage	Burning	N Rate	Irrigation	lnwaterpotential
299	0.114	43	1	2	1	CT	NB	L	NI	-3.219
300	0.135	43	1	2	1	CT	NB	L	NI	.
301	0.162	43	1	2	1	CT	NB	L	NI	.
302	0.031	44	1	2	2	NT	NB	H	NI	3.068
303	0.043	44	1	2	2	NT	NB	H	NI	1.946
304	0.055	44	1	2	2	NT	NB	H	NI	1.019
305	0.078	44	1	2	2	NT	NB	H	NI	-0.094
306	0.094	44	1	2	2	NT	NB	H	NI	-0.713
307	0.110	44	1	2	2	NT	NB	H	NI	-1.514
308	0.145	44	1	2	2	NT	NB	H	NI	-1.661
309	0.037	45	2	2	3	NT	NB	L	NI	3.296
310	0.051	45	2	2	3	NT	NB	L	NI	2.108
311	0.068	45	2	2	3	NT	NB	L	NI	0.854
312	0.098	45	2	2	3	NT	NB	L	NI	-0.494
313	0.109	45	2	2	3	NT	NB	L	NI	-0.693
314	0.133	45	2	2	3	NT	NB	L	NI	-1.139
315	0.167	45	2	2	3	NT	NB	L	NI	-2.040
316	0.037	46	2	2	2	CT	NB	L	NI	2.518
317	0.049	46	2	2	2	CT	NB	L	NI	1.374
318	0.065	46	2	2	2	CT	NB	L	NI	0.425
319	0.099	46	2	2	2	CT	NB	L	NI	-0.916
320	0.110	46	2	2	2	CT	NB	L	NI	-1.427
321	0.127	46	2	2	2	CT	NB	L	NI	-2.813
322	0.165	46	2	2	2	CT	NB	L	NI	-3.912
323	0.035	47	3	2	3	NT	NB	H	NI	3.270
324	0.045	47	3	2	3	NT	NB	H	NI	2.135
325	0.166	47	3	2	3	NT	NB	H	NI	.
326	0.072	47	3	2	3	NT	NB	H	NI	0.365
327	0.084	47	3	2	3	NT	NB	H	NI	-0.186
328	0.108	47	3	2	3	NT	NB	H	NI	-0.654

obsv #	watercontent	plot	tblock	bblock	rep	Tillage	Burning	N Rate	Irrigation	lnwaterpotential
329	0.128	47	3	2	3	NT	NB	H	NI	-1.022
330	0.020	48	3	2	3	CT	NB	L	NI	2.907
331	0.034	48	3	2	3	CT	NB	L	NI	1.281
332	0.050	48	3	2	3	CT	NB	L	NI	0.577
333	0.085	48	3	2	3	CT	NB	L	NI	-0.892
334	0.085	48	3	2	3	CT	NB	L	NI	-1.347
335	0.126	48	3	2	3	CT	NB	L	NI	-4.605
336	0.160	48	3	2	3	CT	NB	L	NI	-2.526

Appendix G

This appendix contains a graphical representation of the growing-season climate data presented in Table 1 of Chapter 3.



Temperature
Precipitation
Air Temperature (°C)
Precipitation (cm)
Year
28
27
26
25
24
23
22
100
80
60
40
20
0
6
7
8
9
10
11
12
13