EVALUATION OF THE IMPACT OF ALTERNATIVE WHEAT RESIDUE AND WATER MANAGEMENT ON SOIL PROPERTIES AND SOYBEAN YIELD IN A WHEAT-SOYBEAN DOUBLE-CROP SYSTEM, EASTERN ARKANSAS

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A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy in Crop, Soil, and Environmental Sciences

By

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ABSTRACT

Long-term agricultural sustainability requires evaluation of agricultural management practices that may improve and sustain soil quality and crop productivity over time. The objective of this study was to determine the 6-yr effects of tillage [conventional (CT) and no-tillage (NT)], wheat residue burning (burn and no burn), residue level (low and high), and 3-yr irrigation (irrigated and dry-land condition), on soybean [*Glycine max* (L.) Merr.] yield, soil physical and chemical properties in the top 10 cm, and weed population diversity in a wheat [*Triticum aestivum* (L.)]-soybean double-crop production system. A field experiment was conducted from fall 2001 through fall 2007 in the Mississippi River Delta region of eastern Arkansas on a Calloway silt loam (fine silty, mixed, active, thermic Glossaquic Fraglossudalf). Soil bulk density increased at a greater magnitude under NT (1.22 to 1.35 g cm^{-3}) than CT (1.19 to 1.26 g cm^{-3}) during the first 3 years, but declined at a similar rate in both tillage treatments after the third year. Irrigation increased soil pH (0.2 pH unit yr^{-1}), Mehlich-3 extractable soil Mg (55.1 kg Mg ha^{-1} yr^{-1}), and total C contents (0.11 kg C m^{-2} yr^{-1}) compared to dry-land condition which had no pH change, but had less increase of extractable Mg (36.6 kg Mg ha^{-1} yr^{-1}), and total C content (0.04 kg C m^{-2} yr^{-1}). Soil organic matter (SOM) increased over time in all treatment combinations. Total C (TC) increased at a greater rate in the no burn (0.077 kg C m^{-2} yr^{-1}) and high-residue-level (0.073 kg C m^{-2} yr^{-1}) than in the burn (0.051 kg C m^{-2} yr^{-1}) and low-residue-level (0.054 kg C m^{-2} yr^{-1}) treatments. The total weed species density was greater under CT (513 plants m^{-2}) than under NT (340 plants m^{-2}) early in the soybean growing season in 2006, but did not differ between tillage treatments in 2007. Perennial weed density was greater under burn (99 plants m^{-2}) than no burn (59 plants m^{-2}) in 2006, and in 2007, was greater under NT than CT but unaffected by burn. Retaining crop residues and herbicide application reduced the density of all weed species, grass, and broadleaf weed species. Tillage, burning, and residue level generally did not affect soil penetration resistance in the top 0.20-m in 2003 and in 2006, but soil cone index (CI) was consistently lower under burn than no burn at all depth below 0.20 m. The CI at the 0.05-m depth increased by 35% after 4 years compared to after 1 year of NT soybean. Soybean yield differed over years of the trials. Soybean yield declined during the first 3 years, but increased over the subsequent 3 years in all treatment combinations. Economic analysis showed that management practices with NT will likely be more profitable than the traditional CT practice even when the fertilizer and diesel costs continue to increase. Therefore, NT and non-burning with any residue level have great potential to improve soil quality, reduce weed pressure in the soybean growing season, and maintain profitability in the wheat-soybean double-crop production system.

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DEDICATION

To all good friends I met throughout my life, and to all my teachers who made me love to learn and realize the value of hardworking, to my father, from whom I learned the value of life, and above all, to the Almighty God for all the blessings.

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CHAPTER ONE

Introduction and Literature Review

INTRODUCTION

Improving food supply through improved yields and food quality is still a central role in agricultural production in the world. Although recent developments of improved crop varieties and pest management practices promise increased agricultural productivity, such benefits may not be realized in absence of appropriate soil management practices. Thus, management practices to improve soil resources to sustain the current and future agricultural production is critical for sustainable agriculture. Soil organic matter (SOM) is an important soil property to ensure long-term productivity of agricultural soils. In addition, interaction of SOM and the atmosphere through C and N cycles further necessitate the need to improve SOM storage in soils. Increasing SOM in soil requires a balance between reducing C loss through soil erosion and biochemical oxidation of organic materials to CO_2 and increasing C input to the soil through biomass production and retaining of crop residues.

Management practices that minimize soil disturbance, increase biomass production, and retain crop residues have potential to increase SOM. Wheat-soybean double-crop production system is one of the important cropping systems, well adapted to the climatic conditions of the Mississippi River Delta region of US. The wheat-soybean double-crop system provides winter soil cover that reduces soil erosion and produces a large quantity of biomass for SOM formation if the crop residues are managed properly.

The interaction of agricultural practices and management of water resources further illustrates the need to increase SOM. Conserving water resources through increased infiltration, adsorption, improved soil moisture holding capacity, and reduced evaporation, runoff, and leaching by increasing SOM and soil surface cover is crucial to ensure water quality and quantity under water resource scarcity associated with global climate change. Although 40% of global crop production is obtained from irrigation, only 16% of all agricultural land is under irrigation (Matson et al., 1997). In the United States, 18% of 245 million ha of harvested crops were irrigated, and in Arkansas, 56% of 3 million ha of crop land harvested was irrigated in 2002 (NASS-USDA, 2008a). Therefore, dry-land agricultural production constitutes an important agricultural practice when land area is considered, which further demands management practice that conserve water to ensure crop growth and high yields.

Considering the dynamic nature of soil ecosystems, duration of a consistent practice in a system is important in determining the extent to which management practices influence soil properties. In addition, continuous use of one mode of weed control in soybean production, with changes in management practices, requires assessment of weed species population among alternative residue management practices. Therefore, monitoring changes in soil physical and chemical properties and weed population in both dry-land and irrigated systems under alternative wheat residue management is important. In addition, investigating trends of soil properties and weed population over time is essential to minimize degradation of agricultural soils to a level beyond remediation, or levels that are cost-ineffective for remediation that could result in depletion of agricultural lands. Assessing profitability of alternative management practices relative to an existing management system is an important decision making tool to ensure adoption of appropriate management practices to achieve sustainable agricultural system.

Therefore, this study was conducted to evaluate the alternative residue management practices in the Mississippi River Delta region with climatic conditions more or less similar to many agroecological conditions, where soil and moisture conservation and improving SOM is essential for long-term productivity of agricultural soils. The objective of the study was to evaluate the effect of alternative wheat residue management practices on soil properties and soybean yield in a wheat-soybean double-crop system in eastern Arkansas.

LITERATURE REVIEW

Importance of Soil Organic Matter

Soil organic matter (SOM) is important for maintaining soil fertility, physical properties and biological activity for sustainable crop production (Follet et al., 2001). Soil organic matter helps to prevent compaction, reduce soil erosion by wind and water (Rhoton, 2000), and improve soil workability, water-use efficiency, resistance to surface crusting, and nutrient cycling and availability for adequate plant growth (Weil and Magdoff, 2004). Soils with low levels of SOM require higher levels of fertilizers, irrigation water, pesticides and machinery inputs than soils with adequate SOM to maintain the same crop yield (Magdoff and van Es, 2000). Crop response to mineral inputs is increased in soils with high SOM status due to the effect of SOM on soil biological and physicochemical properties (Wander, 2004). Oades (1995) reported that the quality of water flowing from catchments depends on the sorptive capacity of the soil, which depends on SOM interactions with the inorganic soil matrix. In this regard, there is a need for strategies to increase and/or maintain SOM levels in agriculture soils so as to minimize agricultural impacts on physical environmental degradation and pollution, and maintain agricultural productivity.

Carbon Sequestration

Agriculture is one of the human activities that contribute to the emission of greenhouse gases. Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and water vapor (H_2O) are considered greenhouse gases, which contribute to global warming by absorbing heat while restricting reflection of absorbed heat back to outer space (Follet, 2001). Greenhouse gases behave in the same way as the greenhouse glass accumulates heat in greenhouses. Agriculture contributes to emissions through burning of fossil fuels, farm chemical manufacture, soil erosion processes, denitrification, and the loss of native SOM. Agriculture in the USA is estimated to emit 42.9 million metric tons of carbon (MMTC) per year (Lal et al., 1998), 54 million metric tons of carbon equivalents (MMTEC) per year of CH_4 and 77 MMTEC per year N_2O (USEPA, 1999). Although the reduction of CH_4 and N_2O are equally important in mitigation of the greenhouse gas effect, reduction of CO_2 through C sequestration is given priority due to its potential benefits to soil quality and productivity in agricultural soils.

The soil can function as a source or sink of atmospheric C depending on the imbalance between inputs and outputs of soil C (Cheng and Kimble, 2001). Carbon dioxide in the atmosphere can be removed through photosynthesis by green plants, including crops, to form organic C in plant biomass (Lal, 2001a; Weil and Magdoff, 2004). The root and crop residues returned to the soil will increase the C stored in the soil as SOM. A study in Texas using Houston black clay soil showed that the short-term CO_2 flux was greater in tilled than in untilled soil (Reicosky et al., 1997). Greater CO_2 flux in tilled soil was attributed to enhanced microbial activity due to residue decomposition (Reicosky et al., 1997). Thus, if the rate of input is higher than the rate of SOM mineralization, which tends to return CO_2 back to the atmosphere, the soil can store C (Lal, 2001b; Magdoff and Weil, 2004).

Soil has a larger C pool than the atmosphere. The soil organic carbon (SOC) pool is estimated to be 1550Pg C, which is more than twice the atmospheric C pool (Follett, 2001; Lal, 2001a). Therefore, C sequestration to increase SOM is possible and requires management practices that will increase C inputs, in the form of crop residues and other organic amendments and reduce decomposition. In addition, reduction of fossil fuel combustion, a major source of energy and greenhouse gases, could result in potentially devastating economic hardship. Managing soil to increase C stored as SOM, on the other hand can contribute to an economically feasible strategy to reach greenhouse-gas emission reduction targets as set forth in the Kyoto protocol (Weil and Magdof, 2004).

The amount of C stored in soil as SOM depends largely on environmental conditions and soil forming factors, such as climate (temperature and precipitation), texture, and topography which are beyond human control (Weil and Magdoff, 2004). Southeastern U.S. soils are considered to have generally low sequestration potential due to warmer temperatures than the northern U.S. and lower water deficit than in the western U.S. (Franzluebbers, 2005; Wright and Hons, 2005b). However, a study by Brye et al. (2004) showed there were differences in SOM levels due to differences in management practices and land uses in eastern Arkansas delta soils within the same environmental conditions. This supports the fact that human soil management and land use decisions can produce significant changes in SOM levels, within a given environmental condition (Lal, 2001b; Brye et al., 2004; Weil and Magdoff, 2004).

Eastern Arkansas Soil Organic Matter and Soil Quality Status

Eastern Arkansas has generally low SOM due to its climatic cycles. The Mississippi River Delta region has a relatively warm and wet climate, which is a favorable condition for rapid turnover of SOM and C losses. The SOM content of agricultural soils in eastern Arkansas is estimated to be between 1 and 3.6% (Brye et al., 2004; Cordell, 2004; Brye and Pirani, 2005). Such low levels of SOM pose a threat to agricultural sustainability of this region due to its potential negative effects on soil physical, chemical, and biological properties (Rhoton, 2000; Padgitt et al., 2000). In addition, the general non use of organic soil amendments and the heavy reliance on inorganic fertilizers in eastern Arkansas has exacerbated the depletion of SOM (Slaton et al., 2004). The current status requires alternative management strategies so as to improve SOM levels in the highly agriculturally productive region of eastern Arkansas.

Wheat-Soybean Double-Crop System

Importance of Double-Crop

The wheat/oat-soybean double-crop system is a widely adopted practice in the mid-south and southeastern U.S. (Caviness et al., 1986). Soybean is one of the eight important crops grown in these regions. Arkansas is one of the major soybean producing areas in the mid-south with the area under soybean production estimated at 1.2 million ha, of which approximately 22% was in the double-crop system in 2001 (NASS-USDA, 2008b). The wheat-soybean double-crop system has been very successful in eastern Arkansas and in other parts of southeastern U.S. taking advantage of a long growing season (Scott et., 1998).

The benefits of the wheat-soybean double-crop system include the production of two crops per year, additional income, and productivity per unit land area (Power, 1987; Gill, 1997). The double-crop system provides winter soil cover that helps to reduce wind and water erosion, nutrient leaching, especially nitrate (NO_3) (Gill, 1997) and increase biomass production for SOM formation (Magdof and Weil 2004). However, in Arkansas, the land area under wheat-soybean double-crop system has steadily decreased from about 20% in 2000 to approximately 15% in 2004 followed by a drastic decrease to 5% in 2005 (NASS-USDA, 2008b). While area under soybean-double crop system in Missouri increased from 8% to 13% of all land under soybean production from 2005 to 2007. The fluctuating trend in the land area under soybean-wheat double-crop in areas where double-crop is mostly adapted could be associated to some management difficulties in this system and changes of soybean prices. Therefore, there is a need to evaluate alternative management strategies in the double-crop system so as to obtain maximum befits in terms of yield, sustainability of production, and environmental safety. In the double-crop production system, the amount of rainfall between planting and emergence of the soybean crop has a great effect on the quality and quantity of soybean yield (Scott et al., 1998). Therefore, timely planting and soil water management are of great importance in the double-crop system.

Timing of Soybean Planting

One of the major challenges in the double-crop system is proper timing of soybean planting. Boerma and Ashley (1982) showed that the delay of planting soybean in a wheat-soybean double-crop system from early July to late July (i.e., 5 to 10 wk later than the normal planting date of mid June), resulted in greater yield reduction in non-irrigated than in irrigated wheat-soybean double crop system. However, when late-planted soybean were irrigated during the dry season (June, July and August), there was increase in yield (Boerma and Ashley, 1982). These findings suggest that soil water management is a dominant factor limiting the flexibility of planting time.

Effect of Tillage on Soil Properties

Tillage practices are important in seedbed preparation and weed control. Conventional tillage (CT) in the Delta region commonly involves manipulation of soil by disking followed by harrowing to obtain a loose, fine aggregated seedbed with less than 15% residue cover on the soil surface (Padgitt, et al., 2000). No tillage (NT) on the other hand, is a conservation tillage practice where the soil is left undisturbed after harvest except for nutrient applications and planting operations. In a NT system, weed control is accomplished with herbicides and generally more than 30% residue cover is left on the surface (Padgitt et al., 2000; Franzluebbers, 2004). In 1997, about two-thirds of the soybean acreage in the U.S was under some form of conservation tillage (Padgitt et al., 2000). The use of NT in the double-crop system facilitates fast planting of soybean and limits moisture losses from the seedbed germination zone (Padgitt et al., 2000). However, in the Mississippi River Delta region, only 1.2 million ha (i.e., 19%) of crop land is under NT, whereas CT constitutes three times the land area of NT (Padgitt, 2000). In eastern Arkansas, highly mechanized CT is a common practice, which has the potential to negatively affect soil quality, productivity, and profitability of agricultural soils. The use of either CT or NT affects physical, chemical, and biological properties of soil that determine crop yield response.

Physical Properties

Bulk Density

Some studies have shown that NT results in increased bulk density in the top soil. Wright and Hons (2004) reported increased soil bulk density under NT in the subsurface root zone (5 to 15 cm depth) of 1.63 g cm^{-3}, but not in the soil surface (0 to 5cm depth) in the silty clay loam of south-central Texas. Diaz-Zorita et al. (2004) reported lower soil bulk density in CT than in NT in the silt-loam soils of Kentucky. No tillage treatment resulted in greater bulk density than CT during the first 2 years of study in the silt-loam soil of eastern Arkansas (Cordell, 2004; Brye et al., 2006). In contrast, other studies reported greater to similar soil bulk density under CT compared to NT. Logsdon and Cambardella (2000) reported increased bulk density under CT but no change under NT after 3 years of treatment in loam soil in central Iowa. Brye and Pirani (2005) reported greater bulk density in the top 10 cm silt loam agricultural soil under CT than in native tall-grass prairies in east-central Arkansas, indicating that intensive tillage increases soil bulk density of the surface soil compared to undisturbed (i.e., non-tilled) land use. Lower soil bulk density under NT than CT has also been reported by Green et al. (2005) in silt-loam soil in Maryland. Unger (1996) reported no differences in soil bulk density between CT and NT, but greater bulk density in traffic furrow than non-traffic furrow in both tillage treatments in clay loam soil in Texas. Although tillage loosens the topsoil to obtain a more aerated and finely aggregated seed bed, this benefit is only temporary and after some rainfall or irrigation, the topsoil settles and achieves a greater bulk density than immediately after tillage. Increased bulk density equates to reduced porosity and a potentially reduced zone of aeration within root zone. Altered porosity may result in a change in microbial diversity with potentially more aerobic organisms at the surface and more anaerobic organisms in the subsoil.

Soil Aggregation

Soil aggregation may be promoted through tillage practices if such practices will enhance SOM accumulation. Soil organic matter enhances the binding of soil particles together to form aggregates. Tillage influences the size and stability of aggregates in the soil. Tillage has been shown to reduce formation of macro-aggregates and promote formation of micro-aggregates (Six et al., 2000b). Wright and Hons (2004), Wright and Hons (2005b), and Green et al. (2005, 2007) demonstrated that NT increased the size of the macro-aggregate (>2mm) fraction in the top 5 cm when compared to CT.

Larger aggregates are important because they protect particulate organic matter from decomposition, and provide larger inter-aggregate pores for easy root penetration as well as easy water and air movement into and through the soil surface (Weil and Magdoff, 2004). Macro-aggregates are generally formed around fresh crop residue. If the decomposition of crop residue is slow, it will result in formation of more stable micro-aggregates within macro-aggregates due to gradual encrusting with clay particles and microbial by-products (Six et al., 2000a). The formation of stable micro-aggregates within macro-aggregates is important for aggregate stability (Six et al., 2000a). Rhoton (2000) reported greater aggregate stability after 4 years of NT compared to CT. Conventional tillage, on the other hand, resulted in lower aggregate stability after 8 years, which coincides with the gradual loss of SOM (Rhoton, 2000). Therefore the formation of large, stable soil aggregates may help to counteract the negative effects of NT on root penetration resistance. It can further be noted that improved aggregate size and stability is not realized immediately after adoption of NT.

Soil Penetration Resistance

Many types of tillage operations have been reported to influence soil penetration resistance. A 2-yr study in a loamy sand soil of South Carolina revealed that disking loosened the top 5 to 15 cm of the soil profile (Busscher et al., 2000). However, disking resulted in formation of a hard pan just below the loosened top-soil zone and 60 kPa greater resistances to penetration than without disking (Busscher et al., 2000). Raper et al. (2005) reported that CT resulted in hard pan formation at a shallower depth (0.21m) than in NT in a silt-loam soil in Mississippi. They further showed that in NT, the hard pan was formed at a depth of 0.34 m, and both tillage systems had similar soil moisture at 0- to 30-cm depth. This suggests that wheel traffic is the major cause of hard pan formation and increased penetration resistance in a soil profile. In another study comparing NT and periodic tillage after long-term NT treatment, Diaz-Zorita et al. (2004) showed that penetration resistance of a silt-loam soil in Kentucky was 35% greater in NT (1.24 MPa) than in tilled soil (0.99 MPa), but penetration resistance in both tillage treatments were lesser than the critical levels for normal root growth. Soil penetration resistance has also been shown to affect soybean and wheat yields. Busscher et al. (2000) reported an average soybean and wheat yield decrease of 1.31 Mg ha^{-1} and 1.63 Mg ha^{-1}, respectively, for every mega pascal increase in resistance in the soil profile. Therefore, reducing soil penetration resistance can likely alleviate potential yield reductions.

One way to reduce soil penetration resistance is periodic deep tillage. Deep tillage resulted in 34% lesser soil strength when compared to CT without deep tillage (Busscher et al., 2000). However, deep tillage is expensive as it requires large tractors, more fuel, and labor per hectare (Karlen et al., 1991). Significant yield increases require that deep tillage be carried out every cropping season (Busscher et al. 2000). However, frequent deep tillage has been reported to reduce overall economic benefit of the wheat-soybean double-cropping system when compared to NT (Diaz Zorita et al., 2004). Therefore, there is a need to evaluate long-term, alternative management practices on soil penetration resistance in double-cropping systems.

Soil Moisture

Conventional tillage results in excessive soil moisture loss through evaporation during land preparation. In so doing CT creates a moisture deficit, which reduces emergence and survival of soybean when there is little rainfall soon after planting (Stanford, 1982). Brye and Pilani (2005) showed that the water retention was lower in CT areas as compared to native tall-grass prairie in eastern Arkansas. Diaz-Zorita et al. (2004) reported greater saturated hydraulic conductivity of 16.4 mm h^{-1} under NT than in tillage treatment (5.1 mm h^{-1}) in the silt-loam soil of Kentucky. The greater hydraulic conductivity in NT was attributed to greater macropore continuity and stability of the soil pore system. Therefore it is clear that tillage affects water infiltration, and can potentially affect soil moisture content. No tillage has been reported to improve soil water holding capacity, and thus increase soil moisture when compared to tilled soil. Diaz-Zorita et al. (2004) showed that field moisture holding capacity of a silt-loam soil was significantly greater in NT than in periodically tilled soil. Greater soil moisture content in NT is often attributable to greater pore-size distribution than in CT soils (Diaz-Zorita eat al., 2004).

Chemical Properties

Organic Carbon and Organic Nitrogen

Wright and Hons (2005a) reported that NT significantly increased the amount of soil organic carbon (SOC) and soil organic nitrogen (SON) stored in the soil by 48% and 63%, respectively, averaged across cropping sequences and soil depth as compared to CT. They further revealed that much of the SOC and SON storage due to NT was in the 250 μm to >2 mm aggregate-size fractions. Needelman et al. (1999) also reported that NT resulted in a 15% increase in SOC and total N content in the top 5 cm when compared to CT. On the other hand, CT resulted in greater SOC and total N content than no till in the 5 to 15 cm soil depth in Illinois soils (Needelman et al., 1999). Cordell (2004) reported no change in SOC due to tillage but there was slight increase in SOM by 0.017% due to CT and 0.07% due to NT, which occurred only in combination with high residue level during the first years of the experiment on a silt loam soil of eastern Arkansas. The magnitude of SOC increase due to NT has been reported to be larger in low SOC soils from semiarid areas than in humid regions (Steinbach and Alvarez, 2006). This suggests that soils low in SOM have the potential to increase SOM due to NT.

Soil Electrical Conductivity and pH

The concentration of dissolved ions in the soil solution is an important aspect of soil fertility to ensure sustainable crop production. Changes in management practices can result in changes in electrical conductivity (EC). Brye and Pirani (2005) showed that the EC was higher in CT than in native tall-grass prairies due to irrigation water and fertilizer application to the agricultural soils. Soil pH is also an important chemical property of the soil as it is an indicator for the status of the soil solution chemical equilibrium (Magdoff and van Es, 2000). Soil pH therefore influences nutrient availability for crop production.

The current agricultural practices, whether using NT or CT, can change soil chemical properties. The use of inorganic fertilizers and irrigation water with high levels of calcium and calcium-magnesium carbonates has been reported to increase soil pH in agricultural soils as compared non irrigated undisturbed prairies (Brye and Pirani, 2005). In addition, soil pH may decrease due to the addition of crop residue, which tends to release organic acids during microbial decomposition (Magdof and van Es, 2000). Rhoton (2000) reported a significant decrease in soil pH in the top 2.5 cm after 4 years of NT in a silt loam soil of the lower Mississippi valley, as compared to CT. However, beyond the 2.5 cm depth tillage did not affect soil pH. Roldan et al. (2007) also reported greater soil pH but lower EC under moldboard tillage than NT in the top 5 cm of a clay soil in Mexico.

The change in soil pH due to management can be counteracted by an increase in buffering capacity of soils. Soil organic matter has been reported to improve soil buffering capacity of agricultural soils by releasing protons (H^+) if the soil H^+ concentration decreases, or base concentration is high and accepting H^+ when acidity is produced (Magdof and Van Es, 2000). In addition, SOM helps to ameliorate aluminium toxicities in acid soils due to the reaction between organic ligand from SOM and Al^{3+} to form a hydroxyl Al-organic complex, which is less toxic than Al^{3+} in soil solution

(Huang, 1995). In order to maintain sustainable crop production, it is essential to avoid drastic changes in soil pH. This necessitates the need for alternative management strategies to improve soil buffering capacity to maintain chemical balance of the soil solution for crop production.

Exchangeable Bases

Rhoton (2000) reported greater exchangeable calcium (Ca^{2+}) concentration under NT, and significantly greater exchangeable potassium (K^+) in CT in the upper 2.5 cm after 4 years of study but no tillage effect on exchangeable cations after 8 years in Mississippi. Greater exchangeable Ca^{2+} concentration was attributed to surface application of lime without incorporation in NT. In contrast, Bravo et al. (2007) reported 34% greater Ca^{2+} but less K^+ under CT than NT after 20 years of tillage treatment in un-limed clay soil in southern Spain. However, exchangeable magnesium (Mg^{2+}) was not affected by tillage (Rhoton, 2000; Bravo et al., 2007). Therefore, tillage effect on exchangeable bases varied with management practices and nature of the soil.

Biological Properties

Soil Microbial Biomass

The microbial biomass is responsible for decomposition, mineralization of plant and animal residues, nutrient cycling, pest control, and genesis of more stable humic substance (Rossel et al., 2001). Therefore, microbial biomass plays a central role in the dynamics of SOM and soil quality. Soil microbial biomass is often referred to as an estimate of C in living biomass (Gregorich et al., 1994). Rossel et al. (2001) suggested that microbial biomass is among the soil quality indicators that have greater potential for change than SOM; hence microbial biomass is suitable in evaluating treatment effects on soil fertility and plant production (Rossel et al., 2001; Turco et al., 1994).

Tillage and Soybean Growth, Development, and Yield

Canopy development depends on seedling emergence and subsequent stand development. Stanford (1982) reported that CT (disking and harrowing) resulted in significantly reduced emergence and reduced seedling survival compared to NT when there was no rain soon after planting in silty-clay soil. The reduction of emergence and survival was attributed to excessive moisture loss during land preparation especially when there was no rainfall for 11 days after planting. Popp et al. (2000) reported that tillage (CT vs. NT) had no effect on soybean stand in silt-loam soils while in heavy clay NT resulted in reduced seedling stand compared to CT in eastern Arkansas. The lower seedling stand in clay soil was explained as being due to poor seed to soil contact in this heavy-textured soil. However, the use of improved equipment for NT planting, such as straight coulter or a ripple coulter, has reduced this problem. Cordell (2004) and Brye et al. (2004) reported higher soybean population under NT than CT by 10 days after planting, which was not consistent between two locations and years of experiments in silt-loam soil of eastern Arkansas. These results suggest that soybean growth performs similarly in both CT and NT (Cordell, 2004; Brye et al., 2005).

Poor emergence and reduced survival of emerged seedlings results in poor canopy development, which reduces dry matter production and subsequently yield reduction. A 3 year study in a wheat-soybean double-cropped system resulted in inconsistent tillage effect on soybean yield, where CT resulted in greater yield during the second year of the study, but lower yield in the last year of study (Popp et al., 2000). Soybean yield inconsistencies may be due to short-term effects of initial soil physical property change when management practices are altered.

Wheat Residue Burning and Non-burning and Soil Properties

The need to meet timely planting of soybean for adequate moisture utilization for emergence and yield requires proper wheat residue management. A common crop residues management practice in the Delta region of eastern Arkansas is burning the residue soon after crop harvesting (Stanford, 1982). However, some farmers have opted against burning crop residues. The choice of either wheat residue management practices affects several soil physical, chemical, and biological properties and ultimately crop growth and yield.

Wuest et al. (2005) provided evidence that burning of crop residues is highly degrading practice in agricultural soils. They showed that burning resulted in lower soil C, N, and aggregate stability and infiltration when compared to non-burning. Decreases in soil C, N, P, S, Ca, and Mg due to burning has also been reported by Murphy et al. (2006) when compared to non burning treatments. Sherman et al. (2005) reported that soil pH increased by 0.23 pH units immediately after burning compared to before burning. However, after 1 year there was no lasting pH difference in grassland Ultisols in Maryland. The increase in pH immediately after burning was attributed to the release of soluble cations during burning, which upon hydrolysis resulted in increased soil pH

(Sherman et al., 2005). In contrast, Murphy et al. (2006) showed no burning effect on soil pH and exchangeable calcium and magnesium in forest soil in Nevada.

Burning of crop residues contributes to the release of greenhouse gases. Studies have shown that burning resulted in emissions of nitrogen, carbon, and sulfur gases due to high soil temperature which favor volatilization of the gaseous forms of these elements (Caldwell et al., 2002; Murphy et al., 2006). Since burning results in rapid mineralization of organic forms of most nutrients, burning creates more favorable conditions for nutrient losses. Murphy et al. (2006) reported a significant increase in NH_4^+- and NO_3^--N as well as ortho-P leaching in burned compared to non-burned plots.

Burning has been reported to negatively affect biological properties and activity of agricultural soils. Wuest et al. (2005) reported that glomalin, a fungal-secreted polysaccharide responsible for soil aggregation, was significantly reduced due to burning. This implies that burning of crop residues indirectly affects soil aggregation and may result in poor soil structure. In addition, the Basidiomycetes population was greater in non-burned wheat residues, where Basidiomycetes fungi obtain their carbon source from wheat-residue lignin (Wuest et al., 2005). To my knowledge no long-term studies have been conducted to investigate the effects of burning in agricultural soils of eastern Arkansas.

Weed Population and Diversity

Weeds are one of the most serious problems in crop production in the Southeastern United States, causing a significant economic loss due to crop yield losses (Geddes et al., 1978; Banks et al., 1985). The most important weeds species that causes significant soybean yield losses in Southeastern United States includes the common cocklebur (*Xanthium pensylvanicum* Wallr.) (Geddes et al., 1978), sicklepod (*Cassia obtusifolia* L.) (Banks et al., 1985), annual morningglory (*Ipomoea*), and hemp sesbania (*Sesbania exaltata* (Raf.) Rydb. ex W.A. Hill) (Norsworthy and Oliver, 2002). Crop yield losses due to weeds is caused by greater competition of weeds over the crop for water, light, nutrients, seed germination over a wide range of temperature and soil pH (Geddes et al., 1978). Therefore, weeds control is one of the most important aspects of soybean production.

One of the major reasons for tillage of croplands is to control weeds (Esbenshade et al., 2001). Conventional tillage and burning are advantageous for weed control in agricultural soils. Conventional tillage helps to burry surface weeds along with crop residues to provide a weed-free seedbed. Burning can destroy weed seeds if the temperature gets high enough, hence reducing weed seed bank, and in so doing providing potential for decreased weed infestations (Walsh and Newman, 2006). However, conventional tillage and burning have been reported to have negative environmental impacts.

In contrast, NT can increase weed species diversity and populations due to continual accumulation of weed seeds on the soil surface. Increased weed species population has been reported to be a significant factor responsible for soybean yield decline in NT. Banks et al. (1985) reported a significant decline in soybean yield as sicklepod population increase from 0 to 200,000 sicklepod plants/ha, and in absence of sicklepod interference there were no differences in yield between NT and CT. Wicks and Sommerhalder (1971) reported reduced tillage to have greater weed seed density of

4210/0.1 m^2 compared to conventional tillage with 2830/0.1m^2 in a corn-soybean rotation system in Bridgeport loam soil, Nebraska. Cardina et al. (2002) reported lower germinable seeds of common chickweed [*Stellaria media* (L.)] in CT compared to NT and reduced till in the silt loam soils of Ohio. The reduced germination of common chickweed in the CT is due to common chickweed intolerance to deep plowing (Cardina et al., 2002). Weed seeds buried deep in the soil have lower germination than weed seeds closer to the soil surface due to lack of light trigger, exhaustion of seed energy reserve before emergence, and limitation on soil gas diffusion (Benvenuti and Macchia, 1998; Benvenuti 2003). A study by Benvenuti (2003) further established that reduced weed seeds germination varies with soil texture, where weed germination is less affected in sandy soil (with 50% seed germination depth of 5.3 cm) than clay soil (with 50% seed germination depth of 3.2 cm). Benvenuti (2003) concluded that there is depth-mediated germination inhibition which is explained to be due to specific characteristics of soil gas diffusion. It is possible that reduced soil gas exchange may also contribute to long term accumulation of weed seed in the seed bank. Since tillage influence gas diffusion in the soil through the effect of soil bulk density, moisture content, and aggregation, it may also affect weed population density.

Esbenshade et al. (2001) reported significant reduction of burcucumber (*Sicyos angulatus*) emergence due to NT compared to CT, but no difference in weed population density at late growing season, in Pennsylvania. Low weed emergence in NT has been reported to be due to the effect of crop residue on the surface which suppressed weed emergence. Reddy (2001) reported that cover crop residues suppressed browntop millet [*Brachiaria ramosa* (L.) Stapf] density at 3 weeks after planting in NT compared to no cover crop CT in a silt loam soil of Mississippi. However, at 9 weeks after planting the wheat cover crop did not reduce browntop millet density in NT (Reddy, 2001). Cover crop residues did not affect densities of barnyardgrass [*Echnochloa crus-galli* (L.) Beauv.], prickly sida (*Sida spanos*a L.), and yellow nutsedge (*Cyperus esculentus* L.) (Reddy, 2001). It appears that tillage practices can also result in a change in not only weed population density but also weed diversity.

The current development of efficient herbicides coupled by development of herbicide-resistant soybean varieties has improved weed control in NT and other conservation tillage systems. However, crop residues left on the surface in NT can interfere with herbicides activity and hence reduce herbicide efficiency. Reduced herbicides efficiency results in the need for higher rates and frequent spraying, adding additional costs of production (Reddy et al., 1995; Locke et al., 2002). The reduced herbicide efficiency due to crop residue cover is caused by prevention of the herbicide to reach the soil (Reddy et al., 1995). Reduction of bioactivity of preemergence herbicide to weeds due to crop cover makes additional postemergence herbicide application necessary.

Herbicide sorption can also reduce herbicide efficiency through reducing herbicide bioactivity for weed control (Locke et al., 2002; Reddy et al., 1995). Herbicides sorption tends to be higher in presence of crop residues compared to no residue cover, and tend to increase with increase in length of decomposition (Reddy et al., 1995). Locke et al. (2002) reported higher sorption of positively charged-non- polar-hydrophobic herbicides in NT with cover crop residue than CT in the top 2 cm of a silt loam soil in Mississippi. Higher sorption in NT was attributed to higher SOM on the soil surface. However, retention of herbicides can be slowly released to provide season-long weed control and reduce herbicide contamination to non targeted environments (Reddy et al., 1995).

It appears that the effect of tillage, crop rotation, and residue management on weeds differs among weed type (species). Thus, changes in tillage, residue management, and water management practices can greatly affect weed species population and diversity. To ensure long-term benefit of the alternative management strategies, there is a need to evaluate the effects of alternative residue management practices on weed species population and diversity.

Soil Water Management

Stored soil water is essential for supplying moisture to plants at times when evapotransiration exceeds precipitation (Scott et al., 1998). In eastern Arkansas, the long-term normal rainfall and potential evapotranspiration show that the month of June, July, and August have relatively large moisture deficits for crop production (Scott et al., 1998). In addition, Scott et al. (1998) reported that in any given month, there is a 50% probability of rainfall being below normal in nine years out of ten. The moisture deficit needs to be minimized for optimum crop production through irrigation and/or improving soil water storage. The capacity of soil to store water plays an important role in maintaining high crop yields.

Popp et al. (2000) reported a greater soybean yield in non irrigated eastern Arkansas clay soils compared to silt-loam soils due to differences in water holding capacity. Clay soils have generally greater water holding capacity than silt-loam soils;

hence clay soils have greater potential to supply moisture at the time of moisture deficits throughout the growing season.

Alternatively, irrigation has been widely used in eastern Arkansas as a management option to supply water to a crop to counteract moisture deficit within the cropping season (Scott et al., 1998). In Arkansas, the land area under irrigation has steadily increased from 1.5 million ha in 1997 to 1.7 million ha in 2002 (NASS-USDA, 2008a).

Most of the irrigation water used in eastern Arkansas comes from groundwater. The groundwater in eastern Arkansas is supplied by the Alluvial, Cockfield, Sparta/Memphis, Wicox, and Nacatosh aquifers (Scott et al., 1998). In 2002, Arkansas was among the top 5 major user of groundwater in the USA, with groundwater withdrawals of 6960 Mgal d^{-1} (Solley et al., 1998; ASWCC, 2005). The Alluvial aquifer supplies about 95% of all groundwater in Arkansas, of which 96% is used for agricultural irrigation. Sustainable use of ground water from the Alluvial aquifer requires a maximum withdrawal of 2700 Mgal d^{-1}, which shows that the current water use is more than double the sustainable yield of the Alluvial aquifer (ASWCC, 2005).

In a 4 year survey from 1997 to 2001 of 227 measured wells in Arkansas aquifers, 78.4% of the wells showed a decline of ground water levels ranging from the minimum decline of -0.1 m to a maximum decline of -28.4 m measured in Columbia County (Schrader, 2004). The remaining 21.6% of the wells measured an increase in groundwater level ranging from a minimum of 0.03 m to a maximum of 10.5 m. The maximum decline in groundwater level in eastern Arkansas wells was -11.8 m in Prairie County, while Lee County measured a decline of -1.8 m. It was further revealed that the declining trend was more observed in areas closer to the measured wells (control point), illustrating that the declining trend is more associated by ground water withdrawal than other factors (Schrader, 2004). These observations show that the groundwater supply is being depleted faster than the rate of recharge (ASWCC, 2005).

Groundwater withdrawal trends over the past 25 years have shown that there is a negative slope range of -0.48 to -0.13 m yr^{-1} in 220 wells out of 227 wells measured in Arkansas aquifers (Schrader, 2004). This further confirms that the decline in groundwater is caused by changes in climatic condition as well as increased groundwater use. The current trend of increasing area under irrigation and increasing groundwater use for irrigation shows that soil water management in these areas has relied more on irrigation than improving soil water storage for crop production. It is apparent that alternative soil water management for soybean and wheat growth and production in eastern Arkansas needs to be evaluated.

According to the ASWCC (2005), the continued reduction of groundwater levels will not only result in adverse effects on agricultural irrigation, but will also result in permanent damage of aquifers and groundwater storage. Eastern Arkansas represents an important lower Mississippi hydrological region (08) of the U.S., with a total of 16 watersheds covering about 49.9% of the state (Scott et al., 1998). Therefore one major concern for agriculture production in this area is the quality and quantity of water, and hence water management.

Wheat Residue Decomposition

Biochemical Structure of Wheat Residue

Residue quality plays a significant role in regulating the rate of decomposition and subsequent long-term SOM storage. Residue quality is generally governed by the C/N ratio of the material, where it is generally considered that high quality crop residues have low C/N ratio and thus are rapidly decomposable. Wright and Hons (2004) reported that wheat residue is less susceptible to rapid microbial degradation due to its higher C/N ratio than grain sorghum (*Sorghum bicolor*) or soybean residue. The C/N ratio of crop residues also affects the amount of SOC stored in the soil. Potter et al. (1998) showed that wheat residue resulted in greater SOC than sorghum residue despite larger quantities of sorghum above ground biomass.

Crop residues also differ in rate of decomposition due to differences in biochemical and structural characteristics. Using an incubation study, Gaillard et al. (2003) determined that wheat residue decomposed slowly as compared to rye (*Secale cereale*) residue. However, after 10 and 3 days of incubation, for wheat and rye, respectively, both had the same amount of C mineralized. It was also revealed that the amount of C in the particulate fraction of wheat residue was greater than that in rye. The slow decomposition rate of wheat residue is due to the high cellulose and hemicellulose content (Gaillard et al., 2003). It is argued that although slowly decomposable materials take longer time to exert maximum impact on soil aggregation, they are more effective in long-term aggregate stability (Wright and Hons, 2004).

Crop residue Bioavailability and Accessibility

Bioavailability refers to how accessible crop residues are to soil microorganisms. Surface residues decomposed more slowly than incorporated residues because of less contact with soil microorganisms (Reicosky et al., 1995). In contrast, mixing and turning of the soil surface due to CT exposes crop residues to highly aerobic and oxidizing conditions, which accelerates decomposition (Brye and Pirani, 2005).

JUSTIFICATION

The importance of SOM and SOC in agricultural productivity, soil quality, and the potential to contribute to mitigation of global warming requires continual efforts to identify and evaluate management strategies to improve SOM in a wide range of climatic regions. The current and ever-growing concerns for economically and ecologically viable technology for agricultural sustainability illustrate the need to evaluate cost-effective and environmentally friendly management strategies.

The alternative management strategies, such as NT and CT, have potential benefits in improving soil quality. However, there is still a need to maintain or increase yields to ensure the likelihood for adoption of alternative residue management practices in eastern Arkansas. Although there is currently a declining trend in total soybean area under double-cropping in eastern Arkansas, there is the potential for substantial future increases in double-cropped soybean production. Soybean production increases are expected due to the U.S. market strategy and Energy Policy Act of 2005 to replace 7.5 billion gallons of gasoline with renewable fuel by 2012, which gives credit for bio-diesel produced from soybean (ERS-USDA, 2006). These initiatives are expected to increase the demand for soybean. The recent success in the use of soybean oil in the production of bio-diesel may result in increased soybean production, especially in eastern Arkansas. Such projected increases in soybean production may result in serious environmental destruction in the presence of the current excessive tillage, burning, and increasing groundwater demand for irrigation water.

Many soil physical and chemical properties and weed diversity and population changes due to management take time to be realized, and as such, require long-term study of proposed alternative management practices. It is expected that some semblance of equilibrium has been attained after the initial 3 years of a previous study, such that the effects of tillage and residue management may manifest themselves in the current study that will track residue and water management effects for year 4 through year 6 following treatment.

Although eastern Arkansas historically had abundant water sources for irrigation, such resources are being depleted at a rate beyond the aquifer's sustainable yields. The current declining trend in groundwater levels poses a threat to not only the quantity of water available, but also the quality of the groundwater resource. Since agricultural irrigation is the major consumer of water, alternative management strategies to improve soil water conservation will be required for long-term agricultural sustainability. Additionally, such alternative management strategies need to be evaluated in terms of their effects on crop yields and soil quality.

Wheat produces high levels of crop residues due to the relatively small part of the plant that is harvested as grain. Wheat straws biochemical composition consists of high lignin content, which is relatively resistant to decomposition. The decomposition process is also a function of tillage treatment. The potential benefit of SOM in soils is largely dependent on the amount of organic materials in various stages of decomposition. Therefore, further evaluation of wheat residue decomposition is required so as to monitor static and dynamic effects of alternative residue management practices in eastern Arkansas soils.

Therefore the main objective of this study is to evaluate the long-term alternative crop residue and water management practices on soybean yield and soil quality in a wheat-soybean double-cropping system in eastern Arkansas. Specifically this study is aimed at evaluating:

- Tillage effects (NT and CT) on soil fertility, soil quality, and soybean yield
- Wheat residue level effects (low and high residue level) on SOM and other soil properties as well as soybean emergence, growth, and yield
- Burning effects (burning and non-burning) on soil properties and soybean yield
- Alternative residue management practices effects on weed infestations
- Water management effects (irrigation and non irrigation) on soil properties and soybean growth and production
- Alternative residue management practices effects on weed infestations
- Alternative residue management practices economic performance relative to traditional practice (irrigation-CT-burn-high-residue)
- Wheat residue decomposition effects on SOM and soil physical properties of silt-loam soil of east Arkansas under simulated tillage, residues level, management and water management treatment

Hypotheses:

- No-tillage will result in greater SOM and improved soil fertility than CT and that NT will have at least similar soybean yield compared to CT.
- High residue levels will have greater SOM than low residue level and will not negatively affect soybean yield
- Non-burning residue management will increase SOM and soil fertility compared to burning
- No-tillage, non-burning, and irrigated treatments will have greater weed population and diversity compared to CT, burning and non-irrigated treatments
- Irrigation will result in greater SOM and soybean yield due to increased vegetative biomass and reduced rate of turnover caused by high moisture content, which reduces the proportion of air-filled pores spaces
- No-tillage, irrigated, and high-residue level treatment combinations will have greater net returns and percent profitability relative to traditional practice due to crop yield advantage and reduced operation costs
- Soil microbial biomass C (SMB C) and SOM content will change with time of incubation due to wheat residue decomposition

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CHAPTER TWO

Soil Property and Soybean Yield Trends in Response to Alternative Wheat Residue Management Practices in a Wheat-Soybean Double-Crop Production System in Eastern Arkansas

ABSTRACT

Growing concerns over the long-term sustainability of agricultural systems require investigation of agricultural management practices that may improve and sustain soil quality and crop productivity over time. The objective of this study was to determine the 6-yr effects of tillage [conventional (CT) and no-tillage (NT)], wheat residue burning (burn and no burn), and residue level (low and high, achieved with differential N fertilization) on soybean [*Glycine max* (L.) Merr.] yield and soil physical and chemical properties in the top 10-cm soil depth in a wheat [*Triticum aestivum* (L.)]-soybean double-crop production system. A field experiment was conducted from Fall 2001 through Fall 2007 in the Mississippi River Delta region of eastern Arkansas on a Calloway silt loam (fine silty, mixed, active, thermic Glossaquic Fraglossudalf). Soil bulk density increased in both CT and NT during the first three years, but at a greater rate under NT (0.12 g cm^{-3} yr^{-1}) than CT (0.08 g cm^{-3} yr^{-1}), followed by a decline at a similar rate in both tillage treatments. Soil pH and Mehlich-3 extractable soil Ca and Mg contents increased, and electrical conductivity decreased linearly over time. Soil organic matter (SOM) increased over time in all treatment combinations. Total C (TC) increased at a greater rate in the no burn (0.08 kg C m^{-2} yr^{-1}) and high-residue-level (0.07 kg C m^{-2} yr^{-1}) than in the burn (0.05 kg C m^{-2} yr^{-1}) and low-residue-level (0.05 kg C m^{-2} yr^{-1}) treatments. Extractable soil P content declined linearly over years at a greater rate under NT (3.3 kg P ha^{-1} yr^{-1}) and high-residue-level (3.4 kg P ha^{-1} yr^{-1}) than under CT (2.6 kg P ha^{-1} yr^{-1}) and low-residue-level (2.4 kg P ha^{-1} yr^{-1}) treatments. Soybean yield declined at a similar rate in the first 3 years, but increased at a similar rate over the subsequent 3 years in all tillage treatment combinations. Increasing SOM and TC over time were

expected due to relatively low initial SOM levels indicating that silt-loam soils of the Mississippi River Delta region have the potential to sequester C at increasing rates beyond 6 years from initial conversion to alternative residue management practices. Implementation of the appropriate residue management practices has the potential to improve soil quality and maintain long-term productivity of silt-loam soils in the Mississippi River Delta region of the mid-southern United States.

INTRODUCTION

Agricultural sustainability is the ability of agricultural systems to remain productive for an extended period of time (Herdt and Steiner, 1995). A concern with current agricultural practices, however; is whether current or conventional agricultural practices sustain production levels without causing irreversible damage, such as soil erosion, soil organic matter (SOM) depletion, and salinity (Denison et al., 2004). Soil organic matter is an important soil-quality indicator because SOM is sensitive to agricultural management practices, particularly tillage, and can be used to relate soil properties and functions across a range of climates, parent materials, land uses, topographies, and management systems to evaluate the sustainability of agricultural systems (Franzluebbers, 2004; Nunes et al., 2007).

The Mississippi River Delta region of eastern Arkansas, Louisiana, western Tennessee and Mississippi is highly agriculturally productive due in part to its relative warm and wet climate. However, warm and wet climatic conditions are also favorable for rapid decomposition of SOM and carbon (C) losses. In Arkansas particularly, a long history of cultivated agriculture coupled with the warm and wet climate has resulted in generally low SOM, estimated to range from 1% and 3.6% (Brye et al., 2004; Brye and Pirani, 2005) associated with many cultivated, row-crop agricultural soils. Low SOM levels pose a threat to agricultural sustainability in the Mississippi River Delta region due to potential negative effects of low SOM on soil physical, chemical, and biological properties (Rhoton, 2000). In addition, the general lack of use of organic soil amendments and heavy reliance on inorganic fertilizers in eastern Arkansas has exacerbated the depletion of SOM (Slaton et al., 2004). The current relatively low SOM levels will require agricultural management strategies that increase SOM levels in eastern Arkansas for long-term agricultural sustainability to be achieved.

Adoption of crop rotation systems with high biomass production is a primary option to increase SOM (Magdof and Weil, 2004). A wheat-soybean double-crop system is a crop rotation system with the potential to increase biomass production for improved SOM (Magdof and Weil, 2004). Other benefits of the wheat-soybean double-crop system include additional income from two crops per year, increased productivity per unit land area, reduced wind and water erosion and nitrate-nitrogen (NO_3-N) leaching due to the presence of a winter cover crop (Gill, 1997). In 2007, the wheat-soybean double-crop system accounts for approximately 21% of all soybeans produced in Arkansas, which equates to approximately 246,867 ha of the approximately 1.2 million ha of total soybean-planted area (NASS-USDA, 2008a). The wheat-soybean double-crop system is even more widely adopted throughout the mid-south and southeastern U.S. (Caviness et al., 1986). However, one major challenge facing the wheat-soybean double-crop production system in eastern Arkansas is deciding on a wheat-residue management strategy that facilitates soybean planting before 15 June each year to avoid a yield loss (Boerma and Ashley, 1982).

Conventional wheat-residue management practices in eastern Arkansas consist of tillage, specifically multiple passes with a disk followed by harrowing to obtain a finely aggregated seedbed. In addition, prior to tillage, most producers burn the wheat residue to facilitate tillage and timely soybean planting (Sanford, 1982). Conventional tillage (CT) reduces plow-layer bulk density, provides a fine seedbed, and controls weeds for adequate plant growth (Esbenshade et al., 2001). However, it has also been shown that long-term CT can induce soil compaction (Busscher et al., 2000; Brye and Pirani, 2005; Raper et al., 2005; Green et al., 2005), disrupt soil aggregate stability (Green et al., 2005), and increase the accessibility of organic residues to microorganisms, whereby resulting in rapid SOM decomposition and loss of C as carbon dioxide (CO_2) (Reicosky et al., 1995; Needelman et al., 1999; Six et al., 2000a, 2000b; Green et al., 2005).

Some producers in the Mississippi River Delta region have adopted no-till (NT) practices in the wheat-soybean double-crop production system. The use of NT in the double-crop system facilitates timely planting of soybean, limits moisture losses from the germination zone in the seedbed (Padgitt et al., 2000), and reduces farm operating costs relative to CT (Ribera et al., 2004). Wright and Hons (2004, 2005a) demonstrated that the size of the macro-aggregate (>2 mm) fraction of the soil increased more under NT than under CT management in the top 5 cm of a silty clay loam in Texas in a wheat-soybean double-crop system. Macro-aggregates protect SOM from rapid decomposition, increase SOM accumulation, and have large inter-aggregate pores for easy root penetration and water and air movement into and through the soil surface (Magdoff and Weil, 2004). Wright and Hons (2005b) further revealed that much of the soil organic C (SOC) and soil organic N (SON) storage due to NT was in the 250-µm to 2-mm aggregate-size fractions. No-tillage improves soil aggregate stability due to gradual binding of organic residues with clay particles and microbial by-products as a result of slow crop residue decomposition (Six et al., 2000b). Wright and Hons (2005a) also reported greater SOC and SON stored in soil under NT than CT when averaged across cropping sequences and soil depths.

Increase in SOM after change from CT to NT depends on duration of tillage, and the magnitude of SOM increase differs across soil profile. In a 2-yr study Brye et al. (2006a) reported no differences in SOC between NT and CT, but that SOM increased more under NT (0.07%) than under CT (0.02%) in a high-residue treatment in a silt-loam soil in eastern Arkansas. Pikul et al. (2007) also reported no difference in total C (TC) between NT and CT after 4 yr; however, after 10 yr of NT, soil TC was 7% greater than under CT in a clay-loam soil under a corn (*Zea mays* L.)-soybean rotation in South Dakota. In Illinois, NT had 15% greater SOC and total N (TN) in the top 5 cm, but 5.8% lower SOC and TN in the 5 to 15 cm depth than CT (Needelman et al., 1999). However, regardless of tillage, SOC and TN were greater in the top 5 cm than in the 5- to 15-cm depth (Needelman et al., 1999). Green et al. (2005) reported 27% and 22% greater TC and TN, respectively, in the top 5-cm depth under NT than CT and organic system after 10 years of treatment in silt soil in Maryland. West and Post (2002) estimated that 85% of SOC sequestered due to change from CT to NT occurred in the top 7 cm. The magnitude of the SOC increase due to NT has been reported to be larger in low SOC soils from semiarid areas than in humid regions (Steinbach and Alvarez, 2006), indicating that initial SOM influences the rate of SOM change due to tillage. Therefore, characterization of changes of plow-layer SOM over an extended period of time due to alternative tillage practices is essential to evaluate the long-term agricultural sustainability.

Producers are also concerned about yield losses with adoption of NT. Two years of CT resulted in greater soybean yield than in NT, but in the third year CT had lower yield than NT in clay and silt-loam soils in eastern Arkansas (Popp et al., 2000). In contrast, Sanford (1982) reported that CT resulted in significantly lower emergence and seedling survival than NT due to substantial moisture loss silty-clay soil in Mississippi. Cavigelli et al. (2008) reported no differences in soybean and wheat yields between CT and NT after 10 years of tillage treatment in silt-loam soil in Maryland. Verkler (2007) also reported no yield differences between CT and NT after 4 years of consistent management. However, Verkler et al. (2008) showed that NT had a greater ability to retain water for a longer period of time after irrigation and rainfall events than CT, also indicating that NT provides a soil moisture advantage over CT. The apparent inconsistent tillage effects on soybean growth and yield may be due to short-term soil management effects, which further support the need for long-term field studies.

Burning facilitates easy and quick removal of residue, which could interfere with soybean seedling emergence and growth (Sanford, 1982). However, burning reduces soil C, N, aggregate stability, and water infiltration compared to non-burning (Wuest et al., 2005; Murphy et al., 2006). Changes in soil chemical properties due to burning have also been reported. Murphy et al. (2006) reported decreased extractable soil P, S, Ca, and Mg due to burning. Burning increases soil pH, but the pH increase is typically temporary, lasting less than 1 year (Sherman et al., 2005). In addition, burning contributes to the release of greenhouse gases. Several studies have shown that burning resulted in emissions of N, C, and S gases due to the high temperature during combustion, which favors volatilization of the gaseous forms of these elements (Boubel et al., 1969; Caldwell et al., 2002; Murphy et al., 2006). Burning of crop residues is a practice that generally degrades agricultural soils and could threaten the long-term productivity of agricultural and environmental sustainability, which again suggests the need to investigate alternative residue management practices.

Although leaving crop residue unburned is beneficial for the soil as an SOM source, there is concern about potential residue interference with soybean growth and pesticide effectiveness in a wheat-soybean double-crop production system. The presence of wheat residue has been reported to reduce seedling growth of soybean due to allelopathic effects of the wheat residue (Caviness, 1982) and the physical barrier the residue creates, which can reduce sunlight penetration. Improvement or degradation of soil quality due to management practices cannot be easily detected over short periods of time such as within or after one to two growing seasons (Herdt and Steiner, 1995; Denison et al., 2004). Thus, long-term studies are necessary to evaluate management practices affecting soil quality and crop productivity. However, multi-year studies (i.e., >5 yr at a minimum) investigating residue management practices effect on soil properties and soybean yield in the wheat-soybean double-crop production systems in the Mississippi Delta region of the mid-south are limited.

The objectives of this study were two-folds: (i) First, to determine the effects of tillage (CT and NT), residue burning (burn and no burn), and residue level (low and high) on soil properties changes in the top 10 cm and soybean yield and profitability over a 6-yr period of consistent field management and (ii) to determine effect of tillage, wheat-residue level and the incubation time on soil microbial biomass C (SMB C), soil organic matter (SOM), total C (TC), total N (TN), and the C:N ratio in a common silt-loam soil of eastern Arkansas under greenhouse conditions. It was hypothesized that (i) different wheat residue levels can be produced with differential N fertilization, (ii) extractable soil nutrients contents, soil pH, and electrical conductivity (EC) changes over time will differ among treatments, (iii) SOM, SOC, and TN will be greater, and increase over time at greater rate under NT, no-burn, and high-residue than in CT, burn, and low-residue level treatments, and (iv) based on Cordell (2004) and Verkler (2007), it was hypothesized that soybean yield will be similarly increase over time in both CT and NT, but will be greater and increase more over time in the burn and low residue-level treatments. It was also hypothesized that soil microbial biomass C, SOM, soil TC, and TN will be greater under NT, high-residue level, and will increase over time of incubation more than CT and low residue, and will decrease over time under no-residue treatment.

MATERIALS AND METHODS

Field Experiment

Site Description and Experimental Design

A study was conducted at the University of Arkansas Lon Mann Cotton Research Station, Marianna (N 34^0, 44', 2.26"; W 90^0, 45' 51.56", Cordell, 2004) in the Mississippi River Delta region of eastern Arkansas from fall 2001 through fall 2007. The soil is a Calloway silt loam (fine silty, mixed, active, thermic Glossaquic Fraglossudalf) (Web Soil Survey, 2008). The study area was under continuous CT soybean production prior to initiating this field experiment (Cordell et al., 2006).

The experimental design was a split-strip plot with six replications of each of eight treatment combinations. Tillage treatments (CT and NT) represented the main plot and were arranged as a randomized complete block with three replications. Burning treatments (burn and no burn) formed the strip plot and were arranged across tillage treatments with two replications. Residue level [high (H) and low (L)] represented the strip-split plot within tillage and burn treatment combinations. There were a total of 48 plots.

Field Management

In fall 2001, the study area was prepared by disking twice followed by broadcast application of 20 kg N ha^{-1}, 22.5 kg P ha^{-1}, 56 kg K ha^{-1}, and 1120 kg ha^{-1} of pelletized limestone prior to wheat planting. Each fall, wheat (cultivars 'Coker 9663' for 2001 to 2004 and 'Coker 9553' for 2005 and 2006) was drill-seeded with 19-cm row spacing at a rate of between 90 to 126 kg seeds ha^{-1}. Plots, 3-m wide by 6-m long, were established in early spring 2002 and were maintained throughout the study period. In early March 2002 through 2004, all plots were broadcast fertilized with 101 kg N ha^{-1} as urea. To obtain different levels of wheat residue, the high-residue plots (n=24) were broadcast fertilized with an additional 101 kg N ha^{-1} as urea at about the late-jointing stage in approximately late March. In spring 2005, no N fertilizer was applied because a wheat stand was not established due to excessive moisture in fall 2004. In 2006 and 2007, only the high-residue plots were broadcast fertilized with 56 kg N ha^{-1} urea in early March, followed by an additional 56 kg N ha^{-1} in late March. Low-residue treatments did not receive any N fertilizer to ensure a residue level difference was achieved.

Wheat grain from the middle 1-m of each plot was harvested in early June each year, and aboveground wheat residue was uniformly spread back on to each plot. Standing wheat stubble was then mowed to about 3 cm from the soil surface to create a uniform residue-covered soil surface. After mowing, the burning treatment was imposed followed by tillage, either CT by disking twice to a depth of about 10 cm and seedbed smoothing or NT. In 2005 and 2007, residue burning was not possible due to the absence of a wheat stand in spring 2005 and due to wet conditions at planting, and prolonged wet conditions in spring 2007.

Glyphosate-resistant soybean (cultivars 'Pioneer 95B32' maturity group 5.3 for 2002 through 2005 and 'Armor 54-03' maturity group 5.4 for 2006 and 2007) were drill-seeded with a 19-cm row spacing in early to mid-June each year. In 2002 through 2004, all plots were furrow irrigated, but in 2005 though 2007 only 24 plots were irrigated four to six times throughout the soybean growing season, while the remaining 24 plots were managed as dry-land soybeans. Weeds and insects were controlled when necessary using University of Arkansas Cooperative Extension Service recommendations (UACES, 2003a, b). Soybeans from the middle 1- by 6-m section of each plot were harvested using a plot combine in late October to early November each year, except in 2004 where soybean was hand-harvested early December. Soybean and wheat grain were air dried for approximately 4 wk and weighed to determine plot yields. Soybean grain subsamples were oven dried at 70 ^{0}C for 48 h to determine moisture content and soybean yields were adjusted to 13% moisture content for reporting.

Soil Sampling Scheme and Analyses

Composite soil samples were collected by combining seven to ten soil cores from the top 10-cm depth from each plot after wheat harvest, but before tillage and soybean planting. Samples were oven dried at 70 ^{0}C for 48 h and ground to pass through 2-mm sieve for chemical analysis. Soil bulk density was determined twice a year by collecting a single 4.8-cm-diameter core sample from the top 10 cm of each plot at the time of composite soil sampling and approximately 8 wks after soybean planting. Soil pH and electrical conductivity (EC) were determined potentiometrically with an electrode in a 1:2 (w/v) soil:water suspension. Total soil N and C were determined by high-temperature combustion using a LECO CN-200 analyzer (LECO, Corp., St. Joseph, MI). Soil organic matter was determined by weight-loss-on-ignition at 360 ^{0}C for 2 h (Schulte and Hopkins, 1996). Mehlich-3 extractable soil P, K, Ca, Mg, Na, S, Fe, Mn, Zn, and Cu concentrations were determined based on a 1:10 (w/v) soil-to-extraction solution ration (Tucker, 1992) using inductively coupled argon-plasma spectrophotometry (ICAP; CIROS CCD model, Spectro Analytical Instruments, MA). Concentrations of SOM, TC, TN, and all extractable nutrients were multiplied by the soil bulk density determined at the time of composite soil sampling and soil sampling depth to express each on a mass-per-area basis. The soil C:N ratio was also calculated by dividing the measured total soil C concentration by the measured total soil N concentration.

Precipitation Data

Daily precipitation was recorded on station near the study area. Daily precipitation data from the first soybean growing season of the study in 2002 to 2007 were used to calculate total and mean soybean season precipitation. The 30-yr mean monthly precipitation during the soybean season were obtained from NOAA (2002). Precipitation variability within soybean growing season in each year was determined by calculating the coefficient of variation (CV).

Economic Analysis

An economic analysis was performed to compare the relative profitability of alternative practices to traditional management practices. Residue management systems consisted of all 16 combinations of tillage, irrigation, burning, and residue level. Costs for each residue management system were estimated based on production budget estimates published by the University of Arkansas Cooperative Extension Services for double-crop soybean and wheat crops (UACES, 2008). Due to the small-plot nature of this study, no material or labor costs were assigned for burning. All costs for each of the six years included in this study were estimated using 2007 dollars to allow comparisons of each system over time. Each management systems' costs were generated using the direct expenses of inputs used and field operations performed as per the field management that occurred each year.

Historical five-year soybean and wheat grain prices received by producers for Arkansas from 2003 to 2007 (NASS-USDA, 2008b) were adjusted to real prices. The real prices were obtained by multiplying the historical price of each crop in each year to their respective calculated 2007=100 price index (NASS-USDA, 2008c). The 5-year average of real prices for soybean (\$254 Mg^{-1}) and wheat (\$111 Mg^{-1}) were used to calculate the gross revenue for both crops in each year to allow comparison of revenue over the 6-year period. Total revenue from each residue management system was calculated as a sum of wheat and soybean gross revenue obtained by multiplying the crop price by the respective mean crop yield for each year. The economic net return of each system in each year was calculated as the difference between the cost and revenue for each management system. The relative net return of each management was calculated as the percentage increase or decrease using the traditional management practice (i.e., irrigated-CT-burn-high residue level) as a baseline.

Sensitivity analysis was also performed to determine if economic performance of alternative management practices relative to the traditional practice under different crop and input price change scenarios. The first scenario was to increase crop prices based on wheat and soybean 2008/9 projected prices. The wheat price was increased by 125% (Vocke and Allen, 2008) and soybean price by 86% (Ash and Dohlman, 2008) relative to the base budget. In all crop-price increases in the first scenario, costs of each management system were maintained at 2007 dollar values. The second scenario was to increased input costs while maintaining 5-yr average real crop prices. Among inputs, only fertilizer and diesel fuel costs were considered, and increases in both costs were analyzed. The increase of fertilizer and diesel fuel prices were considered because in fact these are inputs where price increases have already been seen. The fertilizer price was increased by 136% for urea, 169% for diammonia phosphate (DAP) based on the free-on-board (FOB) price increase from 2007 to 2008 in the North America fertilizer market (The Market, 2008), and 6.6% for potash mixed-fertilizer (NASS-USDA, 2008c). The diesel fuel price was increased by 6.3% (NASS-USDA, 2008c), and it was assumed that the cost of disking, harrowing, seed drilling, furrow cultivation, and combine harvester would increase at the same percentage as diesel fuel. The third scenario was to increase both fertilizer and diesel fuel prices in addition to increasing both crop prices by 65% for wheat and 52% for soybean, as in 2007 crop prices (NASS-USDA, 2008a), and by 125 and 86% for wheat and soybean, respectively, as in the first scenario.

Greenhouse Experiment

A greenhouse, plant-less, soil incubation study was conducted in Fayetteville, AR to determine wheat residue decomposition effects on the potential to increase SOM in a common silt-loam soil of eastern Arkansas. The incubation study was initiated on 19 May 2007 and was conducted for 56 weeks through 5 June 2008 as a complement to the field experiment described in the previous section. A Calloway silt loam (fine silty mixed active thermic Glosaaquic Fraglossudalf (Web Soil Survey, 2008) collected at the 10-cm depth from the site of the field study was used for this experiment.

Experimental Design

Three factors, simulated tillage, residue level, and time were included in the greenhouse soil incubation study. Undrained 7-cm diameter by 5-cm deep incubation pots (ziplock storage containers) were used in this study. Tillage consisted of simulated conventional tillage (CT) and no-tillage (NT). Simulated CT was achieved by incorporating wheat residue in the soil and packing to a bulk density of 1.23 g cm^{-3}. Simulated NT was achieved by packing soil to a bulk density of 1.27 g cm^{-3} and applying residue on the surface of the pot. The two contrasting bulk densities were chosen based on the 2006 field experiment bulk densities for CT and NT. Residue amounts of 0, 3, and 6 g pot^{-1}, which were equivalent to 0, 5.5, 11.0 Mg residue ha^{-1} were applied to each pot. The varied residue levels were chosen based on the high-residue level achieved in 2006, which was then halved to obtain the low-residue level amount to be used in this greenhouse experiment. The residue added to the pots was obtained from harvest of non-burn, low- and high-residue level treatment combinations from the field experiment in

2006. Soil in pots were destructively sampled a total of six times (i.e., after 2, 4, 8, 17, 34, and 56 weeks). The duration and actual time of the incubation experiment was chosen to simulate one complete growing season of the wheat-soybean, double-crop rotation system. The experimental design was a 2 x 3 x 6 completely randomized factorial design that was replicated three times in one trial run of incubation.

Pot Preparation

Moist, soil from the top 10 cm of a 101-cm average diameter area was collected on 21 April 2007 from a single spot in a non-plot area under CT from the site of the field experiment at the Lon Mann Cotton Research Station, eastern Arkansas. The bulk soil was thoroughly mixed by hand. Six sub-samples were oven-dried at 70 ^{0}C for 48 h for determination of gravimetric moisture content. Wheat residue from above-ground wheat biomass was collected from the field experiment in June 2006, oven-dried at 55 ^{0}C for 3 days, and ground to pass through a 8-mm mesh sieve and stored in a closed bad at room temperature until used.

Approximately 285 and 300 g of moist soil, adjusted according to 18% (w/w) moisture content at the time of compacting, was weighed into incubation pots and compacted to the 200-cm^{-3} mark to achieve contrasting bulk densities of 1.23 and 1.27 g cm^{-3} for the simulated CT and NT treatment, respectively. Pre-weighed, ground wheat residue (i.e., 0, 3, and 6 g pot^{-1}) were randomly assigned to each tillage treatment. The residue was applied on the surface and uniformly spread after packing the soil to the desired bulk density in the NT treatment. For the CT treatment the residue was thoroughly mixed with the soil by hand before compacting to the desired bulk density.

Soil was compacted using a flat-surface object of equal surface area as the pot top surface (~ 7 cm in diameter) and uniformly pressed manually against the soil in the pot. All pot preparations were completed and transferred to the greenhouse on the same day to begin the incubation.

Experiment Management

Soil moisture was maintained as close to the non-irrigated field conditions as possible by irrigating the pots once a month to achieve approximately the frequency of 30-yr normal precipitation in eastern Arkansas. The irrigation amount was determined by weighing the pots after every 4 weeks and applying enough water to achieve a volumetric field moisture content of approximately 25% for the Calloway silt loam soil. Pots were loosely covered to reduce evaporation loss and were kept weed-free at all times by manually removing germinating weeds.

A datalogger (model 21X, Campbell Scientific Inc., Logan, UT) was installed in the greenhouse at the initiation of the incubation experiment to monitor air temperature and relative humidity using a Vaisala probe (model C5500, Campbell Scientific Inc.) for comparison with field weather conditions during the same time period at the field experiment site. The sensor continuously measured air temperature and relative humidity at 10-minutes intervals and output hourly averages.

Soil Sampling and Sample Preparations

At each sampling time, 18 pots were transferred to the laboratory. The contents of each pot were emptied on a clean sheet of paper and thoroughly mixed by hand. The un-decomposed surface residue was scrapped off the soil from the NT pots before mixing the soil sample. The soil sample was divided into two sub-samples. One sub-sample was oven-dried at 70 ^{0}C for 48 h for determination of gravimetric water content and subsequently ground and sieved to pass though 2-mm sieve for determination of soil TC and TN. The second sub-sample was kept moist and placed in plastic bags and stored at 4 ^{0}C in the refrigerator for determination of total microbial biomass C within 2 weeks of sampling.

Soil Analyses

Moist soil samples from each pot were analyzed for soil microbial biomass C using the modified chloroform-fumigation extraction method (Vance et al., 1987). Soil samples were divided into two sets. One set was fumigated with chloroform at 25 ^{0}C for 24 h and the other set was left unfumigated before extraction with 0.5M K_2SO_4 at a 1:5 soil:extraction-solution ratio. The extracted organic C concentration from both sets was determined using a Total Organic Carbon Analyzer (Model TOC-V, Shimadzu Scientific Instruments, Columbia, MD). Soil microbial biomass C was calculated as the difference in C between fumigated and unfumigated samples. The soil microbial biomass C was then adjusted to a dry-weight basis for reporting using the gravimetric moisture content at the time of sampling. Total soil C and N were determined by high-temperature combustion and SOM was determined by weight-loss-on-ignition as was done for soil samples collected from the field experiment. The C:N ratio was calculated using the measured total C and N concentrations.

Statistical Analyses

The effect of fertilizer N application on wheat residue level for each of the 6 years of this study was determined by analysis of variance (ANOVA) as a per split-strip plot design each year separately to show there were differences between low and high residue level. Means were separated using least significant difference (LSD) at $\alpha = 0.05$. The effects of 6 years of consistent management on soil physical and chemical properties and soybean and wheat grain yields were determined by analysis of covariance (ANCOVA). All soil properties and crop yields were analyzed as dependent variables, the experimental factors investigated (i.e., irrigation, tillage, burning, and residue level) were used as covariates, and year was used as an independent variable. An ANCOVA was performed separately from all other factors to investigate the effect of irrigation because the irrigation factor was identical to the blocking structure of the burning factor. Therefore, there were six replications for every tillage-burning-residue-level combination and three replications for every tillage-irrigation-burning-residue-level combination. All statistical analyses were performed using SAS (Version 9.1, SAS Institute, Cary, NC). Although the burn treatment was not imposed in 2005 and 2007, burning was included in the statistical analysis models because previous burning effects on soil quality could have manifested themselves in subsequent years. Data from the greenhouse incubation experiment were analyzed by ANOVA as per three-factor fixed factorial design.

RESULTS AND DISCUSSION

Field Experiment

Wheat Residue Level Differences

Differential N fertilization resulted in significant ($P < 0.05$) differences in surface wheat residue levels in 4 out of 6 years (Table 1). The amount of crop residue remaining on the soil surface at the time of soybean planting was significantly ($P < 0.05$) greater in high- than in the low-residue treatment in all years except for the first and third years of study (Table 1). Greater N availability increases biomass production that can potentially increase SOM if returned to the soil and is appropriately managed thereafter. These results also agree with Carter (2002) who reported increased C inputs due to increased crop biomass obtained through improved soil fertility and plant nutrition. Salinas-Garcia et al. (1997) attributed increased SOC accumulation under high-N fertilization due to greater stover production. Since significantly different residue levels were achieved in 4 out of 6 years of this study, evaluating the effect of residue level as an actual experimental treatment on soil properties and soybean yield is valid.

Soil Bulk Density

Soil bulk density is an important physical characteristic of the soil that affects plant root growth, water infiltration, gas exchange, and hence forms, solubilities and accessibilities of plant nutrients. Soil bulk density showed a significant ($P = 0.001$) quadratic trend over time, which differed ($P = 0.030$) between tillage treatments (Fig. 1). Soil bulk density initially increased in both tillage treatments, but at greater magnitude under NT (from 1.22 to 1.35 g cm^{-3}) than CT (1.19 to 1.26 g cm^{-3}) during the first 3 years of study. After the third year (i.e., 2005), soil bulk density decreased over time under both CT and NT, and the rate of change in soil bulk density changed as a function of time (Fig. 1). Soil bulk density trends over time were unaffected by the burning, residue-level, and irrigation treatments.

These results show that NT resulted in a greater increase in soil bulk density relative to the CT soon after adoption. However, continued NT beyond 3 years showed a numerically greater, but statistically similar decline in soil bulk density compared to CT, suggesting that NT has greater benefits on soil tilth in the long-term. Decreasing soil bulk density after 3 years of consistent management suggests that some equilibrium likely was attained within 3 years after changes in cropping system and management practices occurred. The increase in soil bulk density shortly after management practices and cropping-system change is likely due to the time period required for soil to build up humus, stabilize structure, and re-establish pores spaces before fully regenerating improved structure (Lampurlanes and Cantero-Martines, 2003). However, the increasing then decreasing trend over time for soil bulk density shows that the soil needs time for decomposition of wheat residue to occur before the advantage of increased SOM on soil physical properties is realized.

In contrast to this study, Lampurlanes and Cantero-Martines (2003) reported no significant tillage effect on changes in soil bulk density over time in the top 7 cm of loamy soils in Spain after 5 years of treatment, despite greater soil bulk density under NT than CT. However, similar to the present study, soil bulk density increased over time, and the trend differed between crop management systems, where soil bulk density increased 16% under continuous cropping, 11% under fallow, and 6% in a crop-fallow rotation (Lampurlanes and Cantero-Martines, 2003). Logsdon and Cambardella (2000) also reported no changes in soil bulk density after 4 years of NT in the top 30 cm, but increased soil bulk density under CT in the top 12 cm of a loamy soil in central Iowa. Comparing between CT and NT, Brye et al. (2006a) and Verkler (2007) reported no significant differences in soil bulk density after two and four years of tillage and residue management in the same plots as this study. Collectively, past studies generally suggest that anticipated increases in soil bulk density under NT compared to CT have not occurred in silt loam and loamy soils. None of the soil bulk densities measured in the top 10 cm throughout the first 6 years of this study exceeded 1.6 g cm^{-3} for silt loam soil which is considered the threshold at which root penetration begins to be limited (Fulton et al., 1996; Logsdon and Karlen, 2004).

Soil pH and EC

The soil solution condition measured in terms of pH and EC governs soil nutrient and water supply to plant and leaching potential. Changes in the soil solution can occur due to management practices and are temporally dependent which can affect short- and long-term soil productivity. Irrigation and burning (Fig 2; Fig. 3) resulted in significant differences in soil pH trends ($P = 0.001$) over time. Soil pH increased significantly ($P = 0.001$) under irrigation at the rate of 0.2 pH unit yr^{-1}. However, soil pH under dry-land conditions decreased at the rate of 0.04 pH unit yr^{-1}, which did not differ from zero, indicating no change in soil pH over time (Fig. 2). The initial soil pH differed ($P = 0.001$) between irrigation treatments, which was expected because the dry-land was initiated in the fourth year of the study (i.e., 2005), whereas the irrigated treatment had been imposed since 2002.

Averaged across all treatment combinations, soil pH increased over time at the same rate ($P = 0.001$) of 0.09 pH units yr^{-1} in the two burning treatments (Fig. 3). However, the y-intercept was significantly ($P = 0.003$) lower for the burn (pH = 6.7) than the no-burn treatment (pH = 6.9). These results show that on average, soil pH was consistently greater under no burn than burn in each year for the initial 6 years of this study. Although soil pH increased over time, the mean soil pH in the whole study area after 6 years of residue management (i.e., in 2007) was 7.3, which is slightly greater than the optimal pH range for soybean production (pH 5.8 to 7.0) in eastern Arkansas (UACES, 2000). Soil pH trends over time were unaffected by tillage and residue level treatments. It appears that lime dissolution rate was similar between tillage and residue level treatments.

The increase in soil pH may be attributed to progressive dissolution of the lime applied at the initiation of the study in 2001 to adjust soil pH for adequate soybean production. The greater increase in soil pH over time under irrigation than dry-land indicates that irrigation water quality can also affects soil pH. Increase in soil pH due to irrigation has been reported to be caused by high concentration of Ca- and Mg-bicarbonates in irrigation water (UACES, 2006). Irrigation water quality indicators measured showed that irrigation water used in the study area had high concentrations of Ca- and Mg- bicarbonates and high pH of 9.1 (Table 3). In addition, increased soil moisture availability due to irrigation might have increased dissolution of lime materials applied. Thus prolonged irrigation using alkaline water and improved moisture availability resulted in increased soil pH under irrigation but not under dry-land. Treder (2005) also reported a 0.55 pH increase after seven years of irrigation with alkaline water, but 0.95 pH decrease in non-irrigated in sandy loam soils of Poland.

Although soil pH did not differ statistically among all treatments in the first 4 years of wheat residue management, soil pH was numerically lower under burn than no burn (Cordell, 2004; Verkler, 2007). The regression analysis with burn and no burn as covariates showed that the initial numerical differences in soil pH between burning treatments were consistently maintained over the 6-yr study period. The consistent lower soil pH under burn than no-burn treatment may be due to greater mineralization of organic residues under burn and subsequent nitrification. Burning has been reported to cause high N mineralization and nitrification in grasslands of Australia (Romanya et al., 2001).

In contrary to soil pH, soil EC was unaffected by any field management practices in this study and decreased significantly ($P = 0.001$) over the 6-yr study duration at the rate of 0.012 dS m^{-1} yr^{-1}, (Fig. 4).

The decreasing soil EC over the 6-yr study period indicates little potential for the build up of salinity and total soluble salts. In this study, irrigation water had low EC, Na, and Cl^- concentration (Table 3), which explains no differences in EC between irrigation treatments. In contrast to this study, Nune et al. (2007) reported increased EC under irrigated relative to rain-fed soils due to gradual addition of electrolytes from irrigation water despite good water quality used in various soil Orders in Spain and Portugal. The decreasing in soil EC over time relative to the initiation of the study may be partly explained by the ability of winter wheat to scavenge and take up dissolved solutes, especially NO_3-N. Mikha et al. (2006) reported a positive correlation between soil EC and NO_3-N (r = 0.74). Therefore, although the decrease in EC over time in this non-saline soil is not agronomical important, it indicates an overall benefit of the wheat-soybean double-crop system to soil quality.

Soil Micronutrients

Extractable soil Fe, Zn, Mn, and Cu contents trends over time were unaffected by tillage, burning, and residue-level treatments. Extractable soil Cu trends over time were also unaffected by irrigation treatment. However, extractable soil Fe ($P = 0.001$), Mn ($P = 0.001$), and Zn ($P = 0.001$) (Fig. 5) contents trends over time differed by irrigation treatment. Extractable soil Fe and Mn contents increased ($P = 0.001$) over time at rates of 17.2 kg Fe ha^{-1} yr^{-1} and 10.7 kg Mn ha^{-1} yr^{-1}, respectively, under irrigation. However, under dry-land conditions extractable Fe and Mn did not change over time as the rate of Fe increase (0.5 kg Fe ha^{-1} yr^{-1}) and Mn decrease (6.9 kg Mn ha^{-1} yr^{-1}) did not differ from zero. In contrast, extractable soil Zn content differed ($P = 0.001$) between irrigation treatments, and showed an increase at the rate of 0.37 kg Zn ha^{-1} yr^{-1} over the 3-yr period under dry-land conditions, but did not change over time under irrigation (Fig. 5).

The increasing extractable soil Fe and Mn under irrigation and no change under dry-land conditions with the opposite occurring for extractable Zn, may be associated with redox properties of Fe and Mn compared to those of Zn (Fig. 5). Iron and Mn undergo biochemical-redox reactions depending on the status of the soil redox potential (Sposito, 1989; Mullen, 2005). Under irrigation there is likely a greater frequency of at least localized reducing conditions due to greater potential for small pockets of saturated pores than under dry-land conditions. This would favor reduction of Fe and Mn, which increases their solubility in soils (Mullen, 2005). Although soluble forms of Fe and Mn are susceptible to leaching losses, it appears that there was less drainage out of the plow layer due to a plow pan (Amuri and Brye, 2008) that minimized Fe and Mn leaching. Thus, evaporation and increase of exchangeable forms of Fe and Mn due to weathering of Fe and Mn minerals caused by alternate reduction and oxidation reaction might have increased extractable Fe and Mn in the soil surface under irrigation. Alternate bacterial-mediated oxidation and reduction of Fe and Mn has been reported to increase water soluble and exchangeable Fe and Mn relative to well-crystallized Fe- and Mn- oxide minerals (Berghelin et al., 2006), which results in increased extractable Fe and Mn contents. Increasing extractable Zn, a relatively immobile micronutrient, may be associated to reduced Zn uptake by crops under dry-land conditions, hence less export out of the field from harvesting relative to natural release of Zn in the soil system. Throughout duration of the study all measured soil micronutrients (i.e., Fe, Mn, Cu, and Zn) were in the adequate range for soybean production in eastern Arkansas (UACES, 2000).

Soil Macronutrients

Similar to soil micronutrients, the effects of alternative residue management practices and irrigation on extractable soil macronutrients over time were variable. Changes in extractable soil Ca contents over time did not differ among tillage, burning, and residue-level treatments, and increased over time at a rate of 26.4 kg Ca ha^{-1} yr^{-1} (P = 0.010; Fig. 4). Extractable soil Mg contents increased at the rate of 36.7 kg Mg ha^{-1} yr^{-1}

across tillage, burning, and residue-level treatments (Fig. 3). However, the y-intercept for the regression characterizing the extractable soil Mg content trend over time was greater ($P = 0.001$) for the burn than the no-burn treatments. In contrast to all other field treatments, extractable Mg contents increased at different rates ($P = 0.001$) between irrigation treatments (Fig.2). Under irrigation, extractable Mg contents increased at a greater rate (55.1 kg Mg ha^{-1} yr^{-1}) than under dry-land conditions (36.6 kg Mg ha^{-1} yr^{-1}).

Similar to soil pH, the increasing extractable soil Ca and Mg contents over time were also expected due to progressive dissolution of lime applied at the beginning of the study. In addition, increase of extractable soil Mg at a greater rate under irrigation than dry-land condition can be explained as due to continuous addition of Mg from irrigation water, as shown by high Mg concentration in irrigation water used in this study (Table 3). These results also suggest that there was greater release of Mg due to burning than non-burning (Fig. 3). A high release of Mg due to burning was also reported Sherman et al. (2005). Similar rate of change in extractable Mg contents between burning and no burning is supported by the similar extractable Mg content reported in two 2-yr studies from 2002 to 2003 by Brye et al. (2006a) and from 2005 to 2006 by Verkler (2007). Similarly, Murphy et al. (2006) reported no differences in exchangeable Mg concentration between burn and no burn after 1 year of treatment. However, comparing before and after burning, exchangeable soil Mg concentration was lower in post-burn than in pre-burn samples in both burn and unburned treatments suggesting temporal variation of exchangeable soil Mg content due to management changes (Murphy et al., 2006).

Extractable soil Na and K contents had no significant trend over time after 6 years of consistent management in any tillage, burning, as residue-level treatment combination. However, regression analysis with irrigation as covariate showed a significant linear trend over time for extractable soil K content ($P = 0.004$; Fig.2), and differed ($P = 0.001$) between irrigation treatments. Extractable soil K content decreased linearly at the rate of 4.3 kg K ha^{-1} yr^{-1} under irrigation, but increased under dry-land conditions at the rate of 9.6 kg K ha^{-1} yr^{-1}. These results suggest that irrigation depletes more K from the top 10 cm of soil due to increased K absorption by crops and potential leaching below 10 cm. The lack of a significant trend over time for extractable Na and K due to tillage, burning, and/or residue level indicates that extractable Na and K contents were maintained over 6-yr study period at a level similar to those at the initiation of the study.

Similar to EC trends, extractable soil Na content over time indicates little potential for sodium build up. Potassium was applied in 2005 to all plots to replenish an average low soil-test-K level, which was less than adequate for optimal soybean production in 2004. The applied K fertilizer increased soil K content in year 5 and 6 of study (i.e., 2006 and 2007, respectively) to the levels similar to those in first 2 years of study (i.e., 2002 and 2003; Fig 2). Decreased soil-test-K under irrigation and increased soil-test K under dry-land conditions indicates that irrigation likely increased available K for plant uptake and removal through grain harvesting and/or increased K leaching losses. Both plant uptake and removal and leaching likely resulted in greater removal of K from the top 10 cm of soil. In contrast to results from this study, Russell et al. (2006) reported low exchangeable soil K under N-fertilization than under non-fertilized control in fine-loamy soils of Iowa. Black (1973) reported no significant effect of N and P fertilizer application rate to wheat on exchangeable soil K in a sandy-loam soil in Montana. However, exchangeable soil K was greater when wheat residue was returned to the soil than when residue was removed suggesting that crop residue removal through burning or baling results in reduced soil fertility (Black, 1973). Rhoton (2000) compared tillage treatments and reported greater soil K content under NT than CT in the top 2.5 cm in a wheat-soybean double-crop system on a silt loam soil in Mississippi. In addition, Du Preez et al. (2001) reported increased soil K content in the top 25 cm due to wheat residue burning in a continuous wheat-fallow system in South Africa. Different from Black (1973), Du-Preez et al. (2001), and Russel et al. (2006) where K fertilizer was not applied, in Rhoton et al. (2000) and in the current study, K fertilizer was applied to maintain adequate soil-test K for crop production. However, none of the above studies listed previously investigated changes of exchangeable cations over time.

Similar to soil EC, but in contrast to soil Ca, extractable soil P content decreased ($P = 0.001$) over time. Extractable soil P content trends over time differed significantly ($P < 0.05$) between tillage (Fig. 1), burning (Fig. 3), and residue-level (Fig. 6) treatments. Averaged across all other treatments extractable soil P decreased at the similar ($P = 0.001$) rate of 2.92 kg P ha^{-1} yr^{-1} between burn treatments (Fig. 3). However, the overall soil P loss over time was greater under burning than under no burning as illustrated by a significantly ($P = 0.002$) lower y-intercept for extractable soil P over time in the burn compared to in the no-burn treatment. Extractable soil P decreased at a greater rate ($P = 0.039$) under NT (-3.3 kg P ha^{-1} yr^{-1}) than CT (-2.6 kg P ha^{-1} yr^{-1}) (Fig.1) and at a greater rate ($P = 0.005$) under the high- (3.4 kg P ha^{-1} yr^{-1}) than under the low-residue treatment

(2.4 kg P ha^{-1} yr^{-1}) (Fig. 6). As indicated by the y-intercept of the regressions, all tillage and residue level treatments had similar initial P content of 56.3 kg P ha^{-1}.

These results show that P availability was likely improved under NT and the high-residue level, hence greater P removal from the soil by the soybean and wheat crops. The improved P availability may be associated with greater SOC under NT and a high-residue level. Similar to the results of this study, Al-Kaisi and Kwaw-Mensah (2007) reported greater grain P uptake due to N fertilization. However, these results differ from Du Preez et al. (2001) who reported greater soil P accumulation under reduced tillage and burning than under CT and without burning wheat straw in a Planthosol in South Africa. Rhoton (2000) reported a positive correlation between extractable soil P concentration and SOM. In this study, extractable soil P content decreased over time in all treatments despite an increase in SOM over time in the same reside treatments (to be discussed below). The lack of differences in extractable soil P content trends between irrigated and dry-land soybean could be due to relatively immobility of P in soils that minimizes direct impact of added irrigation water on soil P under non-flooded conditions. Therefore, the greater decrease in extractable soil P over time due to NT, burning and a high-residue level could be explained by a combination of export through harvested grain in greater P uptake by soybean under NT, excessive P losses during and after burning, and great P uptake by wheat facilitated by the added N fertilizer. Phosphorus loss after burning may be due to removal of ashes with mineralized forms of P through wind and water erosion early in the season before soybean canopy development. Extractable soil S did not vary over time and was unaffected by tillage, burning, residue-level or irrigation treatments. Extractable soil S averaged 17.4 kg S ha^{-1} in the top 10 cm across all treatments over the 6-yr study period.

Soil Organic Matter and Total Soil C and N

Soil organic matter content in the top 10 cm were unaffected by tillage, burning, and residue level over the first 6 years following management-practice conversion from continuous, cultivated soybean to the wheat-soybean double-crop production system (Fig. 4). However, averaged across all treatments, SOM increased over time at a rate of 0.097 kg m^{-2} yr^{-1} ($P = 0.001$). Adding wheat as a second, relatively large biomass producing-crop to the annual rotation resulted in increased SOM in the top 10 cm over the first 6 years of this study. The increase in SOM over time indicates an overall benefit of the double-crop production system at improving SOM in agricultural soils. Liebig et al. (2004) also reported greater SOM in an intensive cropping-system rotation than in a continuous monoculture production system with a fallow period. Similarly, Carter (2002) reported increases in SOM with increases in C input level through an increase in primary production, plant nutrition, organic amendments, and an increase in the proportion of residue returned to the soil with low SOM levels. A review of SOC sequestration studies in the southeastern USA reported a SOC sequestration rate of 0.022 kg m^{-2} yr^{-1} with an increase in cropping system complexity relative to a monocropping system and regardless of tillage (Franzluebbers, 2005). Dallal et al. (2003) showed an exponential decrease in SOC concentration with increasing in time of cultivation in continuous cereal cropping systems of northern Australia. Therefore, double-crop systems with NT or minimum soil disturbance have the potential to increase SOM in agricultural soils.

Similar to SOM, changes of soil TN over time were unaffected by imposed treatments, but unlike SOM, soil TN showed no significant trend over time. The soil TN in this study fluctuated from year to year over the 6 years of the field study. The lack of significant changes of soil TN over time may be associated with ability of winter wheat to absorb residual N and the wide C:N ratio of the wheat residue returned to the soil (C:N 55). Similar to the present study Salina-Garcia et al. (1997) reported no effect of N fertilizer rate on soil TN after 16 years of N fertilization and tillage treatments in sandy-clay-loam soil in Texas under a corn-cotton rotation. However, soil TN was greater in NT than in an intensively tilled treatment suggesting that placement of crop residues have a greater contribution to changes in the active soil N pool of SOM than N fertilization (Salina-Garcia et al., 1997). A comprehensive analysis of the effects of fire on N cycling by revealed that burning increased the amount of soil ammonium and nitrate because of rapid organic residue mineralization due to heat (Wan et al., 2001).

Soil total C content changes over time were affected ($P < 0.05$) by irrigation (Fig. 2), burning (Fig. 3), and residue-level treatment (Fig. 6). Six years of irrigation resulted in a significantly greater ($P = 0.001$) increase in soil TC (0.11 kg C m^{-2} yr^{-1}) than 3 years of dry-land soybean production (0.044 kg C ha^{-1} yr^{-1}) (Fig. 2). The rate of increase in soil TC was also significantly ($P = 0.008$) greater under no burn (0.077 kg C m^{-2} yr^{-1}) than under burn (0.051 kg C m^{-2} yr^{-1}; Fig. 3). The high residue level also had a significant ($P = 0.047$) greater rate of soil TC increase (0.073 kg C m^{-2} yr^{-1}) than the low residue level

(0.054 kg C m^{-2} yr^{-1}) (Fig.6). The mean rate of soil C storage observed in both tillage treatments in the first 6 years of this study was 0.064 kg C m^{-2} yr^{-1}.

These results show there is potential for soil C accumulation in the Mississippi River Delta region with the adoption of the wheat-soybean double-crop system. Irrigation resulted in a greater soil TC sequestration rate than dry-land soybean, possibly because of a slower rate of organic residue decomposition due to reduced oxygen diffusion in moist soil caused by a greater proportion of pores filled with water and greater soybean biomass production under irrigated compared to dry-land condition. The greater rates of soil TC increase under the no burn and high-residue-level than under the burn and low-residue-level treatments, despite a similar rate of SOM increase in this study, shows that there is also a greater potential for soil C accumulation when residue is left unburned and when greater residue mass is produced. The low rate of soil TC storage under burning may be due to the substantial loss of biomass C during combustion. Greater increase of TC in the high rate than in the low-residue-level treatment is also supported by lower surface CO_2 flux under the high- than under the low-residue-level treatment measured in the same plots as this study in 2002 and 2003 (Brye et al., 2006b). In contrast to these results, Grandy et al. (2006) reported greater accumulation of SOC under NT by 0.026 kg C m^{-2} yr^{-1} compared to intensive tillage in the top 5 cm of sandy-loam soils of southwestern Michigan. In this study, CT consisted of disking as opposed to in Grandy et al. (2006) where CT consisted of moldboard tillage followed by disking. Therefore, depth of residue burial and the extent of soil disturbance explains much of the difference in near-surface SOC storage rates between NT and tilled soils.

It has been established that greater SOC sequestration is associated with a lower rate of surface CO_2 efflux due to reduced soil disturbance, despite similar labile organic pool in soils that are both tilled and untilled (Franzluebbers et al., 1998). Considering that the rate of soil C storage over time was similar under both tillage treatments (0.064 kg C m^{-2} yr^{-1}), the greater soil C storage rate under no-burn than under burn and under the high- than the low-residue-level treatments suggests that refraining from burning crop residues and increased biomass production through improved soil fertility may result in greater soil C sequestration potential in arable soils than the simple conversion from CT to NT. Godsey et al. (2006) reported 18 to 23% greater SOC concentration under NT than under CT in the top 15 cm of a silt loam soil in Kansas. Diaz-Ravina et al. (2005) reported 9.9 Mg C ha^{-1} more under NT relative to CT, and greater TN under NT than CT in the top 5 cm of a sandy-loam soil in temperate humid zone of Spain after 8 yr of NT. No-tillage also resulted in 31 kg C m^{-2} more C than CT in a sandy-loam soil in southwestern Michigan (Grandy et al., 2006). Different results could be associated with soil textural differences. The rate of C loss is generally greater in coarse-textured soils under CT than in fine-textured soils under similar tillage treatment. Hao and Kravchenko (2007) reported increase of TC with increase in clay and silt content, and decrease in TC with increase in sand content, and that sand and silt content has been reported to explain > 40% of the variability in TC under NT compared to the variability in TC under CT.

Similar to extractable soil S, the soil C:N ratio did not vary over time and was unaffected by any of the residue management or irrigation treatments. However, despite the soil C:N ratio being unaffected by burning, SOM quality has likely changed somewhat over time since annual burning has added a much more recalcitrant C fraction back to the soil in the form of incompletely combusted organic residue (black carbon) compared to the relatively labile C fraction being added in the only slightly decomposed residue (Kaal et al., 2008). This is because burning has been reported to cause rearrangements of C and N forms in organic residues, and hence synthesis of new structures that are resistant to decomposition (Gonzalez-Perez et al., 2004; Almendros et al., 2003).

The mean rate of C storage observed across all treatment combinations in the first 6 years of this study was 0.064 kg C m^{-2} yr^{-1}, which is only slightly greater than the global mean soil C storage rate of 0.057 kg C m^{-2} yr^{-1} reported by West and Post (2002) for the conversion from CT to NT. Another study by Franzluebbers et al. (1998) expressing C sequestration as a proportion of SOC per unit C input, reported 22% greater SOC storage under NT compared to 9% SOC storage under CT regardless of cropping intensity after 9 years. However, under CT, SOC storage increased with increasing cropping intensity in the warm climate of south-central Texas (Franzluebbers et al., 1998). These studies and the current study show that reducing soil disturbances, high-intensity cropping systems, such as double-cropping and retaining crop residues have great potential to sequester C in soils of the warm southern regions of US in both irrigated and dry-land systems.

Soybean and Wheat Yield

The trend of soybean yield over time did not differ among all treatments and showed a significant ($P = 0.001$) quadratic relationship with time with a varying rate of change over time (Fig. 4). Soybean yield declined during the first 3 years, then increased during the subsequent 3 years (Fig. 4). The soybean yield increase after the third year may be due to the soil attaining some equilibrium after the change in cropping system from continuous soybean to wheat-soybean double-crop production system. Improved soil conditions due to attainment of SOM advantage on soil physical properties after 3 years are also supported by the soil bulk density trend over time discussed previously (Fig. 1). Both the soil bulk density and soybean yield trends over time show the benefit of SOM additions in improving soil physical conditions and subsequent crop yield. Similar to this study, Grandy et al. (2006) reported no soybean, corn, or wheat yield loss from 14 years of NT when compared to CT in sandy-loam soil of southwestern Michigan. These results shows that yield variability among years are comparable between tillage treatments.

The year-to-year soybean yield differences are often due to growing season weather variability and possibly change of soybean cultivars. A study by Andresen et al. (2001) using crop simulation models showed that water availability and air temperature are important causes of year-to-year crop yield variability in the Great Lakes region of the US. Another study by Kravchenko et al. (2005) revealed that yield variability was low in years with above-average precipitation in any cropping system. Smith et al. (2007) also reported less annual soybean yield variability under NT than CT when growing-season precipitation was above the 30-yr mean precipitation. Similar to Smith et al. (2007), changes in soybean yield over time in this study were similar between NT and CT despite the mean growing-season precipitation being below the 30-yr mean in all 6 years (Table 2). Thus, soybean yield trends in this study were apparently unrelated to mean annual growing-season as total annual precipitation. The 2 years with the lowest soybean yields (i.e., 2004 and 2005) had the greatest precipitation variability (> 80%) with the lowest monthly precipitation in August and September corresponding to about the R3 to R6 (2004) and in June corresponding to about the VE to V3 (2005) soybean growth stages. Change in soybean cultivars with slightly different maturity groups and possibly yield potential might have contributed to differences in yields among years with similar weather conditions.

The 6-yr yield and precipitation trends show that the distribution of rainfall throughout the growing season plays a greater role in determining yield than total and mean growing-season rainfall. It appears that the confounded interaction of climatic conditions, pest pressure, and soil physical properties (Kravchenko et al., 2005) may have caused year-to-year yield variations in this study regardless of management practices. The variations likely occurred because the whole study area received similar soybean pest control and fertility management, and there were no visual observed disease, insect, or weed pressure in any treatment combination throughout the study. Therefore, it appears that NT has a similar potential to increase soybean yield in wheat-soybean double crop system as CT.

In contrast to soybean, wheat yields had no significant trend over time and fluctuated from year to year and averaged 2.44 Mg ha^{-1} across all plots and years. Similar to these results, Sanford (1982) reported no effect of tillage-straw management practices on wheat yield in wheat-soybean double-crop system in silty-clay soil in Mississippi.

Economic Returns for Alternative Management Practices

Net returns varied among treatment combinations as well as from year to year due to variations in crop growing conditions. Soybean and wheat growing conditions were poor during 3 out of the 6 years of this study and resulted in reduced crop yields. Both wheat and soybean growing conditions were adequate in 2002, 2003, and 2006. Over the initial 6 years of the wheat-soybean double-crop rotation, net returns were greatest in the first year of study (2002) in all treatment combinations ranging from $ 565 ha^{-1} obtained under the irrigated-CT-no-burn-high-residue combination to $ 864 ha^{-1} obtained under the irrigated CT-burn-high-residue level combination (i.e., the traditional practice). In 2003, all treatment combinations had positive net returns and treatment combinations with NT had greater net returns than treatments combinations with CT (Fig. 7). All treatment combinations produced a net loss in 2004 due to the lowest soybean yields in the 6 years of study that were the result of possibly delayed planting (Cordell et al., 2006).

After the introduction of the irrigation treatment in 2005, net returns continued to fluctuate and differ among treatment combinations under both irrigated and dry-land conditions. In 2005, net returns in all treatment combinations were negative for both irrigated and dry-land conditions (Fig. 8). In 2005 there was no wheat income. Soybean was drilled twice due to poor stand establishment, thereby increasing the soybean cost of production resulting in net loss in all treatment combinations in 2005. In 2006, all treatment combinations with irrigation had positive net returns. The treatment combinations with dry-land conditions had negative net returns except for those combinations with a high-residue level (Fig. 8). In 2007, all treatment combinations with

NT produced positive net returns, except for the NT-burn-low-residue combination under dry-land conditions which had a negative net return of \$-10 ha^{-1}. In contrast, all CT treatments produced negative net returns ranging from -68 to \$-164 ha^{-1} regardless of residue level and irrigation in 2007. In 2007, wheat yields were low because of poor wheat growth conditions caused by late frost at approximately the jointing stage of wheat growth that resulted in reduced gross income from wheat.

These results show that fluctuation of net returns from year to year is attributed to different management practices and their resulting yields. In good years, the NT-burn combination with irrigation maintained greatest net returns of all treatment combinations regardless of residue level. During two out of three years with poor crop growth conditions, all alternative management practices with NT-burn treatment combinations maintained the smallest net losses compared to treatment combinations with CT. In addition, in years when all treatment combinations had negative net returns (i.e., 2004 and 2005), NT produced 72% less negative net returns compared to CT. The general greater net return or less net loss under NT in this study was due to reduced costs under NT compared to CT. The 6-year average CT costs were 18% greater than NT due to extra machinery operations and fuel costs under CT compared to under NT. Similar to the current results, Ribera et al. (2004) reported 33% less net negative returns in wheat-soybean double crop system with NT management compared to CT in a silty-clay-loam soil in Texas and concluded NT was the most preferred management option. Meyer-Aurich et al. (2006) also reported increased profitability under reduced tillage compared to intensive tillage due to a combination of increased yield and reduced costs of soybean production. Over 6 years of this study, soybean and wheat yields did not differ significantly between treatment combinations (Fig. 4). These results suggest that alternative management practices with low production costs are more profitable than high-cost practices (i.e., multiple tillage operations) that cannot be justified by the revenue produced when there are slightly reduced yields under the high-cost management practices.

In this study irrigation did not maintain positive net returns for all treatment combinations in all years. Irrigation resulted in negative net returns during years with poor crop growth conditions because of reduced soybean yield that was not sufficient to offset high irrigation costs. Even though production costs for dry-land treatments were 30 to 38% below those for irrigated treatments in 2005 through 2007, net returns were still lower for dry-land treatment due to poor soybean yields and thus lower revenues than under irrigated treatments. In contrast, Parsch et al. (2001) reported relatively stable net positive returns over 6 years for irrigation compared to dry-land soybean production in clay soils in eastern Arkansas. However, under adequate and well-distributed rainfall, dry-land soybean production had greater net returns than under irrigated soybean systems (Parsch et al., 2001).

These results show that NT and a high-residue level have great potential to improve and maintain profitability across years under both irrigated and dry-land conditions. In contrast to this study, Parsch et al. (2001) reported greater net returns under CT than NT due to high variable costs as a result of greater demand of herbicides under NT. In this study, herbicide was applied for weed control uniformly under all treatment combinations. Similar to this study, Ribera et al. (2004) reported a lower overall cost per hectare under NT than CT, despite greater costs of herbicides under NT, and concluded that management systems with greatest net return per hectare or least negative net return per hectare would be most preferred. Thus, in this study, the irrigated-NT-burn combination at either residue level is the most preferred combination among the alternative management systems evaluated.

Comparison of Economic Performance

Comparison of economic returns among alternative residue management practices relative to the traditional practice over time enables evaluation of the more sustainable option. In the first year of study, the traditional practice (irrigated-CT-burn-high-residue) was equally as profitable as the irrigated-NT-burn-low-residue level treatment combination (Table 4). In the second year (2003), all alternative management practices were 1 to 79% more profitable than the traditional practice, except for the irrigated-CT-no-burn-high-residue (-28%) and CT-no-burn-low-residue (-30%) combinations. In the third year (2004), all management practices were 11 to 60% more profitable than the traditional practice, except for CT-no-burn-high-residue, despite all having net losses. The NT-burn regardless of residue level had the greatest percent profitability relative to the traditional practice in 2003 and 2004. Therefore, under all irrigated treatment combinations, the NT-burn combination at any residue level had the best economic performance of all treatment combinations relative to the traditional practice.

From the fourth to the sixth year of the study, there were 16 treatment combinations after the introduction of irrigated and dry-land treatments. In the fourth year (2005) all treatment combinations were less profitable than the traditional practice, except for the irrigated-NT-burn-low-residue combination, which was 21% more profitable than the traditional practice (Table 4). In 2006, all alternative management practices were 5 to 119% less profitable compared to the traditional practice, except for the irrigated-NT-burn-high-residue combination, which was 44% more profitable relative to the traditional practice. In addition, the most unprofitable practice relative to the traditional practice was the dry-land-CT-burn-low-residue combination. In 2007, all treatment combinations with NT were more profitable than the traditional practice regardless of burning, residue-level, and irrigation. However, dry-land conditions in combination with NT-low-residue at either burning were less profitable than the traditional practice. Reduced wheat income under low N rate and soybean income under dry-land condition, resulted in less percent net return under dry-land-NT-low-residue combination than traditional practice despite low cost in these treatment combinations.

In contrast, all alternative management practices with CT were 355 to 716% less profitable than traditional practice in 2007 (Table 4). Largest profitability differences between treatment combinations with CT relative to traditional practice in 2007 of all 6 years was because of greater fuel and machinery operation costs in 2007 than in all other years. In 2007 the field was disked four times due to excessive drought caused by rye infestation in spring 2007. Increased tillage operation cost in combination with low wheat income, and lower soybean yield than traditional practice resulted in lesser percent profitability of all treatment combinations with CT relative to traditional practice in 2007 than in all other years. Thus, increasing number of tillage machinery passes during seedbed preparation did not improve soybean yield, but reduced profitability of CT.

These results show that the irrigated-NT treatment combinations, regardless of burning and residue level, had greater percent profitability relative to the traditional practice in 3 out of 6 years of this study. In addition, the irrigated-NT-burn treatment combination maintained a consistently equal or greater profitability relative to the traditional practice in all 6 years. Thus, it appears that NT with or without residue burning would ensure greater profitability or less loss than the traditional practice during both good and poor crop growing conditions. However, burning had less advantage in improving SOM, hence may not sustain long-term productivity of Mississippi River Delta region soils. If the disadvantage of burning was considered, burning will invariably reduce profitability in the long-term. The irrigated treatment combinations with NT-no-burn at any residue level ranked third in all years in maintaining consistent greater percent profitability or least loss relative to the traditional practice. The management practices with the least percent profitability relative to the traditional practice was treatment combinations with CT regardless of burning, residue levels or irrigation and CT in combination with dry-land conditions in years where irrigation treatments were included (2005 to 2007).

Similar to this study, Sanchez-Giron et al. (2007) also reported 12% greater gross and net margins in dry-land NT than moldboard plowing in a wheat-forage legume [vetch (*Vicia sativa* L.) or peas (*Pisum sativum* L.)] rotation in a loamy soil in Spain, and that NT maintained greatest profit per unit area compared to intensive tillage. In the silt-loam soil of the Delta region of eastern Arkansas the moisture conservation (Verkler et al., 2008) and reduced costs associated with NT allow NT practice to be more profitable than CT under dry-land soybean production. These results show that alternative residue management practices with NT will provide the best economic performance.

Sensitivity Analysis

Increasing wheat and soybean prices, either each separately or both prices together, resulted in increased net revenue (Table 5). Increasing the wheat price to $250 Mg^{-1} (125% increase from the base price) increased net returns relative to the real price by 33 to 4248% in all years except in 2005, where net returns did not change because there was no wheat yield. However, increasing wheat price did not change the performance of alternative management practices relative to the traditional practice in 2004, 2005, and 2007, where treatment combinations with NT had a greater percent profitability relative to the traditional practice. In the first year (2002), increasing the wheat price resulted in the traditional practice being the most profitable of all management practice combinations. In 2003, only the NT-burn combination was more profitable than the traditional practice. In 2006, the irrigated-no-burn-high-residue-level combination at either tillage treatment became more profitable than the traditional practice after increasing wheat price by 125%.

Similar to increasing the wheat price, increasing soybean price by 86% increased net returns of all management systems in all years, and the increase was 41% greater than net return increase resulted from increasing wheat price by 125% (Table 5). In addition, increasing the soybean price by 86% caused the irrigated-burn treatment combination to produce positive net returns regardless of tillage treatment, despite the absence of a wheat crop in 2005. The soybean price increase improved the performance of alternative management practices with irrigated-NT in 2003, 2004, and 2007 relative to the traditional practice, and improved the performance of the traditional practice in the rest of years relative to the base budget. Thus, generally under increased prices of both crops and low input costs, the traditional practice and the alternative practices with the combination of irrigation and NT performed best.

In contrast to increasing crop prices, increasing fertilizer costs by 136% resulted in the net return changes ranged from 241% reduction to no change of net return (Table 5). Increasing fertilizer costs resulted in a greater percent profitability for the NT-burn-low-residue level treatment combination in 2002 relative to the traditional practice. The performance rankings of alternative practices relative to the traditional practice were similar in all years to that in the base budget. Likewise, increasing diesel fuel costs by 6.3% without increasing crop prices reduced the net income by 2 to 130%, but did not change the performance of alternative management practices relative to the base budget. Similar to this study, Skalsky et al. (2008) reported a 37 and 72% decrease in profit of major cropping systems in Wyoming when fuel prices were increased by 100 and 200%, respectively.

Simultaneously increasing both fertilizer and fuel costs resulted in 13 to 22% greater net return reduction compared to increasing costs of either fertilizer or diesel fuel separately. However, increasing costs of both fertilizer and diesel fuel had similar impact as increasing fertilizer costs alone on the percent profitability of alternative management practices relative to the traditional practice. Therefore, management practices with NT will likely be more profitable than the traditional CT practice if the fertilizer and diesel costs continue to increase even soon after management practice change.

A combined increase in fertilizer and fuel prices with 65 and 52% price increases for wheat and soybean, respectively, to 2007 crop prices resulted in increased net returns by 265% over six years. In addition, under the relatively low crop price increase, 65 and

52% increase for wheat and soybean prices, respectively, the traditional practice was as equally profitable as the irrigated-CT-burn-low-residue level combination in 2003, and as the irrigated-NT-burn-low-residue level combination in 2005.

Increasing crop prices by 125 and 86% for wheat and soybean, respectively, along with fertilizer and diesel fuel price, increased net returns by 28 to 6934% (Table 5), which was 224% more than the net return increase due to 2007 crop prices relative to the base budget. These results are similar to projections from agricultural and biofuel markets report that increasing wheat and soybean prices will cause sharp increases in cash receipts that will increase producers' net returns to offset the rise in production expenses (FAPRI, 2008). However, in this study, the profitability of all management practices relative to the traditional system did not change in 3 out of 6 years (Table 5). In contrast from the base budget, the traditional practice out-performed all alternative management practice in 2002, but was less profitable than all treatment combinations with irrigation and NT combinations in 2003, 2004, and 2007.

These results show that the sensitivity of profitability of management practices to changes in output and input prices fluctuates among years and management practices. High crop prices improved the economic performance of the traditional practice, but only in the first year of this study regardless of changes in costs. In all other years, irrigation and NT in combination with either burn or no burn was consistently more profitable and stable than the traditional practice under all price-change scenarios. Stability of NT treatment combinations with changes in price scenarios can be explained by the relatively low input requirements of NT and similar yields to the traditional practice. Similar to these results, Meyer-Aurich et al. (2006) also reported a greater reduction of profitability of moldboard plow compared to chisel plow, despite small differences in energy requirements between the tillage practices when energy prices increased by 50%. Meyer-Aurich et al. (2006) also reported a greater impact of increased energy prices on cropping system with high energy requirements, such as continuous corn, than in low-energy requirement systems such as in rotations with wheat and soybean. Skalsky et al. (2008) reported 40% less decline in producers' profits with increases in fuel and fertilizer prices by 200% when growing high-price crops, less N fertilizer requirements, and few field operations are included in the cropping system in Wyoming than when growing low-price crops with greater fertilizer and field operations. The current and the previous studies show that producers can maintain profitability despite rising input prices, not only when crop prices increase, but also when adopting management practices with less inputs, especially fertilizer, and field operation requirements that maintain adequate crop yields.

Greenhouse Experiment

Soil Microbial Biomass C

Soil microbial biomass plays a central role in decomposition of organic residues and ultimately changes in SOM. The average SMB C before initiation of the incubation (day 0) was 228 mg C kg^{-1} soil. The total soil microbial biomass C differed over time (P = 0.001), between simulated tillage treatments (P = 0.001), and among residue levels (P = 0.030) (Table 6). The soil microbial biomass C sharply increased during the first 8 weeks, followed by a decline to 172 mg C kg^{-1} soil, 22% below the initial level between 17 and 34 weeks after incubation (Fig 9). At 56 wk of incubation, SMB C increased to 243 mg C kg^{-1} soil (Fig. 9). The increase and decrease of SMB C over the 56-wk incubation time coincided with increasing and decreasing air temperatures during the soil incubation experiment (Fig. 10).

The changes in SMB C over time showed that the population of microorganisms was likely affected by the changes in air temperature. Follet et al. (2007) reported a decrease in microbial biomass C with time due to possible decreased substrate amounts, but CO_2-C evolution increased by 50% with increases in temperature by 3 to 6.5 ^{0}C in a long-term incubation without addition of substrate, which indicates the sensitivity of microbial activity to temperature. Another study by Carter and Melle (1992) reported greater microbial biomass C during spring than autumn and winter seasons in a sandy-clay-loam soil under field conditions in northeastern Australia indicating that even in presence of sufficient amount of organic substrate, SMB C is sensitive to temperature.

Soil microbial biomass C was greater ($P < 0.05$) when wheat residue was incorporated in the CT treatment (330 mg C kg^{-1} soil) than when left on the surface in the NT treatment (219 mg C kg^{-1} soil). In addition, the high-residue treatment had greater ($P < 0.05$) SMB C (309 mg C kg^{-1} soil) than no-residue treatment (239 mg C kg^{-1} soil), and there was no differences between the no-residue and the low-residue treatment (276 mg C kg^{-1} soil).

These results indicate that increased soil-residue contact through residue incorporation increased the microbial population due to improved residue availability for microbial attack. Greater SMB C under CT than NT in just over 1-year period under greenhouse conditions indicates the slow microbial decomposition process under NT that results in reduced loss of SOM shortly after conversion to NT. However, in contrast to this study, Govaerts et al. (2007) reported greater SMB C in the top 15-cm soil under NT than CT after 14 years of tillage treatments under field conditions in Mexico. Alvarez et al. (1995) also reported greater SMB C in the top 20-cm soil under NT than CT under field conditions after 12 years of tillage treatments.

Therefore, the quantity of crop residue returned to the soil contributes to increased microbial population due to a greater supply of labile C for microbial nutrition. The increase in SMB C due to crop residue application depends mainly on the increased C availability (Kushwaha et al., 2000). Both substrate availability and accessibility to microorganisms are important factors affecting microbial populations in soils. Similar to this study, Kushwaha et al. (2000) reported 82% greater microbial biomass C due to the combined effects of minimum tillage and residue incorporation than when residue was removed in a sandy-loam soil in India under dry-land field conditions. Govaerts et al. (2007) reported 1.2 times greater SMB C when crop residue was retained than when residue was removed.

Changes in Soil Organic Matter and C:N ratio

Soil organic matter differed among tillage-residue-level combinations ($P = 0.013$) and changed over time ($P = 0.004$) (Table 6). Soil organic matter content was greater under the CT-high, CT-low, and NT-high-residue treatments combinations (> 1.19 kg m^{-2}) than under the CT-no-residue treatment (1.14 kg m^{-2}) (Fig. 11). The NT-low and NT-no-residue treatments had slightly greater SOM (> 1.16 kg m^{-2}) than CT-no-residue level, but did not differ from each other (Fig. 11). Soil C:N ratio differed ($P = 0.034$) between tillage and changed over time ($P = 0.001$) (Table 6). Soil C:N ratio was greater ($P < 0.05$) under CT (9.3) than under NT (9.1). In contrast to SMB C, SOM and C:N ratio decreased sharply during first 4 weeks, followed an increase through 17 weeks of incubation before declining at 34 weeks of incubation before a slow increase thereafter (Fig. 9). Soil organic matter content, C:N ratio, and SMB C were lowest after 34 weeks of incubation when the lowest air temperatures throughout the duration of incubation were recorded. Similar to the results of this study, Wagai et al. (1998) reported greater CO_2 flux rates during the warm than cool season in both prairie and cultivated and NT agroecosystems in a silt-loam soil in south-central Wisconsin suggesting a greater effect of temperature than soil moisture on SOM mineralization.

Total soil C and N

Total soil C and N are important fractions of SOM and changes in soil TC and TN are affected by both the substrate quantity and accessibility to microorganisms and their changes over time. A combination of tillage, residue-level, and time affected soil TC ($P = 0.004$) and TN ($P = 0.036$) (Table 6). Soil TC and TN did not differ among treatment combinations during the first 17 weeks of incubation (Fig. 12). However, by 34 weeks of incubation and after, soil TC and TN were greater under the CT-high-residue-level than all other tillage-residue-level treatment combinations (Fig.12). Soil TN increased between 17 and 34 weeks of incubation, and then decreased thereafter (Fig. 12).

The greater TC under the CT-high-residue-level than the CT-low-residue-level treatment combinations showed the importance of crop residue quantity at increasing soil TC in agricultural soils. The greater TC increase under CT than NT in 56 weeks of incubation at any residue-level combination indicates a greater rate of microbial transformation of residue to soil TC under CT compared to NT. The rate of TC increase under CT-high-residue was 0.10 kg C m^{-2} yr^{-1} under greenhouse condition. This rate of C storage is greater than the rate of C increase under field condition of 0.064 kg C m^{-2} yr^{-1}, which did not differ between tillage treatments. The decreasing trend of soil TC over time under NT (Fig. 12) indicates a slower rate of residue microbial transformation to TC under NT than CT likely due to reduced soil-residue contact, which might have resulted in decomposition of labile C in SOM. The decreasing trend in TC under the no-residue treatment indicates a great loss of soil TC when crop residues are removed, which will lead to decreasing SOC with either tillage treatment in the long-term.

In contrast to this study, Zibilske and Bradford (2003) reported greater soil organic C and N under NT than CT after a 36-d soil incubation. Zibilske and Bradford (2003) used soil with nine years of CT and NT treatments before incubation, which had inherent soil TC and TN differences due to differences in tillage, rather than a similar uniform soil as in the current study. Similar to the results of this study a long-term incubation study by Follet et al. (2007) showed a decrease in SOC with time of incubation under both CT and NT without the addition of substrate, but also showed a greater fraction of original SOC under NT than CT after 853 days of incubation. Thus, the current and all previous studies showed that the rate of SOM decomposition is slower under NT than under CT. In addition, although NT results in a slow transformation of organic residues to SOM in the short-term, in the long-term, NT results in greater net C stored in the soil than under CT due to reduced loss of soil C as CO_2 (Reicosky et al. 1997).

The results from the greenhouse incubation showed that low air temperature reduced SMB C and decomposition of organic residue. Soil microbial biomass SMB C was lower under NT than CT, resulting in slower increase in SOM, and TC in short term. In addition, retention, quantity, and soil contact of crop residue is crucial for SOM or SOC sequestration in agricultural soils.

CONCLUSIONS

Non-burning of wheat residue has a greater rate of soil C sequestration in eastern Arkansas soils regardless of tillage and residue level compared to residue burning. The high-residue-level treatment achieved by a higher N fertilizer rate increased SOC storage at a greater rate than the low-residue-level treatment likely due to increased above- and below-ground biomass. Tillage, burning, and residue level had no effect on soil TN and C:N ratio. All treatments resulted in similar soybean yield trend, and the soybean yield trend appears to be influenced by growing-season rainfall distribution and soil physical conditions. No-tillage, burning of wheat residue, and high N fertilizer rate for wheat grain in the wheat-soybean double-crop system resulted in greater soil P depletion than CT, unburned residue, and a low N fertilization rate. The greenhouse incubation study showed that SMB-C plays a significant role in organic residue decomposition and transformation to increase SOM and TC in the soil. Therefore, for C sequestration to be achieved, management practices that promote a greater balance between C input and C losses are essential, thus, NT with retained crop residue is recommended. No-tillage and non-burning have great potential to improve soil quality with any residue level in the wheat-soybean double-crop production system.

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Table 1. Effect of fertilizer-N application on mean surface residue in a wheat-soybean double-crop production system on a silt-loam soil in the Mississippi River Delta region of eastern Arkansas.

		Residue level (kg ha^{-1})	
Year	N[†]	Low	High
2002[‡]	12	3916	3254
2003	12	4137	6168*
2004	12	6026	7677
2005	24	2103	3463*
2006	24	6455	11 036*
2007	24	5806	9381*

[†] Number of observations (N)

[‡] Results for 2002 to 2004 were obtained from Cordell et al. (2006), and for 2005 and 2006 were obtained from Verkler (2007).

Asterisks (*) indicates a significant difference (P <0.05) between the Low- and High-residue-level treatments within year.

Table. 2. Monthly soybean growing-season precipitation for 6 years in a wheat-soybean double-crop production system in the Mississippi River Delta region of eastern Arkansas.

	Soybean season precipitation(cm)							
	Month							CV
Year	June	July	Aug.	Sept.	Oct.	Total	Mean	(%)
2002	0.3	13.4	8.1	8.7	10.7	41.2	8.2	59.5
2003	5.3	10.2	5.3	8.7	2.5	32.0	6.4	47.7
2004	15.7	8.1	1.3	0.4	9.9	35.4	7.0	90.1
2005	0.4	9.6	10.8	14.7	1.1	36.7	7.3	86.0
2006	5.1	3.2	5.2	11.1	4.3	28.9	5.8	52.8
2007	9.2	15.3	2.3	7.6	4.9	39.3	7.9	62.9
30-yr mean†	11.2	9.7	6.9	8.0	9.6	45.5	9.1	18.0

† Obtain from NOAA (2002).

Table 3. Well water quality parameters determined in 2004 for irrigation water used at the Lon Man Cotton Research Station, Marianna, eastern Arkansas.

Water quality parameter	Level	Water quality parameter	Level
pH	9.10	SO_4^{2-} (mg L^{-1})	26.55
EC (dSm^{-1})	0.59	Fe (mg L^{-1})	<0.01
P (mg L^{-1})	0.24	Cu (mg L^{-1})	<0.01
K (mg L^{-1})	1.94	Cl^- (mg L^{-1})	24.00
Ca (mg L^{-1})	109.65	Sodium adsorption ratio (SAP)	0.30
Mg (mg L^{-1})	48.06	Bicarbonates (mg L^{-1})	691.00
Na (mg L^{-1})	17.14		

Obtained from Brye et al. (2006a).

Table 4. Percent net returns for each alternative management system relative to the traditional management practice (i.e., irrigated-CT-burn-high-residue) in a wheat-soybean double-crop production system in the Mississippi River Delta region of eastern Arkansas.

Treatment combinations	Relative net returns					
	2002	2003	2004	2005	2006	2007
	%					
Irrigated:						
CT-burn-low	-24	1	11	-58	-17	-455
CT-no burn-high	-35	-28	-13	-79	-12	-500
CT-no burn-low	-11	-30	23	-68	-55	-698
NT-burn-high	-21	79	60	-12	44	682
NT-burn-low	0	55	74	21	-6	633
NT-no burn-high	-28	19	48	-59	-5	819
NT-no burn- low	-17	24	51	-52	-57	620
Dry-land:						
CT-burn-high	-[†]	-	-	-51	-72	-552
CT-burn-low	-	-	-	-40	-119	-716
CT-no burn-high	-	-	-	-58	-84	-355
CT-no burn-low	-	-	-	-76	-105	-638
NT-burn- high	-	-	-	-49	-59	99
NT-burn- low	-	-	-	-21	-106	-136
NT-no burn- high	-	-	-	-46	-55	757
NT-no burn- low	-	-	-	-38	-101	-23
Irrigated-CT-burn-high	0	0	0	0	0	0

[†] No dry-land treatment in 2002, 2003, and 2004, all treatment combinations were irrigated

Table 5. Impact of increasing prices of wheat (by125%), soybean (86%), fertilizer (136% for urea, 169% for DAP, and 6.6% for potash), and fuel (6.3%) on the percent net returns for each alternative management system relative to the traditional management practice (i.e., irrigated-CT-burn-high-residue-level) and relative changes in net returns (in parenthesis) for each alternative management system relative to the base budgets in a wheat-soybean double-crop production system in the Mississippi River Delta region of eastern Arkansas.

Treatment combination	2002	2003	2004	2005	2006	2007
	%					
Irrigated:						
CT-burn-low	-17 (194)	0 (254)	212 (114)	-117 (90)	-13 (257)	-34 (627)
CT-no burn-high	-24 (211)	-17 (313)	-227 (67)	-160 (69)	-5 (268)	-33 (572)
CT-no burn-low	-8 (178)	-18 (320)	390 (142)	-138 (79)	-34 (396)	-48 (342)
NT-burn-high	-19 (176)	36 (172)	884 (320)	-67 (127)	20 (183)	33 (377)
NT-burn-low	-4 (160)	24 (185)	1091 (537)	0 (216)	-12 (217)	24 (376)
NT-no-burn-high	-23 (186)	3 (209)	650 (221)	-161 (65)	-7 (232)	43 (337)
NT-no-burn-low	-15 (173)	5 (205)	686 (235)	-148 (71)	-42 (365)	24 (384)
Dry-land:						
CT-burn-high	-†	-	-	-183 (50)	-50 (516)	-61 (340)
CT-burn-low	-	-	-	-160 (61)	-80 (447)	-76 (211)
CT-no-burn-high	-	-	-	-197 (44)	-56 (863)	-50 (651)
CT-no-burn-low	-	-	-	-231 (31)	-71 (1946)	-67 (271)
NT-burn-high	-	-	-	-217 (28)	-46 (341)	-33 (840)
NT-burn-low	-	-	-	-161 (54)	-78 (1371)	-53 (3775)
NT-no-burn-high	-	-	-	-210 (30)	-46 (307)	15 (276)
NT-no-burn-low	-	-	-	-196 (36)	-75 (6934)	-43 (1902)
Irrigated-CT-burn-high	0 (169)	0 (257)	0 (89)	0 (192)	0 (241)	0 (2709)
Mean	(181)	(239)	(216)	(78)	(930)	(875)

[†] No dry-land treatment in 2002, 2003, and 2004, all treatment combinations were irrigated

Table 6. Summary of analysis of variance (ANOVA) on the effect of time of incubation, tillage, and residue-level on changes in soil microbial biomass C (SMB C), soil organic matter (SOM), soil total C (TC), and total N (NT) of silt loam soil from wheat-soybean double-crop system in the Mississippi River Delta region of eastern Arkansas.

Source of Variation	df[†]	SMB C	SOM	TC	TN	C:N ratio
				P		
Tillage	1	0.001	0.034	0.001	0.013	0.034
Residue level	2	0.030	0.001	0.001	0.001	0.125
Time	5	0.001	0.004	0.001	0.001	0.001
Tillage*residue level	2	0.169	0.013	0.001	0.067	0.097
Tillage*time	5	0.235	0.433	0.012	0.024	0.459
Residue level*time	10	0.125	0.280	0.002	0.229	0.468
Tillage*residue level*time	10	0.421	0.486	0.004	0.036	0.447

[†] df, degrees of freedom

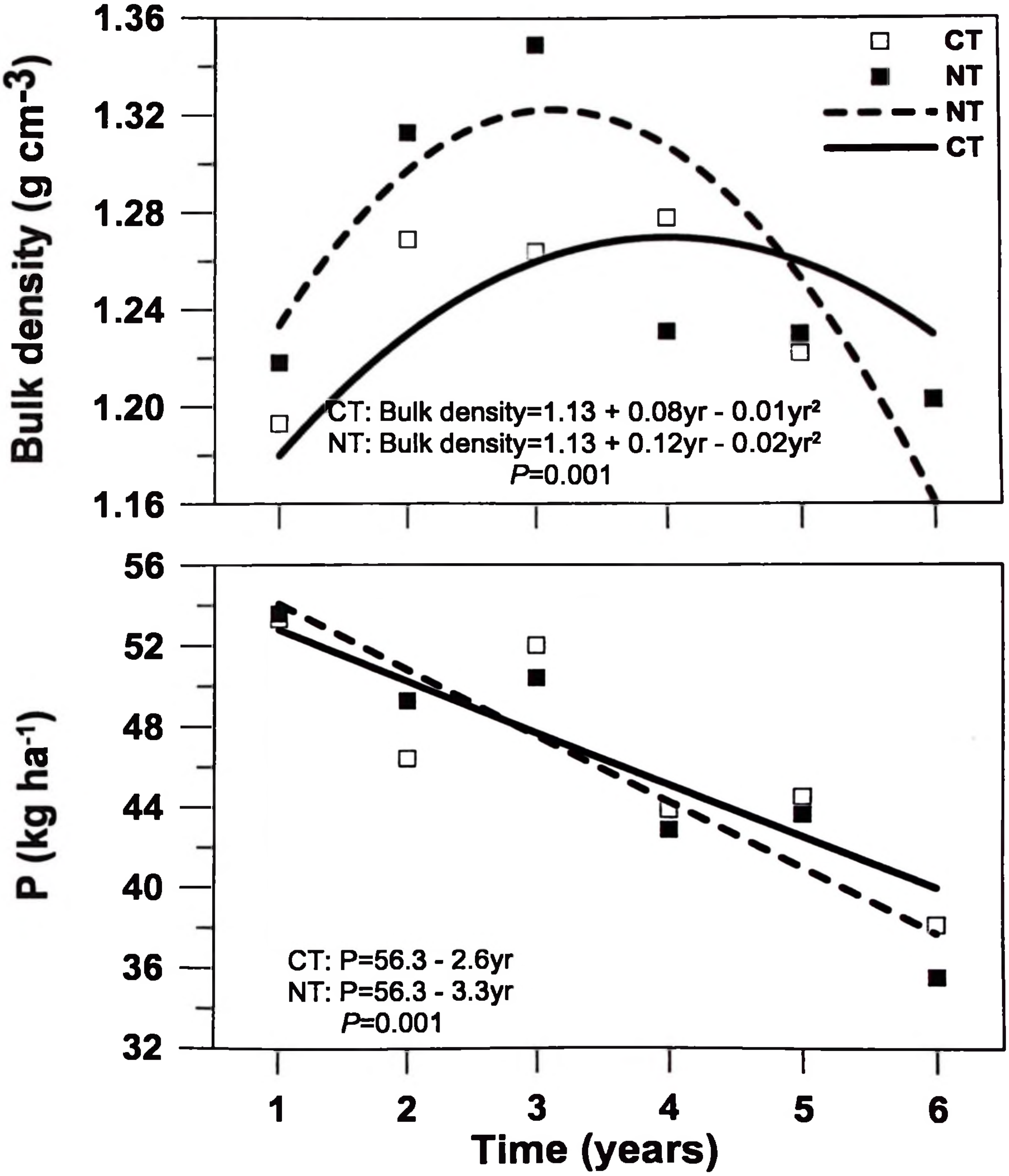

Figure 1. Influence of tillage [conventional tillage (CT) and no-tillage (NT)] on soil bulk density and extractable P content over time in a wheat-soybean double-crop system in the Mississippi River Delta region of eastern Arkansas. Time refers to duration in the wheat-soybean, double-crop rotation.

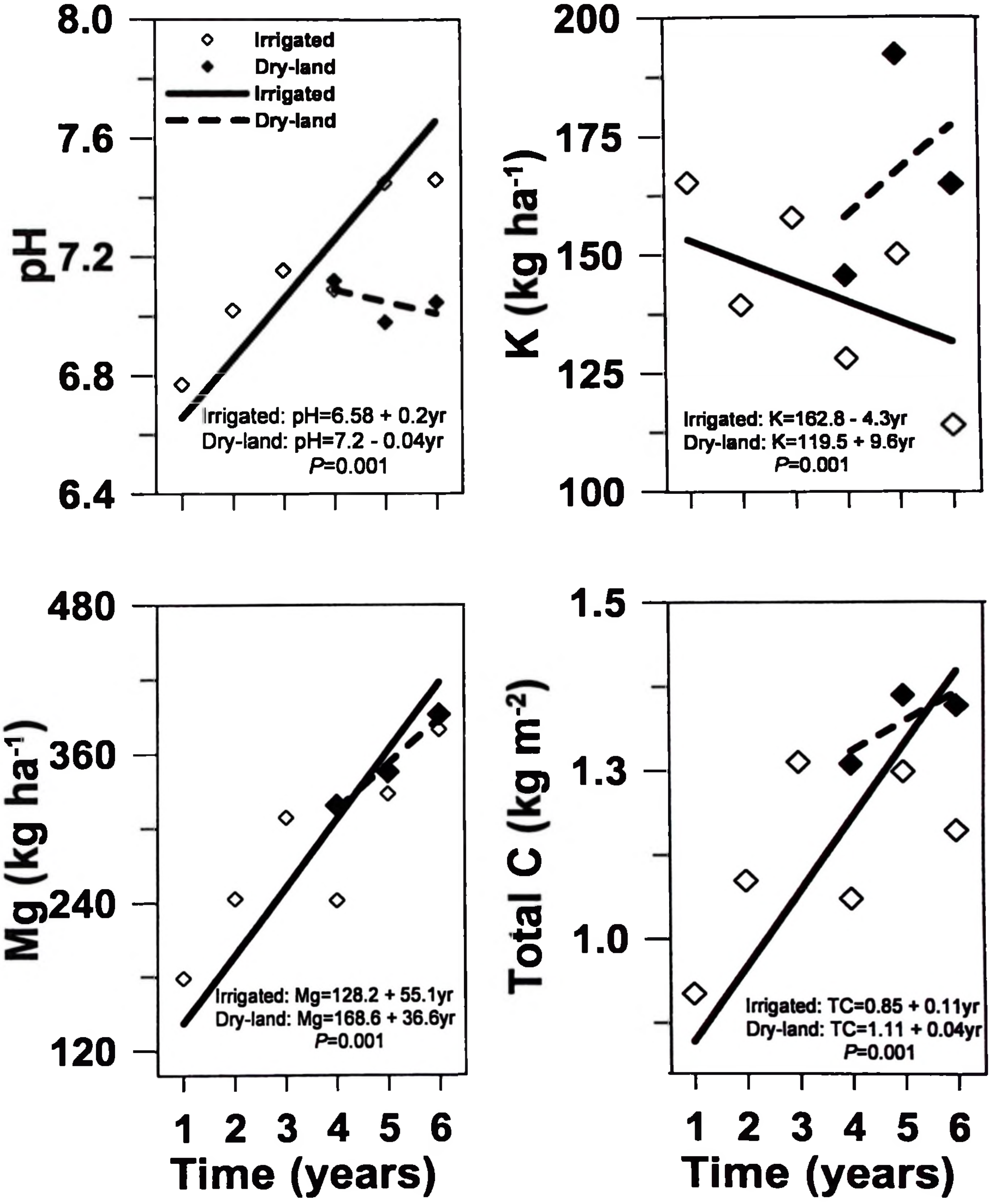

Figure 2. Influence of irrigation (irrigatted and dry-land) on soil pH, extractable soil K, and Mg, and total C contents over time in wheat-soybean double-crop system in the Mississippi River Delta of eastern Arkansas. Time refers to duration in the wheat-soybean, double-crop rotation.

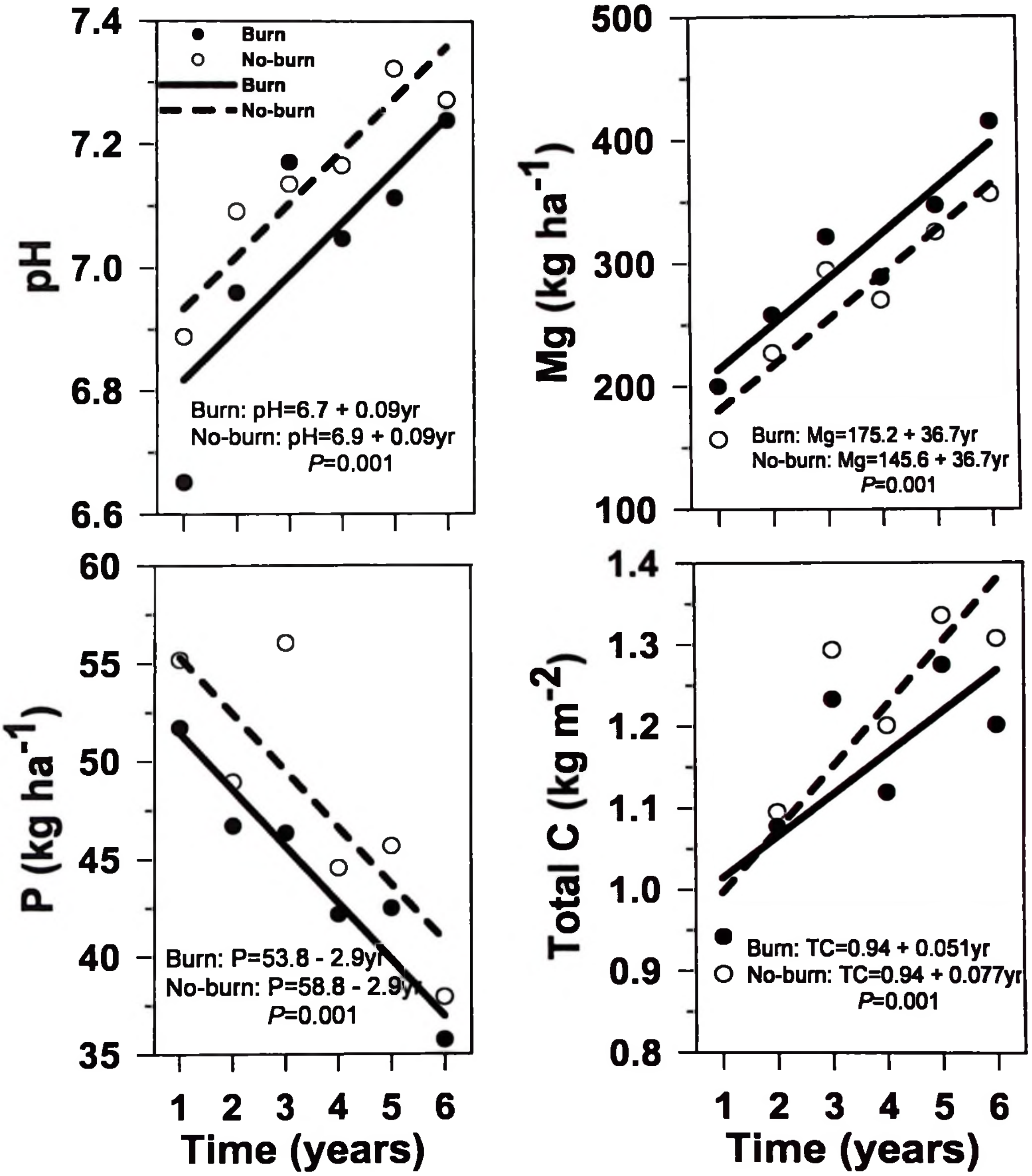

Figure 3. Influence of wheat-residue burning (burn and no-burn) on soil pH, extractable Mg, P, and total C contents over time in wheat-soybean double-crop production system in the Mississippi River Delta region of eastern Arkansas. Time refers to duration in wheat-soybean double-crop rotation.

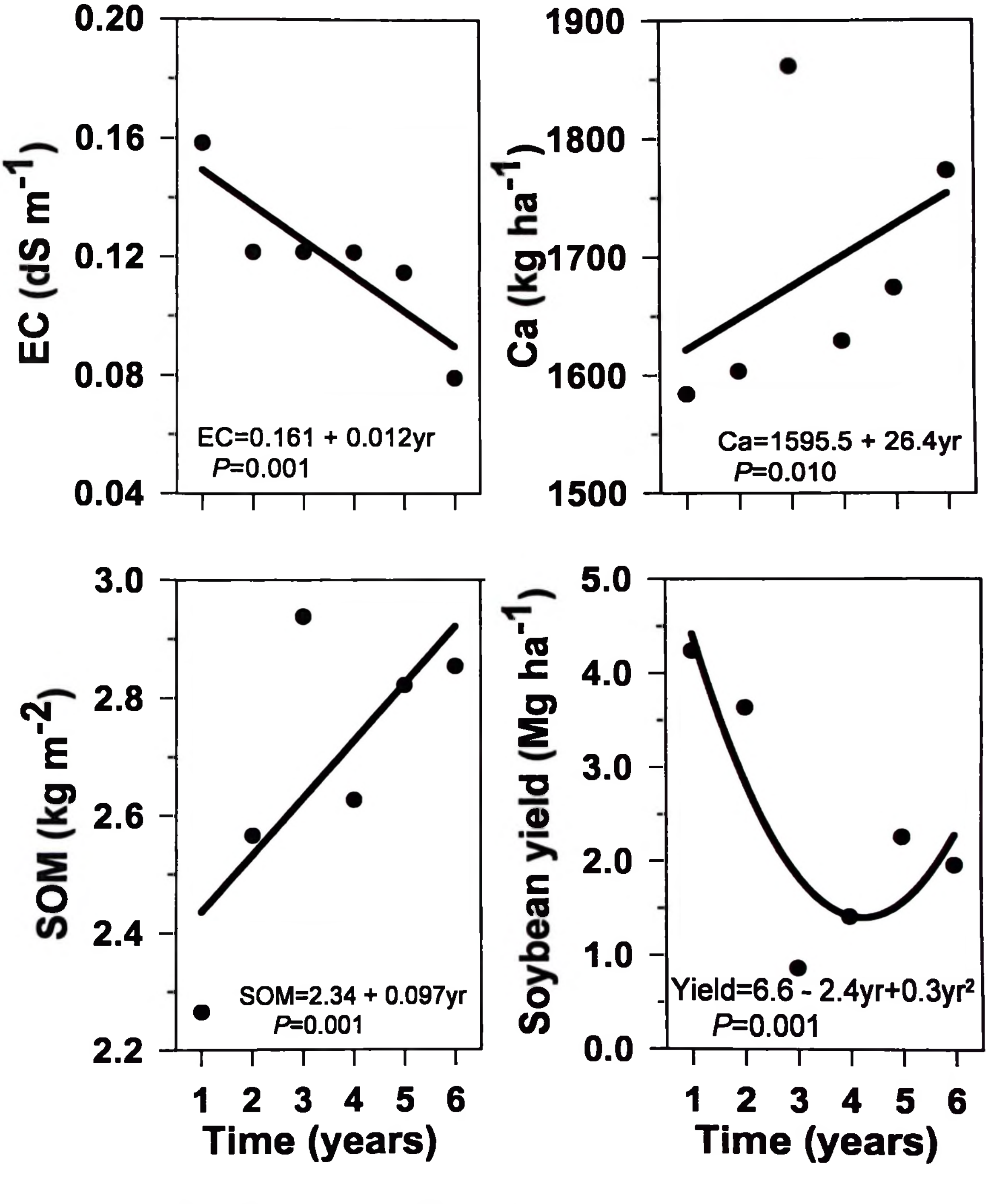

Figure 4. Soil electrical conductivity (EC), extractable soil Ca, soil organic matter (SOM), and soybean yield over time in wheat-soybean double-crop system in the Mississippi River Delta region of eastern Arkansas. Time refers to duration in wheat-soybean double-crop rotation.

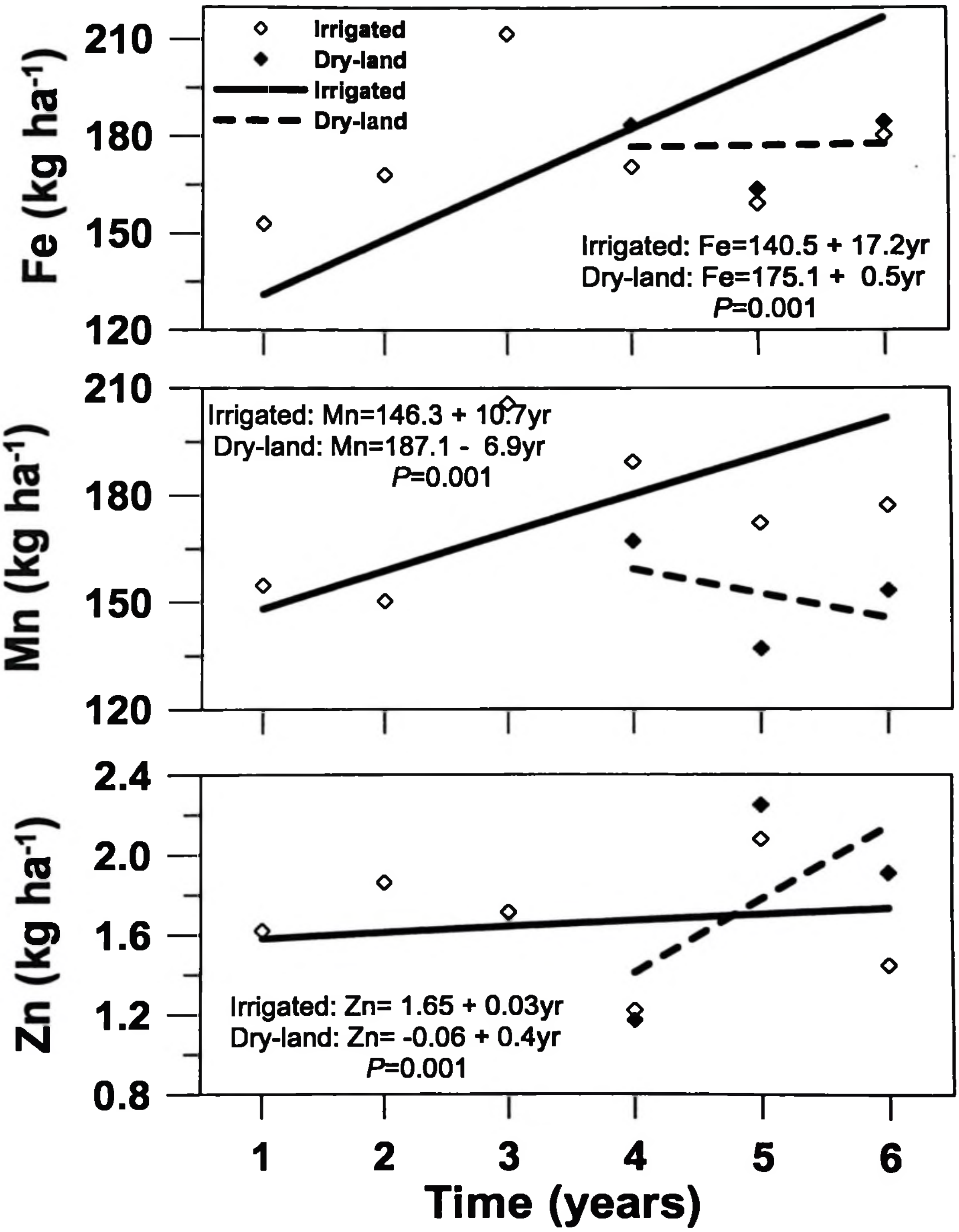

Figure 5. Influence of irrigation (irrigated and dry-land) on extractable soil Fe, Mn, and Zn contents over time in wheat-soybean double-crop system in the Mississippi River Delta region of eastern Arkansas. Time refers to duration in wheat-soybean double-crop rotation.

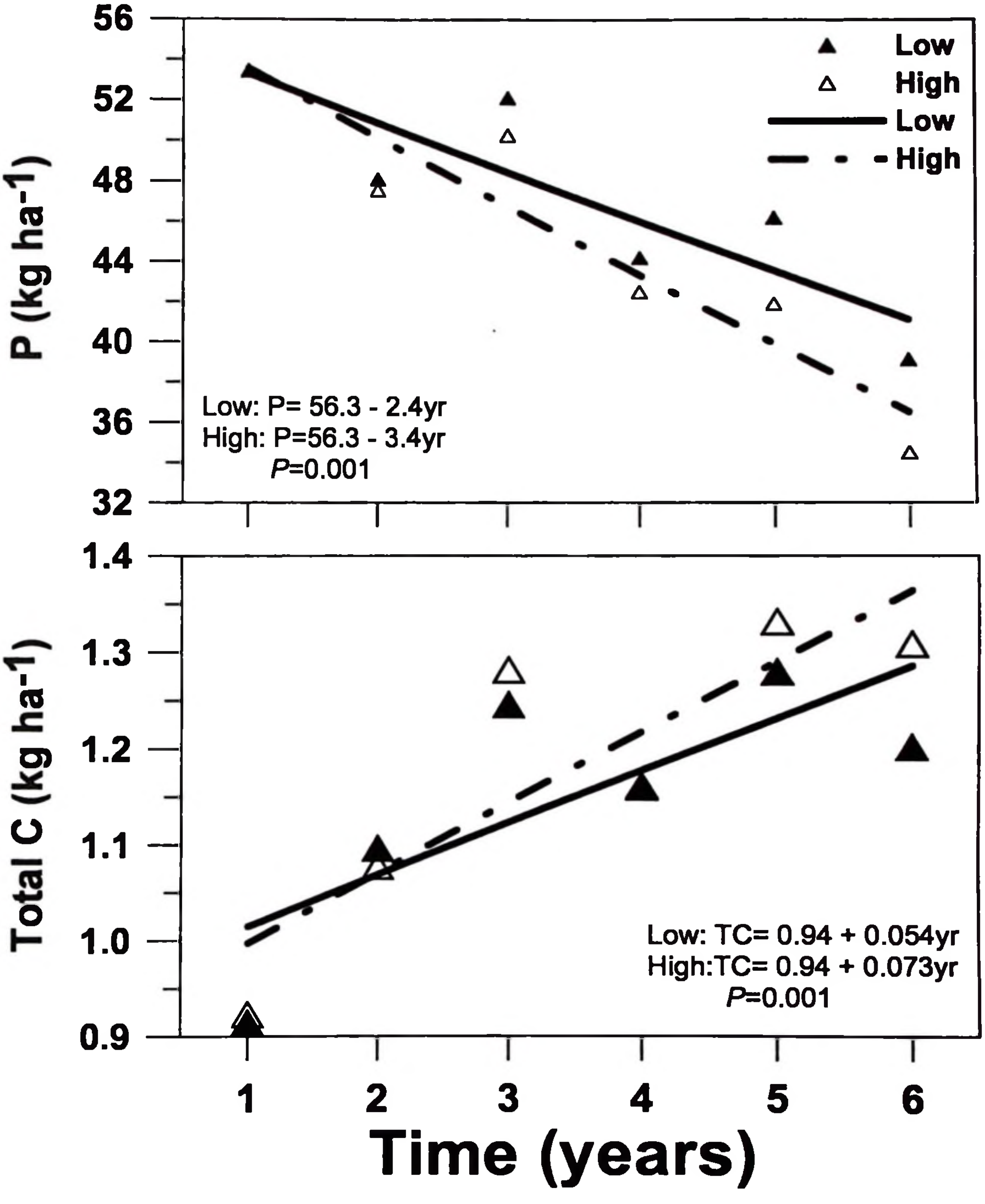

Figure 6. Influence of wheat residue level (low and high) on extractable soil P and soil total C contents over time in wheat-soybean double-crop system in the Mississippi River Delta region of eastern Arkansas. Time refers to duration in wheat-soybean double-crop rotation.

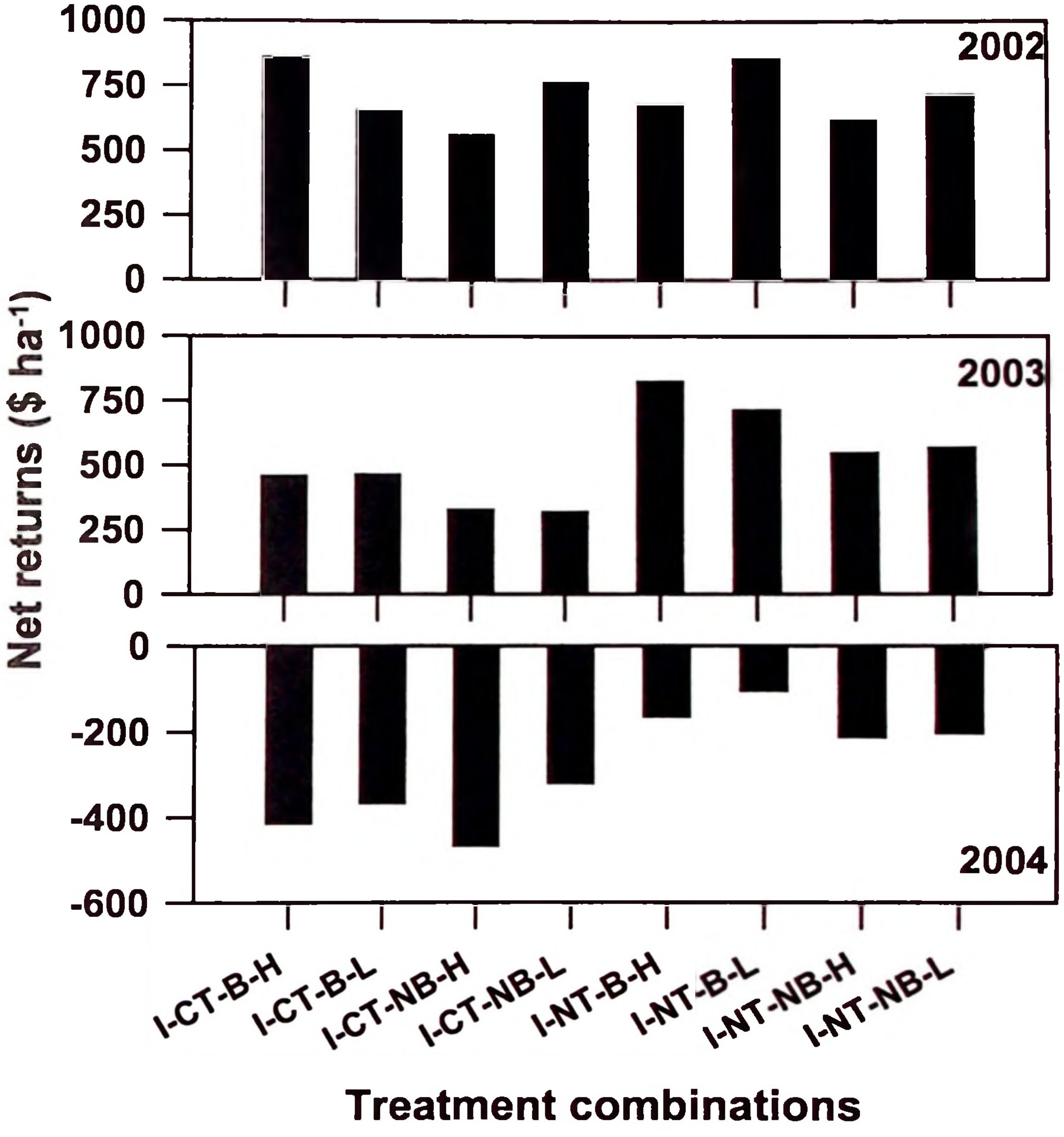

Figure 7. Net returns for eight treatment combinations of irrigation (I), tillage [conventional tillage (CT) and no-tillage (NT), burning [burn (B) and no burn (NB)], and residue level [low (L) and high (H) from 2002 to 2004 in a wheat-soybean double-crop production system in the Mississippi River Delta region of eastern AR.

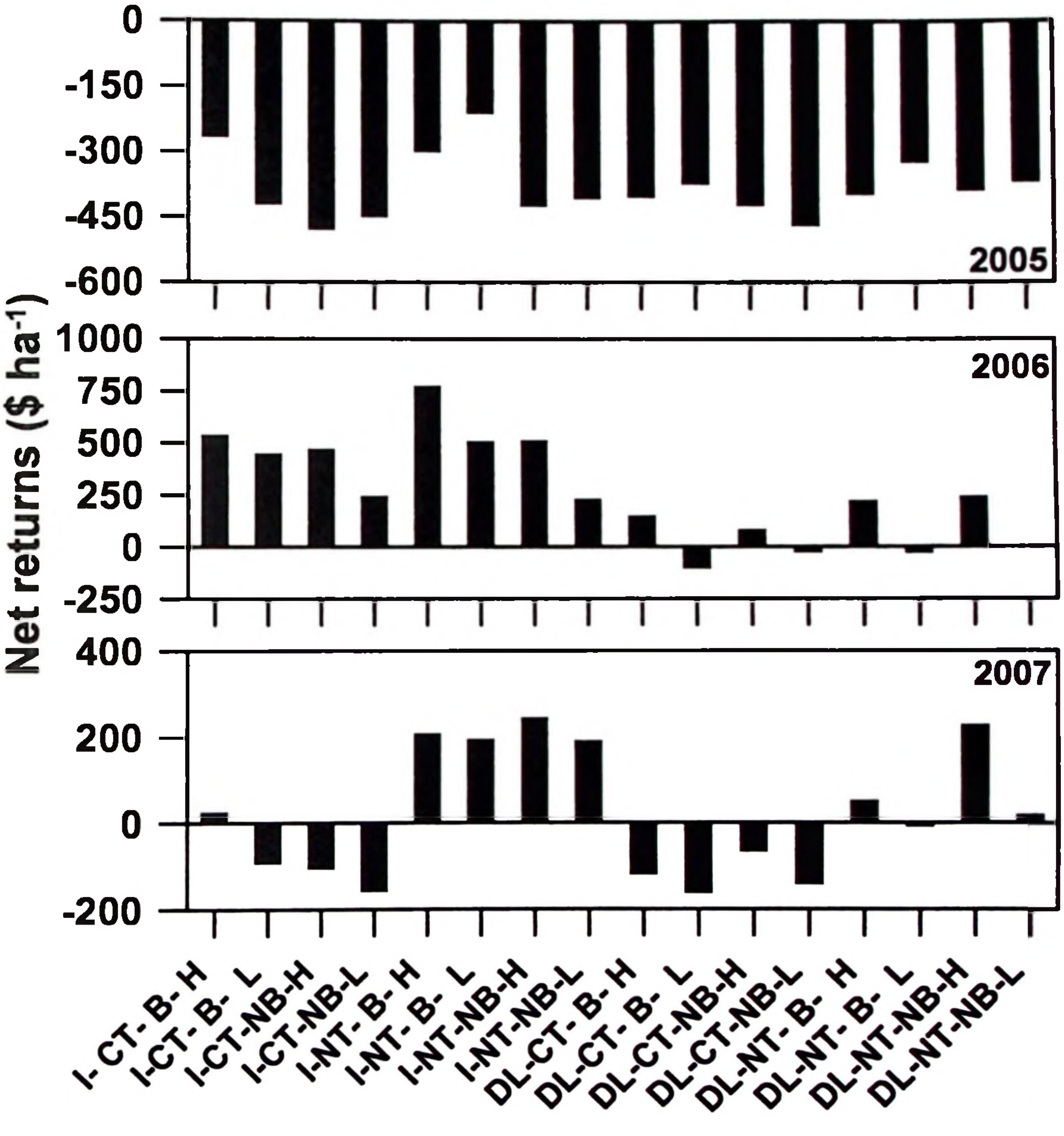

Figure 8. Net returns for 16 treatment combinations of irrigation [irrigated (I) and dry-land (DL)], tillage [conventional tillage (CT) and no-tillage (NT)], burning [burn (B) and no burn (NB)], and residue level [low (L) and high (H)] from 2005 to 2007 in a wheat-soybean double-crop production system in the Mississippi River Delta region of eastern AR.

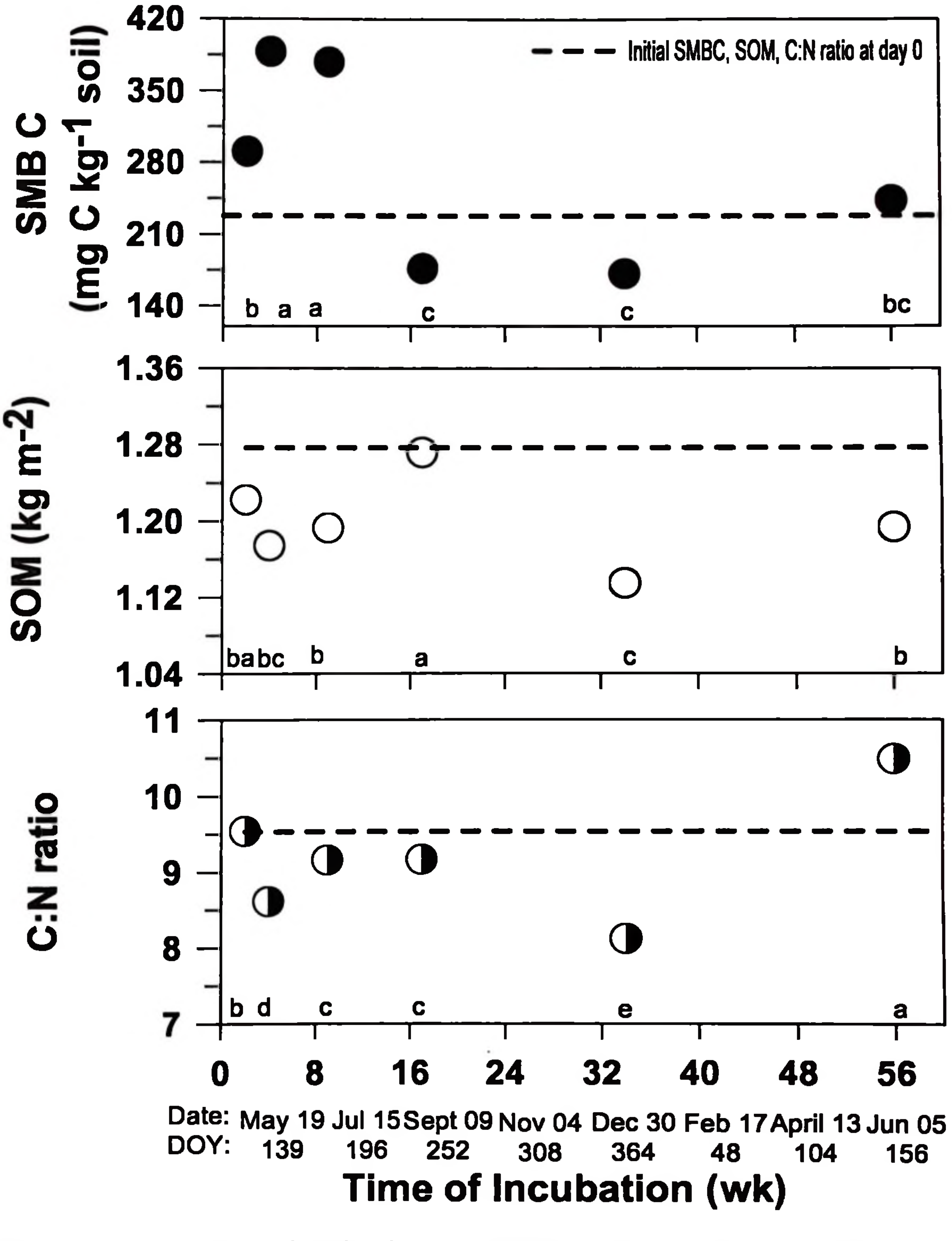

Figure 9. Changes of soil microbial biomass C (SMB C), soil organic matter (SOM) and C:N ratio with time of incubation in weeks and respective dates and days of year (DOY) from May 19 2007 to June 5 2008. Symbols within a panel at time with different letters are significantly different ($P < 0.05$).

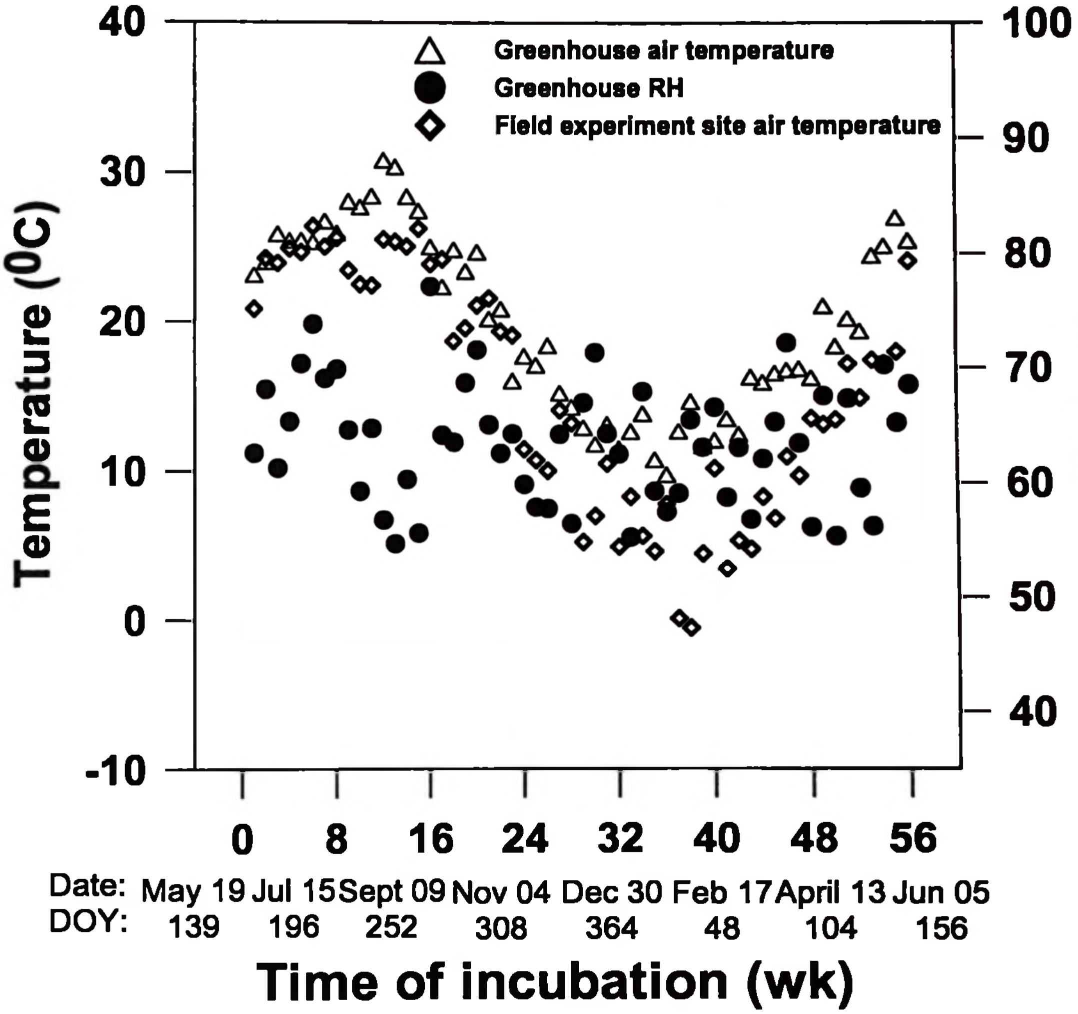

Figure 10. Air temperature and relative humidity (RH) at the University of Arkansas, Fayetteville, AR and at the field experiment site at the Lon Mann Cotton Research Station, Marianna, AR, during soil incubation experiment.

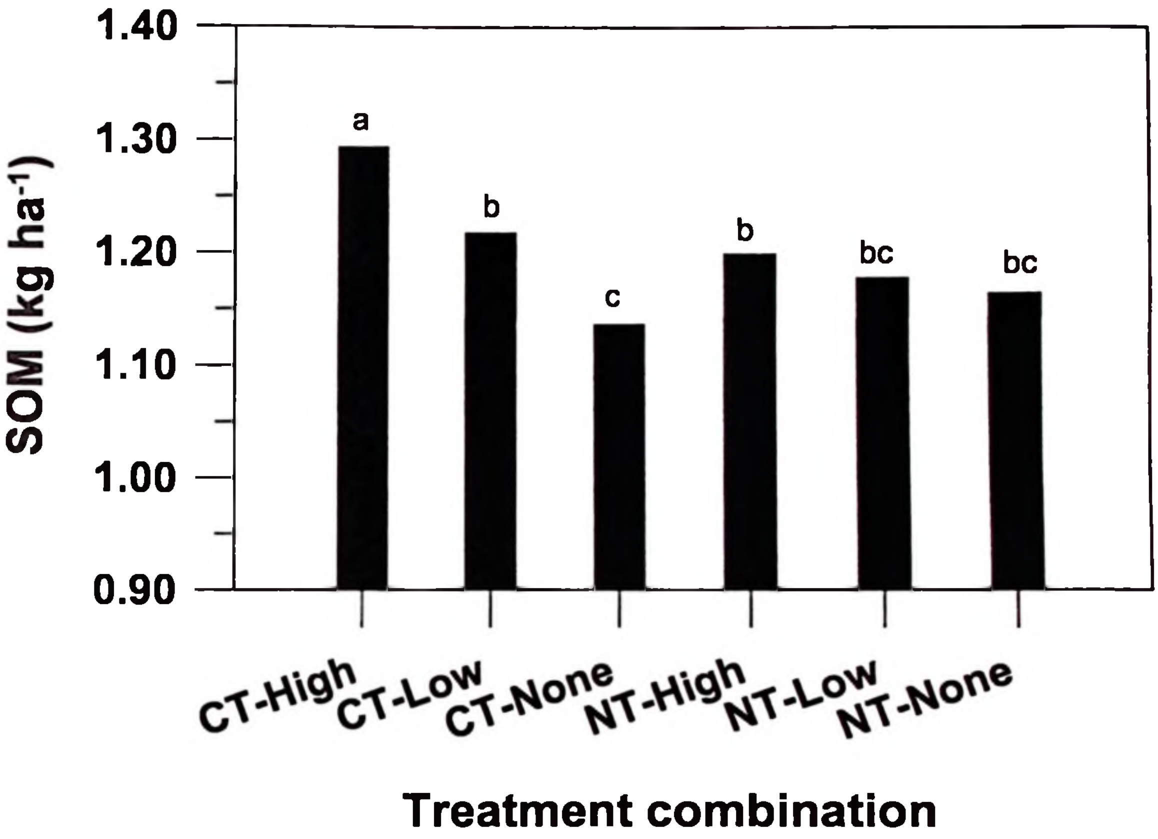

Figure 11. Effect of simulated tillage [conventional tillage (CT) and no-tillage (NT) and residue level (none, low, and high) on soil organic matter (SOM) content after 56 weeks of incubation. Bars with different letters are significantly different ($P < 0.05$).

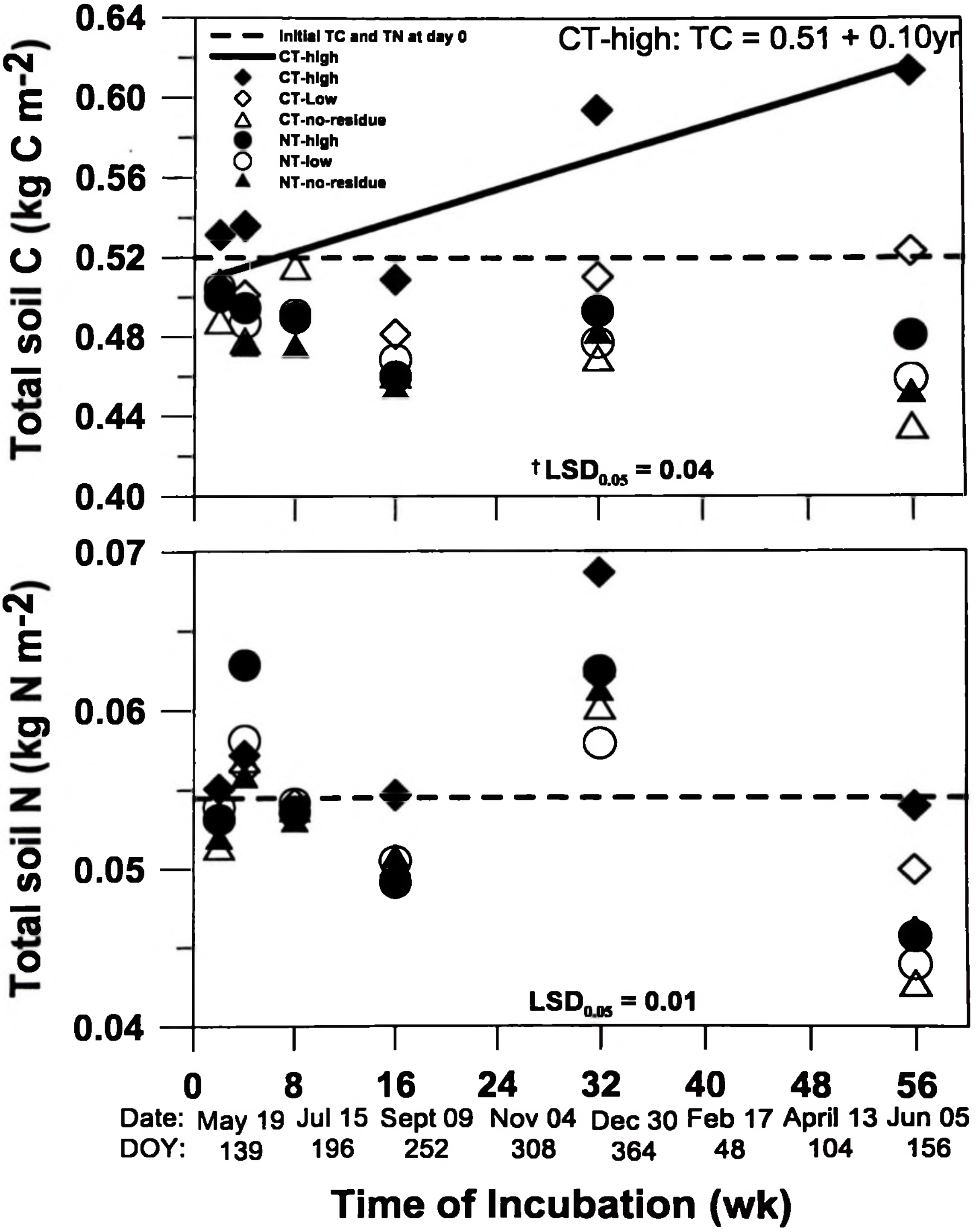

Figure 12. Effect of tillage [conventional tillage (CT) and no-tillage (NT)], wheat residue level (high and low) on Changes in soil total C (TC) and N (TN) with time of incubation in weeks and respective dates and days of year (DOY) from May 19, 2007 to June 05, 2008. † Least significant difference (LSD) at 0.05 level.

CHAPTER THREE

Weed Population Density and Diversity as Affected by Residue Management Practices in a Wheat-soybean Double-crop Production System

Abstract

Management practices and cropping systems that serve as integrated weed management practices, while at the same time improve soil quality, will be important for the sustainability of agricultural production systems. The objective of this study was to assess weed species population densities under contrasting tillage [conventional tillage (CT) and no-tillage (NT)], residue burning (burn and no burn), residue level and (low and high) treatments after 5 and 6 years of consistent management in a wheat-soybean, double-crop production system. A field experiment was conducted between fall 2001 and fall 2007 in the Mississippi River Delta region of eastern Arkansas on a Calloway silt loam (fine silty, mixed, active, thermic Glossaquic Fraglossudalf). Weed assessments were conducted twice during the soybean growing season before (early-season) and after herbicide application (late-season) in 2006 and 2007. The total weed species density was greater under CT (513 plants m^{-2}) than under NT (340 plants m^{-2}) early in the soybean growing season in 2006, but did not differ between tillage treatments in 2007. Grass species density was greatest under NT-burn-low-residue (139 to 167 plants m-2) and lowest under NT-no-burn (41 to 63 plants m^{-2}) of all tillage-burn-residue-level combination early in the soybean growing season in 2006 and 2007. Sedge weed species density was greater under high (48 plants m^{-2}) than low-residue (32 plants m^{-2}) in 2006 but did not differ between residue levels in 2007. Conventional tillage had greater sedge density (198 to 201 plants m^{-2}) than NT (116 to 149 plants m^{-2}) in combination with either burn or no-burn. Broadleaf weed density was greater early (200 to 349 plants m^{-2}) than late (18 to 20 plants m^{-2}) soybean growing season under both CT and NT in 2006, but in 2007 broadleaf weed density did not differ between seasons. Perennial weed

density was greater under burn (99 plants m^{-2}) than no burn (59 plants m^{-2}) in 2006. In 2007, perennial density was low and was unaffected by burn treatments, but greater under NT than CT. The total weed species, grass, sedge, broadleaf, and perennial weed species densities were lower during late-season in all treatment than early-season, indicating that glyphosate controlled most weed effectively. Retaining crop residues by no-burning along with either CT or NT reduced the density of most broadleaf and grass weed species. No-tillage, no-burning, and a high-residue level under both irrigated and dry-land conditions appeared to contribute significantly to the suppression of most weed species without reducing herbicide efficiency.

Nomenclature: Wheat, *Triticum aestivum* L.; soybean *Glycine max* (L.) Merr.

Introduction

Adoption of the double-crop production system with appropriate residue management techniques, such as no-tillage (NT) and retaining crop residues on the soil without burning, have potential to increase crop productivity and soil quality by minimizing potential negative effects of weeds. Crop rotation and conservation tillage are among the important components of integrated weed management systems that modify soil and crop micro-environments to reduce germination, growth, and dissemination of weeds, hence minimizing the need for and use of herbicides (Swanton and Murphy 1996; Liebman and Davis 2000; Locke et al. 2002a). However, there is concern about shifting of weed species with the adoption of the double-crop system and conservation tillage that is associated with crop yield losses (Locker et al. 2002a; Shrestha et al. 2002) and increased demand for pest control inputs, particularly in the long-term. Therefore periodic weed assessments conducted in conjunction with changes in cropping systems and agronomic management practices are essential to ensure long-term agricultural productivity.

Multiple abiotic, biotic, agronomic, (i.e., tillage and cover crop), environmental factors (moisture and temperature), herbicide use, and soil fertility influence the weed community in agricultural systems (Derksen et al. 1993; Davis 2007). Shrestha et al. (2002) reported greater weed density in conventional tillage (CT) than in NT in winter wheat-soybean rotation systems on a loamy sand in Ontario, Canada. Increased weed density under CT has been shown to be related to increased aeration and exposure of weed seeds to light, thus promoting germination and rapid weed growth (Teasdale 1993; Shrestha ct al. 2002). In contrast, other studies have reported greater weed density under

NT than CT due to the reduction of annual weeds under CT and/or increases in perennial weeds and grasses under NT in loamy-sand soil in the central United States (Buhler 1992). Soil N fertility has been reported to affect weed seed mortality and germination, but the effect differed among weed species depending on seed coat composition and quality of weed seed that determine seed decay and persistence in soil (Davis 2007). Enriching soil organic matter also has had an impact on weed population and diversity. A study by Davis (2007) reported reduced velvetleaf (*Abutilon theophrast* Medicus.) seed mortality with the application of corn (*Zea mays* L.) stover, which was attributed to a reduction of microbial predation of velvetleaf seed due to presence of additional labile C for microorganism consumption.

Weed diversity is also affected by changes in tillage management practices. Buhler et al. (1994) reported greater perennial weed populations and diversity in reduced-tillage compared to moldboard plowing tillage after 14 years of continuous corn and corn-soybean rotations in loam soils in Iowa. Greater wind-dispersed weed species, such as plumless thistle (*Carduus acanthoides* L.) and annual sowthistle (*Sonchrus oleraceus* L.) in NT than CT were also observed in a wheat-soybean rotation in Argentina (Puricelli and Tuesca 2005). Another study in the sub-humid tropical region of Mexico also reported greater densities of perennial weeds (i.e., *Taraxacum*, *Oxalis*, and *Cyperus*) under NT than CT, but that the perennial weed density tended to decrease when wheat was in rotation with corn and a legume compared to mono-cropped wheat (Fischer et al. 2002). However, CT had a greater total weed density than NT during 5 years of treatment (Puricelli and Tuesca 2005). Wruckle and Arnold (1985) reported greater frequencies of grasses under NT than CT, but inconsistent tillage effects on broadleaf weeds after 5 years in a corn-soybean rotation on a silty-clay-loam soil in South Dakota.

Crop rotation affects weed populations and diversity through altering weed seedbank community and weed growth, hence can contribute to improved weed management regardless of tillage. Studying rotation effects on the weed seedbank, Bellinder et al. (2004) observed greater broadleaf weed densities in rotation with ryegrass (*Secale cereale* L.), despite known allelopathic effects of ryegrass, which was attributed to the non-use of herbicides and insufficient allelopathic effect to suppress weeds. In contrast, weed seed densities were low under alfalfa (*Medicago sativa* L.), clover (*Trifolium pratense* L.), and sweet corn (*Zea mays* L. var. *rugosa* Bonaf.) rotations due to advantages of legumes in rotations in deterring weed seed return and recruitment and the use of herbicides in sweet corn rotations (Bellinder et al. 2004). Teasdale at al. (2004) reported lower smooth pigweed (*Amaranthus hybridus* L.) and common lambsquarters (*Chenopodium album* L.) when orchardgrass (*Dactylis glomerata* L) hay and wheat were included in rotation sequence before corn in 6-yr crop rotation study in Maryland. Thus, crop rotations with different phenological characteristics have potential for reducing annual broadleaf weed species (Teasdale et al., 2004).

Multi-species crop rotations with different growing seasons and varied herbicide usage may have the advantage of counteracting herbicide resistance, hence reducing the number of troublesome weeds in any particular growing season (Fischer et al. 2002). However, Smith and Gross (2006) reported greater weed community variability in a corn-soybean-wheat rotation than in a continuous corn system in loam and sandy-loam soils in Michigan. The results of the study by Smith and Gross (2006) indicated the presence of greater weed community diversity under multi-species crop rotations due to the seedbanks containing seeds from the diverse and abundant weed species associated with each crop in the rotation. Thus, inconsistencies in the effect of crop rotation, management practices, and weed species affected further necessitate weed assessments beginning shortly after management practice changes are implemented, particularly in the increasingly more common wheat-soybean double-crop production system popular in the Mississippi River Delta region.

Crop residues left on the soil surface under conservation tillage contribute to weed management through allelopathic inhibitory effects and acting as a physical barrier for light penetration (Liebman and Davis 2000; Fischer et al. 2002; Shrestha et al. 2002; Bellinder et al. 2004). Steinsiek et al. (1982) reported inhibition of germination and growth of ivyleaf morningglory [*Ipomoea hederacea* (L.) Jacq.], velvetleaf, pitted morningglory (*Ipomoea lacunosa* L.), hemp sesbania [*Sesbania exaltata* (Raf.) Cory], sicklepod (*Cassia obtusifolia* L.), and Japanese barnyard millet [*Echinochloa crus-galli* var. *frumetaceae* (Roxb.) Link] due to allelopathic effect of wheat residue. In a wheat rotation with corn and legumes, Fischer et al. (2002) reported greater annual grass weeds under NT with wheat residue removed compared to when residue was left on the soil surface in clay-loam and sandy-loam soils in Mexico indicating that retaining crop residue on the surface may suppress grass weeds. In addition, the current development of efficient herbicides coupled with development of herbicide-resistant soybean varieties have improved weed control in NT and in other conservation tillage systems used for soybean production. However, crop residues left on the soil surface in NT can interfere with herbicide activity and, hence, reduce herbicide efficiency (Locke et al. 2002a, b).

Reduced herbicide efficiency due to crop residue cover is caused by preventing the herbicide from reaching the soil (Reddy et al. 1995) and herbicide sorption due to increased soil organic matter (SOM) after residue decomposition (Locke et al. 2002a). Reduced herbicide efficiency results in the need for greater rates and increased frequencies of spraying, which add to the costs of production (Reddy et al. 1995; Locke et al. 2002a). The contrasting residue-level effect on weed species populations suggests the need to assess weed populations in cropping systems with alternative residue management practices and differential N fertilization schemes to generate information necessary for achieving and maintaining sustainable crop production, particularly in the wheat-soybean double-crop production system.

The use of wide-spectrum herbicides, such as glyphosate, along with adoption of glysphosate-resistant soybean, have improved weed control, particularly under conservation tillage. However, continuous use of glyphosate has been reported as a major factor causing changes in weed species composition in agricultural systems (Puricelli and Tuesca 2005; Rankins et al. 2005). Puricelli and Tuesca (2005) observed reduced densities of early emerging annual weeds, such as common purslane (*Portulaca oleracea* L.), and annual grasses, such as large crabgrass [*Digitaria sanguinalis* (L.) Scop.], but increased densities of late-emerging weeds, particularly under NT. Rankins et al. (2005) observed increased density of yellow nutsedge (*Cyperus esculentus* L.) in soybean fields over an 8-yr period in the Mississippi River Delta region due to continued use of glyphosate, which has been shown to be less effective on yellow nutsedge. It is evident that investigation of alternative management practices as an integrated weed management tool is important to determine if such practices will ameliorate some of the limitations associated with the continuous use of herbicides with a single mode of action. In addition, weed assessment is necessary to determine the effect of alternative residue management practices in continuous double-crop production beyond 5 years without a fallow period and whether those practices are ecologically and economically sustainable.

Inconsistencies in weed responses to management practices indicate the need for weed assessments under field conditions to determine the effect of tillage, irrigation, burning, and residue level treatments. Therefore, the objective of this study was to assess weed species population density and diversity early and late in the soybean growing season under contrasting tillage (CT and NT), burning (burn and no burn), residue level (low and high), and irrigation (irrigated and dry-land) treatments after 5 and 6 years of consistent management in a wheat-soybean, double-crop production system in the Mississippi River Delta region of eastern Arkansas. It was hypothesized that CT, residue burning, low-residue level, and dry-land conditions will have greater weed density and diversity due to the creation of more safe sites for weed germination and growth than in NT, no residue burning, high-residue level, and irrigated conditions. Also, weed species density and diversity will be greater early in the soybean growing season before herbicide application and full canopy development than late in the season after herbicide application and canopy closure.

Material and Methods

Site Description and Experimental Design

A wheat-soybean, double-crop rotation was initiated in fall 2001 at the University of Arkansas Lon Mann Cotton Research Station, Marianna (N 34^0, 44', 2.26"; W 90^0, 45'

51.56"; Cordell 2004) in the Mississippi River Delta region of eastern Arkansas. The soil is classified as a Calloway silt loam (fine silty, mixed, active, thermic Glossaquic Fraglossudalf) (Web Soil Survey 2008). The study area was under continuous soybean production using CT prior to initiating this field experiment (Cordell et al. 2006; Brye et al. 2006).

The experimental design was a four-factor, split-strip plot consisting of tillage, irrigation, burning, and residue-level factors. Tillage treatments (CT and NT) represented the main plot and were arranged as a randomized complete block with three replications. Burn treatments (burn and no-burn) formed a strip plot and were arranged across tillage treatments within two burning blocks. Residue level [high (H) and low (L)] represented the strip-split plot within tillage-burning treatment combinations. There were six replications of each of the eight treatment combinations for a total of 48 plots. The whole study area was then divided into two blocks for imposing the irrigation treatment (irrigated and dry-land) across tillage treatments, which was similar to the burning blocks (Appendix 1).

Field Management

In fall 2001, the study area was prepared by disking twice followed by a broadcast application of 20 kg N ha^{-1}, 22.5 kg P ha^{-1}, 56 kg K ha^{-1}, and 1120 kg ha^{-1} of pelletized limestone prior to wheat planting. Wheat was a winter crop (cultivars 'Coker 9663' for 2001 to 2004 and 'Coker 9553' for 2005 and 2006) and was drill-seeded in fall each year. Plots, 3-m wide by 6-m long were established in early spring 2002 and were maintained throughout the study period. In early March 2002 through 2004, all plots were broadcast fertilized with 101 kg N ha^{-1} as urea. To obtain different levels of wheat residue, the high-residue plots (n = 24) were broadcast fertilized with an additional 101 kg N ha^{-1} as urea at about the late-jointing stage in approximately late March. In spring 2005, no N fertilizer was applied because a wheat stand was not established due to excessive moisture in fall 2004. In 2006 and 2007, only the high-residue plots were broadcast fertilized with 56 kg N ha^{-1} as urea in early March followed by an additional 56 kg N ha^{-1} in late March. Low-residue treatments did not receive any N fertilizer to ensure a residue-level difference was achieved.

Standing wheat stubble was mowed to about 3 cm from the soil surface to create a uniform, residue-covered soil surface after wheat grain harvest in early June. The burn treatment was then imposed followed by tillage. In 2005 and 2007, residue burning was not possible due to the absence of a wheat stand in spring 2005 due to wet conditions at planting and prolonged wet conditions in spring 2007. Thus wheat residue was retained on the soil surface as under no-burn treatment. Tillage treatments consisted of either CT as disking twice to a depth of about 10 cm and seedbed smoothing or NT.

Glyphosate-resistant soybean (cultivars 'Pioneer 95B32' maturity group 5.3 for 2002 through 2005 and 'Armor 54-03' maturity group 5.4 for 2006 and 2007) was drill-seeded in early to mid-June each year. Irrigation was performed during the soybean growing seasons only. In 2002 through 2004, all plots were furrow irrigated while in 2005 though 2007 one half of the plots were irrigated four to six times throughout the soybean growing season. The other half of the plots were left as dry-land between 2005 and 2007.

Pest management was performed uniformly in all plots on an as-needed basis. Glyphosate was sprayed once approximately 10 to 20 days after planting (DAP) soybean as per recommendations by the University of Arkansas Cooperative Extension Service (UACES 2003a, b). During the wheat growing season, thifensulfuron + tribenuron-methyl herbicide was sprayed uniformly on all plots as per University of Arkansas Cooperative Extension Service recommendations (Cordell et al. 2006; UACES 2003a, b) in March each year, except in 2005 when there was no wheat stand and in 2007 when a herbicide application was not needed.

Weed Population Assessment

Weed species and population density assessments were conducted in two randomly located 0.25-m^2 sections in each plot by visual observation and identification. Weed population assessments were conducted twice during the 2006 and 2007 soybean growing seasons, once, before herbicide application (early-season), and again late in the growing season approximately 97 DAP and after herbicide application. Weed species populations from the two locations per plot were averaged to obtain one weed density value per species per plot and converted to plants m^{-2} before being subjected to statistical analysis.

Statistical Analyses

Weed density data were analyzed by analysis of variance as per the four-factor split-strip plot design to determine the effects of tillage, burning, and residue level on weed population density. Year and season (i.e., 2006 and 200 and early- and late-season weed densities) were included in the statistical model to determine treatment effects before and after herbicide application and emergence of late-season weeds in different treatments. Means were separated using least significant difference (LSD) at $\alpha = 0.05$. All statistical analyses were performed using the PROC MIXED procedure of SAS (SAS Institute, Inc., Cary, NC) according to the split-strip experimental design.

Results and Discussion

During the 2006 and 2007 soybean growing seasons, 29 weed species were observed (Table 1). Of the species observed, weed population densities throughout the whole study area were generally low, ranging from 0.02 plants m^{-2} for bermudagrass to 38 plants m^{-2} for smooth pigweed (*Amaranthus hybridus* L.).

All weed species densities differed among tillage-year-season treatment combinations ($P = 0.011$) (Table 2). All weed species densities were greater ($P < 0.05$) early in the soybean growing season before herbicide application in both tillage treatments (513 for CT and 340 for NT in 2006 and 149 for CT and 151 plants m^{-2} for NT in 2007, respectively) than late in the season (48 in both CT and NT in 2006 and 32 for CT and 60 plants m^{-2} for NT in 2007, respectively) (Table 3). Comparing between years, there was a greater total weed species density in 2006 than 2007, but only early in the soybean growing season before herbicide application. However, late in the soybean growing season, total weed species density did not differ between years. These results indicate that weed control using glyphosate was equally effective in all treatments and during both years of weed assessment. Total weed species density was greater under CT (513 plants m^{-2}) than NT (340 plants m^{-2}) early in the 2006 growing season (Table 3).

However, in 2007, NT had a greater total weed species density (60 plants m^{-2}) than CT (32 plants m^{-2}) late in the season (Table 3). These results indicate there was a reduction of early season weed species density with adoption of NT in 2006 and 2007, but an increase in weed species under NT late in the soybean growing season. Thus, reducing soil disturbance has the potential to reduce weed infestations early in the soybean growing season in the wheat-soybean double-crop system.

Other weed species with large densities (i.e., > 5 plants m^{-2}) were carpetweed (*Mollugo verticillata* L.), cheat (*Bromus secalinus* L.), henbit (*Lamium amplexicaule* L.), red sprangletop [*Leptochloa filiformis* (Lam.) Beauv.], rice flatsedge (*Cyperus iria* L.), prickly sida (*Sida spinosa* L.), and pitted morningglory, which mostly occurred early in the soybean growing season before herbicide application, except for henbit which only occurred late in the season. Other weed species with moderate densities (i.e., 2 to 5 plants m^{-2}) included Palmer amaranth (*Amaranthus palmeri* S. Wats), goosegrass [(*Eleusine indica* (L.) Gaertn)], spotted spurge [*Chamaesyce maculata* (L.) Small], yellow woodsorrel (*Oxalis stricta* L.), fall panicum (*Panicum dichotomiflorum* Michx.), entireleaf morningglory (*Ipomoea hederacea var. integiuscula* Gray.), and large crabgrass [*Echinocloa crus-galli* (L.) Beauv.] (Table 1).

The weed species observed in this study were similar to the most common weed species reported in a weed survey in the Mississippi River Delta region after 10 years of adoption of glyphosate as the major weed control practice in the glyphosate-resistant soybean production system (Rankins et al., 2005). Similar to this study, Rankins et al. (2005) observed an abundance of carpetweed early in the soybean growing season, which was attributed to the lack of use of preemergence herbicides. Puricelli and Tuesca (2005) also reported a decrease in total weed density with the use of glyphosate, but late-emergence weed species increased in a wheat-soybean, double-crop rotation and in continuous soybean and maize (*Zea mays* L.) systems on a loam soil in Argentina. The results from this study and Legere et al. (2008) provided evidence that postemergence-herbicide-program performance in soybean production is similar between NT and CT.

The density of grass weed species differed significantly among all treatment combinations ($P = 0.023$) (Table 2). The grass weed species density early in the soybean season was greatest ($P < 0.05$) under the NT-burn-low residue in 2006 (167 plants m^{-2}) (Table 4) and NT-burn-high-residue in 2007 (139 plants m^{-2}) (Table 5) compared to all other tillage-burning-residue-level treatment combinations within a year. In contrast, the NT-no-burn combination had a lower grass weed density (41 to 47 plants m^{-2} in 2006 and 56 to 63 plants m^{-2} in 2007, respectively) than the CT-burn and no-burn and NT-burn (44 to 167 plants m^{-2} in 2006 and 82 to 139 plants m^{-2} in 2007, respectively) treatments combinations early in the growing season in both years. Late in the season, grass species density was lower (< 32 plants m^{-2}) than early in the season at any tillage-burning-residue level combination in either year (Table 4 and 5), except in 2006 where the NT-burn combination had a greater grass density (68 for high and 47 plants m^{-2} for low residue level) than all other treatment combinations late in the season (Table 4). These results show that retaining wheat residue (i.e., without burning) was sufficient to suppress the growth of grass weed species and that NT without surface residue was insufficient to reduce grass weed density. Thus, retaining crop residues either on the soil surface or via incorporation to the soil by cultivation is an effective weed control method to suppress grasses. Low grass species densities late in the soybean growing season after herbicide application in all treatments indicates that no substantial herbicide interference occurred under either tillage treatment or in the presence of surface residue (i.e., in the no-burn treatment) for grass weed species control.

Most grass weed seeds are small and require sunlight to trigger germination and promote growth, thus placement of such seeds near the surface or at a shallow depth and exposure to sunlight is essential for weed seed germination and growth (Liebman and Davis 2000). It is possible that blocking of sunlight due to surface residue and allelopathic effects of wheat residue (Steinsiek et al., 1982) have contributed to low grass weed species density under the no-burn treatment. Similar to this study, Bilalis et al. (2003) reported a reduction in weed species density when 60% of wheat residues were retained on the soil surface in clay-loam soil in Greece due to reduction of weed photosynthesis. Cultivation or a soil disturbance that buries weed seed to a deeper depth and/or maintains a surface residue cover that blocks sunlight can contribute to effective grass weed species control (Cardina et al. 2002; Locke et al. 2002a, b) without repeated herbicide applications. Fischer et al. (2002) reported greater annual grass densities under NT when wheat residue was removed than when residue was retained in a clay-loam and sandy-clay-loam soil in Mexico.

Similar to this study, Fraud-Williams et al. (1983) reported greater total numbers of weed seedlings under plowed than uncultivated treatments. However, annual grasses were more prevalent in uncultivated and shallowly cultivated soil than in deep-plowed soil in Britain (Fraud-Williams et al., 1983). Cardina et al. (2002) observed greater grass seed densities under reduced tillage than NT in both continuous corn and in corn-soybean rotations in a silt-loam soil in Ohio suggesting greater survival of grass seed. Thus, greater grass weed species my occur under moderately disturbed soil than under undisturbed soil with a surface residue cover.

The grass weed species observed throughout the study area were bermudagrass, fall panicum, goosegrass, large crabgrass, red sprangletop, and cheat. Among all grass weed species, cheat, fall panicum ,large crabgrass, goosegrass, and red sprangletop were significantly affected by the residue management practices. Large crabgrass ($P = 0.039$) and goosegrass ($P = 0.037$) densities differed among tillage-year-season treatment combinations, and goosegrass density differed among burning-year combinations ($P = 0.009$) (Table 6). Cheat ($P = 0.001$) and fall panicum ($P = 0.001$) differed among year-season (Table 6). Cheat, a cool season grass was observed in 2007 early in the soybean growing season only while fall panicum mostly occurred in 2006, and was greater late (27 plants m^{-2}) than early in the soybean growing season (6 plants m^{-2}) (Fig. 2).

Large crabgrass density was greater early in the season (6 plants m^{-2}) than late in the season (0 plants m^{-2}) only under NT treatments in 2006, but was similar between seasons in all other tillage-year combinations (< 3 plants m^{-2}) combinations (Table 3). Similarly, goosegrass was greater early in the season (20 under CT and 10 plants m^{-2} under NT, respectively) than late in the season (< 1 plants m^{-2}) in both tillage treatments in 2006. Goosegrass density was greater under no burn (9 plants m^{-2}) than burn (6 plants m^{-2}) in 2006 (Fig. 1). In 2007, large crabgrass and goosegrass densities were lower than in 2006 and did not differ among season and tillage treatment combinations (Table 3). Similar to this study, Norsworthy (2008) reported a decrease in large crabgrass density after two years of tillage and herbicide application.

Similar to total grass weed density, red sprangletop density, which accounted for 40% of all grasses observed in this study, differed among tillage-burning-residue-year-season combinations (Table 6). Red spangletop density was greatest early in the soybean growing season under the NT-burn-low-residue combination (137 plants m^{-2}) in 2006 compared to all other tillage-burning-residue-year-season (< 53 plants m^{-2}) combinations, and under CT, burn and no burn had similar red sprangletop density (Table 4). Red sprangletop occurred mostly in 2006 early in the soybean season. These results indicate the advantage of retaining crop residue in reducing red sprangletop infestation under NT. The low red sprangletop density late in the soybean growing season also shows that glyphosate was effective at controlling red sprangletop and other grasses. The red sprangletop density late in the soybean growing season did not differ between burning treatments in 2006 (Table 4), but in 2007, red sprangletop density was greater under the NT-burn-low-residue (13 plants m^{-2}) than under NT-no-burn combination at either residue level (2 plants m^{-2}) (Table 5). These results also suggest that the presence of wheat residue has the added advantage for red sprangletop control in addition to the use of glyphosate when using NT practice in the wheat-soybean, double-crop rotation.

Wheat residue management practices also affected sedge species density, where the sedge density differed among year-residue (P = 0.040), year-season (P = 0.001), and tillage-burning-season treatment combinations (Table 2). Sedge density was greater in 2006 than in 2007 and greater early than late in the season (Fig. 2). In 2006, sedge density was greater under the high- (48 plants m^{-2}) than the low-residue-level treatment (32 plants m^{-2}) (Fig. 1). Among tillage-burn-season combination, sedge density was greater under CT-no-burn (201 plants m^{-2}) and CT-burn (198 plants m^{-2}), than under NT in combination with either burn (149 plants m^{-2}) or no burn (116 plants m^{-2}) early in the soybean season before herbicide application in 2006 (Fig. 3). In this study sedge density was reduced with application of glyphosate. In contrast, Rankins et al. (2005) reported an increase in the occurrence of yellow nutsedge in glyphosate-resistant soybean production systems relative to before use of glyphosate to control weeds, which was likely due to the known ineffectiveness of glyphosate on yellow nutsedge.

Averaged across years, the density of broadleaf weeds was greater [99 standard error (SE) = 9 plants m^{-2}] compared to that of grass [49 (SE = 5) plants m^{-2}] and sedge [21 (SE = 4) plants m^{-2}] weed species throughout the whole study area. The average broadleaf species density was greater in 2006 [147 (SE = 17) plants m^{-2}] than in 2007 [50 (SE = 5) plants m^{-2}].

Similar to all weed species, total broadleaf weed species density was affected by tillage-year-season combinations (*P* = 0.001) (Table 2). The broadleaf density was greater early (349 for CT and 200 plants m^{-2} for NT, respectively) than late (18 plants m^{-2} for CT and 20 plants m^{-2} for NT, respectively) in the soybean season at same level of tillage in 2006 (Table 3). In 2007, broadleaf density did not differ between seasons (< 67 plants m^{-2}) (Table 3). Similar to all weed species, broadleaf species density was greater under CT (349) than NT (200 plants m^{-2}) early in the season in 2006, but in 2007, CT had fewer broadleaf species (50 and 30 plants m^{-2} early and late in the season, respectively) than NT (66 and 55 plants m^{-2} early and late in the seasons, respectively) in 2007 (Table 3).

Among broadleaf weed species, the density of carpetweed, henbit, pitted morningglory, prickly sida, and smooth pigweed were also affected by the residue management practices investigated. Carpetweed density differed among tillage-year-season combinations ($P = 0.001$) (Table 7) and was greater in 2006 early in season and under CT (153 plants m^{-2}) than NT (35 plants m^{-2}). In 2007, carpetweed density did not differ between season and tillage treatments (Table 3). Pitted morningglory density differed among tillage-burning-residue-year combinations ($P = 0.047$) (Table 7) and was greater in 2006 under CT in combination with all burn-residue combinations (7 to 14 plants m^{-2}) than in 2007 (1 to 3 plants m^{-2}), but under NT, pitted morningglory density did not differ between years (Table 8). These results show that NT maintained a relatively low pitted morningglory density in both years. Norsworthy and Frederick (2005) also reported a lower pitted morningglory weed under NT than CT in loamy-sand soil in South Carolina, which was attributed to increased emergence under CT due to pitted morningglory's large seed size.

Tillage-residue ($P = 0.024$), residue-year-season ($P = 0.021$), and tillage-burning-year-season ($P = 0.045$) combinations significantly affected prickly sida density (Table 7). Prickly sida density was greater under the NT-low-residue (10 plants m^{-2}) than all other tillage-residue combinations (Fig. 1). In addition, prickly sida density was greater under burning treatment in combination with NT in both years and both season (10 to 20 plants m^{-2}) than under no burn at any tillage-year-season combination (1 to 7 plants m^{-2}) (Table 3). Similar to grasses, surface residue removal in the absence of cultivation appears to have stimulated germination and growth of prickly sida.

The results of this study indicate that CT and NT in the presence of a high level of surface residue can reduce the density of most broadleaf weed species. In contrast, Reddy (2001) reported no effect of surface residue on prickly sida density in silt-loam soils in Mississippi. However, similar to this study, Anderson (2005) reported reduced weed seedling emergence under NT with > 2000 kg ha^{-1} of crop residue. In this study, the high-residue treatment with the low prickly sida density had an average surface residue cover of 14.7 Mg ha^{-1} in 2006 and 9.8 Mg ha^{-1} in 2007 at the time of soybean planting (Table 9). Nguojio et al. (2003) also reported few weed species and a low weed density under NT with surface residue both early and late in the season sandy-loam soils in California.

The density of smooth pigweed also differed among year-season ($P = 0.001$) and tillage-residue-year ($P = 0.013$) combinations (Table 7). Most of the smooth pigweed occurred in 2006 early in the season with a mean density of 138 plants m^{-2} compared to 14 plants m^{-2} in 2007 (Fig. 2), which did not differ among tillage and residue level treatments (Fig. 3).

Cutleaf evening-primrose (*Oenothera laciniata* Hill), henbit, and northern jointvetch were also affected by residue management practices (Table 7) and some management practices appeared to have effective control of these species. Cutleaf evening-primrose also occurred in low densities under the NT-low-residue combination only in both years. Henbit, a winter annual, was not observed in 2006, but was present in 2007 late in the season only (Fig. 2) and was greater under NT than CT (Fig. 1). Similar to these results, Locke et al. (2002b) reported a dominance of evening-primrose (*Oenothera spp.*) in the absence of a cover crop in silt-loam soils in Mississippi. Legere et al. (2008) also reported greater weed species diversity under NT than CT despite statistically similar weed species densities between tillage treatments in soybean production in a clay and clay-loam soil in Canada.

Perennial weed density was also affected by tillage-year-season ($P = 0.006$) and burn-year-season ($P = 0.020$) combinations (Table 2). Similar to all weeds and broadleaf weed, perennial density was greater early than late in the season in 2006 (Table 3). In 2007, perennial weed density was also greater early than late in season, but only under NT (Table 3). Under CT, the perennial weed density was similar between seasons (5 and 2 plants m^{-2} early and late in the season, respectively) (Table 3). These results indicate that CT reduced perennial weed density and, although perennial weed density increased under NT, some perennial weeds were effectively controlled by glyphosate application. Among burning-year-season treatment combinations, perennial density was greater under burn (99 plants m^{-2}) than no burn (59 plants m^{-2}) early in the soybean season in 2006, but did not differ between burn treatments in 2007 (12 and 18 plants m^{-2} under burn and no burn, respectively) (Fig. 1). The lack of burning effect in 2007 may be due to retaining crop residues under the burn treatment in 2007 because the burn treatment was not possible to impose due to prolonged wet conditions in Spring 2007. However, in both burn and year combinations, perennial weed density was similar late in the season after herbicide application (< 5 plants m^{-2}). Retaining crop residue by without burning suppressed perennial weeds by 40% early in the season before herbicide application. Similar to these results, Norsworthy (2008) reported an increase in perennial weed density under NT in absence of glyphosate application, but not when glyphosate was applied in soybean-corn rotation in sandy-loam soil in South Carolina.

Among the perennial weeds observed in this study, wild onion, rice flatsedge, and yellow woodsorrel were affected by residue management practices. Wild onion differed among tillage-burning-residue-year-season ($P = 0.031$) combinations (Table 9) was greater under burning in combination with NT and CT at either residue level (3 to 8 plants m^{-2}) than all other tillage-burning-residue combinations and was observed only late in the season in 2007 (Table 5). The density of rice flatsedge differed among burning-year-season ($P = 0.020$) combinations and was greater under burn (31 and 64 plants m^{-2} in 2006 and 2007, respectively) than no burn (22 and 31 plants m^{-2} in 2006 and 2007, respectively) in both years during early in the season, but lower later in the season under both burning treatments (Fig. 4).

Yellow woodsorrel occurred in low density under NT only in 2006 (1 plants m^{-2}). In 2007, yellow woodsorrel density was greater under NT in combination with either residue level early in the season (13 to 36 plants m^{-2}) than in all other tillage-residue-year-season combinations. However, in both years, yellow woodsorrel density was lower late than early in the season, indicating effective control by glyphosate application.

Although the density of trumpetcreeper [*Campsis radicans* (L.) Seem. ex Bureau] was unaffected by residue management practices, trumpet-creeper was not observed under the CT treatment in either year. These results suggest that cultivation and retaining crop residue without burning may be an effective control measure for perennials by disrupting the rhizomes. Bilalis et al. (2003) observed the greatest perennial weed biomass under NT with no surface cover compared to CT with and without the presence of surface cover in a clay-loam soil in Greece, which was attributed to the lack of disturbance of lateral roots, stolons, and rhizomes under NT.

In this study, a low density of Virginia pepperweed (*Lepidium virginicum* L.) (1.5 plant m^{-2}) occurred in the NT treatment only. Although in low densities, it appears that the NT and low residue/residue removal treatments are likely to have more diverse weed species than the CT-high-residue-level treatments before or in the absence of herbicide applications. These results show that reduced-tillage or NT can decrease weed densities, but, without sufficient crop residues covering the soil surface, weed species composition may be increased under NT.

The difference in weed densities between the two years of this study could be associated with differences in weather conditions. The mean precipitation early in the soybean season (June and July) was 67% greater in 2007 than in 2006. Adequate moisture supply by rainfall early in the season might have favored faster soybean growth and canopy closure in 2007 than in 2006 resulting in a reduction of most weed species in 2007 compared to that in 2006. In addition, the absence of the actual burn treatment in 2007 might have contributed to a reduction of most weed species in 2007 compared to that in 2006. Norsworthy (2008) also reported variation in weed species density from year to year and a general decrease in density of grass and broadleaf weed species after four years of tillage and herbicide application in sandy-loam soil in South Carolina.

Successful integrated weed management practices in agricultural systems are determined not only by adequate levels of weed control, but also by their effect on crop yield. Since most weed species densities differed between tillage, burn, and residue level treatments soybean yield under these treatment combinations were used to asses the effect of weeds on soybean yield. In the two years of weed assessment, which correspond to fifth and sixth year of consecutive residue management practices, soybean yield was unaffected by tillage, burn, and residue level treatments (Table 10) (Verkler, 2007). Soybean yields under CT were numerically greater than under NT, despite greater weed species density under CT early in the soybean growing season and similar weed density between tillage treatments late in the season, indicating no significant effect of weed pressure early in the season before herbicide application on soybean yield reduction. These results suggest that the post-emergence herbicide rate and timing of application used in this study controlled weeds during the critical weed free period required for soybean growth and yield.

Similar to this study, Swanton et al. (2002) reported similar soybean and corn yields among weed management practices despite differences in weed densities under NT in a silt-loam soil in Canada. In this study, NT appears to have greater weed species composition and numerically lower soybean yields than CT. Reddy et al. (2003) also reported similar soybean yield between CT and NT treatments and crop covers (i.e., rye cover crop and no cover crop), but greater yield when herbicide was applied postemergence than when no herbicide was applied in a silt-loam soil in Mississippi. In addition, pre- and postemergence herbicide applications had similar soybean yields as the postemergence herbicide application in the presence of a surface residue cover (Reddy et al. 2003). These results suggest that, in the absence of appropriate weed control, weed density and biomass can result in a significant yield reduction. The previous and the current studies show that integrating weed control using herbicides and retaining soil surface residue cover have the potential to reduce weed problems and maintain soybean yields, while reducing the frequency of herbicide applications and improving farm profitability.

The results of this study, which represents the cumulative effect of five and six years of consistent residue management, provide evidence that if managed properly, little to no increase in weed problems can be realized in a continuous, wheat-soybean, double-crop rotation. This is evidenced by the generally low weed densities and the decreased total weed species density in the sixth year (2007) relative to the fifth year (2006) of consistent management using alternative wheat residue management practices. Low densities of early emergence weed species and grasses late in the soybean growing season also show that glyphosate applied at recommended rates provides sufficient control of weeds in soybean in eastern Arkansas. Retaining crop residues on the surface without burning combined with either shallow cultivation or NT reduced densities of grasses, prickly sida, and cutleaf evening-primrose. Therefore, the NT, no burning, and high-residue level treatments appeared to contribute significantly to the suppression of most weed species without reducing herbicide efficacy. In addition, this study can serve as a baseline for future weed assessments to determine trends in potential weed species shift after a greater duration of consistent alternative residue management practices in a wheat-soybean, double-crop system in the Mississippi River Delta region of eastern Arkansas.

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Table 1. Summary of the combined weed species present during the 2006 and 2007 soybean growing seasons before (i.e., early season) and after (i.e., late season) herbicide application and their mean (N = 96) density throughout the whole study area in a wheat-soybean, double-crop production system in the Mississippi River Delta region of eastern Arkansas. Standard errors are shown in parenthesis.

Scientific name	Common name	Bayer code	Weed species density	
			Early	Late
			Plants m^{-2}	
Aeschynomene virginica (L.) B.S.P.	northern jointvetch	AESVI	0.0	0.3 (0.1)
Allium canadense L.	wild onion	ALLCA	0.0	0.8 (0.4)
Amaranthus hybridus L.	smooth pigweed	AMACH	75.8 (9.9)	0.7 (0.3)
Amaranthus palmeri S. Wats.	Palmer amaranth	AMAPA	4.6 (0.7)	0.2 (0.1)
Bromus secalinus L.	cheat	BROSE	30.5 (4.8)	0.0
Campsis radicans (L.) Seem. ex Bureau	trumpetcreeper	CMIRA	0.1 (0.1)	0.3 (0.1)
Conyza Canadensis (L.) Cronq.	horseweed	ERICA	0.0	0.2 (0.1)
Cynodon dactylon (L.) Pers.	bermudagrass	CYNDA	0.0	0.02 (0.02)
Cyperus esculentus L.	yellow nutsedge	CYPES	0.8 (0.6)	0.9 (0.6)
Cyperus iria L.	rice flatsedge	CYPIR	39.3 (6.3)	0.0
Digitaria sanguinalis (L.) Scop.	large crabgrass	DIGSA	2.1 (0.5)	0.0
Echinocloa crus-galli (L.) Beauv.	barnyardgrass	ECHCG	0.1 (0.1)	0.0
Eclipta prostrate (L.) L.	eclipta	ECLAL	1.7 (0.5)	0.0
Eleusine indica (L.) Gaertn.	goosegrass	ELEIN	8.6 (1.4)	0.1 (0.0)
Euphorbia maculata (L.)	spotted spurge	EPHMA	9.3 (4.0)	0.4 (0.2)
Ipomoea hederacea var. integriuscula Gray.	entireleaf morningglory	IPOHG	1.3 (0.3)	0.9 (0.3)
Ipomoea lacunosa L.	pitted morningglory	IPOLA	5.0 (1.1)	5.4 (1.0)
Lamium amplexicaule L.	henbit	LAMAM	0.0	16.7 (3.6)
Lepidium virginicum L.	Virginia pepperweed	LEPVI	0.4 (0.1)	0.0
Leptochloa filiformis (Lam.) Beauv.	red sprangletop	LEFFI	37.2 (4.5)	1.8 (0.5)

Table 1. Continued.

Scientific name	Common name	Bayer code	Weed species density	
			Early	Late
			Plants m^{-2}	
Mollugo verticillata L.	carpetweed	MOLVE	59.9 (7.7)	0.3 (0.1)
Oenothera laciniata Hill	cutleaf evening-primrose	OEOLA	0.3 (0.1)	0.0
Oxalis stricta L.	yellow woodsorrel	OXAST	6.8 (1.9)	0.1 (0.1)
Panicum dichotomiflorum Michx.	fall panicum	PANDI	3.3 (0.8)	13.4 (2.9)
Physalis angulata L.	cutleaf groundcherry	PHYAN	0.8 (0.3)	0.0
Portulaca oleracea L.	common purslane	POROL	0.5 (0.3)	0.3 (0.1)
Sida spinosa L.	prickly sida	SIDSP	7.8 (1.0)	4.8 (0.9)
Trifolium pratense L.	red clover	TRFPR	0.0	0.04 (0.04)
Trifolium repens L.	white clover	TRFRE	2.0 (1.6)	0.0

Table 2. Analysis of variance summary of the effects of tillage, residue burning, residue level, year, and season [early (pre-) and late (postherbicide applications)] on densities of total weed species, all grasses, broadleaf, sedges, and perennial weed species that occurred in 2006 and 2007 during the soybean growing season in the Mississippi River Delta region of eastern Arkansas. Only interactions terms that were significant for at least one of the five weed groups tested are reported. All other interactions were not significant at the 0.05 level.

Source of variation	df[†]	All species	Grasses	Broad-leaf	Sedges	Perennials
		P				
Tillage	1	0.035	ns[‡]	0.009	ns	ns
Burning	1	ns	ns	ns	0.026	ns
Residue	1	ns	ns	ns	ns	ns
Year	1	ns	ns	ns	ns	ns
Season	1	0.001	0.001	0.001	0.001	0.001
Till*burn	1	ns	0.011	ns	ns	ns
Burn*residue	1	ns	ns	ns	ns	0.041
Till*year	1	0.037	ns	0.010	ns	0.011
Till*season	1	0.008	ns	0.003	0.040	ns
Residue*year		ns	0.019	0.001	0.040	ns
Year*season	1	0.001	0.001	ns	0.001	0.001
Till*residue*year	1	ns	0.006	ns	ns	0.026
Till*burn*season	1	ns	ns	ns	0.041	ns
Till*year*season	1	0.011	ns	0.001	ns	0.006
Burn*year*season	1	ns	ns	ns	ns	0.020
Till*burn*residue*year	1	ns	0.017	ns	ns	ns
Till*burn*residue*yr*season	1	ns	0.023	ns	ns	ns

[†] degrees of freedom (df)

[‡] not significant (ns)

Table 3. Effect of tillage and season on the densities of total weed species, broadleaf, perennial weeds, carpertweed (MOLVE), large crabgrass (DIGSA), and goosegrass (ELEIN) in 2006 and 2007 in a wheat-soybean, double-crop system in the Mississippi River Delta region of eastern Arkansas.

Year	Season	Till	All species	Broad-leaf	Perennial	MOLVE	DIGSA	ELEIN
			plants m^{-2}					
2006	Early	CT	513aA*[†]	349aA*	99aA*	153aA*	2aA*	20aA*
		NT	340aB	200aA	60aA	35aA	6aA	10aA
	Late	CT	48bA	18bA	4bA	1bA	0aA	0bA
		NT	48bA	20bB	< 1bA	1bA	0bA	< 1bA
2007	Early	CT	149aB	50aB*	5aB*	10aB	< 1aA	2aB
		NT	151aA	66aB	25aB	2aB	< 1aB	2aB
	Late	CT	32bA*	30aA*	1aA	0aA	0aA	0aA
		NT	60bA	55aA	2bA	< 1aA	0aA	< 1aA
[‡]^{1}LSD$_{0.05}$			57	43	20	14	2	5
^{2}LSD$_{0.05}$			34	20	17	19	1	3
^{3}LSD$_{0.05}$			19	12	15	14	1	1

[†] Means of different season within a column followed by different lower case letters are significant different using ^{1}LSD$_{0.05}$

Means of different year within a column followed by different upper case letters are significant different using ^{2}LSD$_{0.05}$

Means of different tillage within a similar year-season combination column followed by an asterisk (*) are significant different using ^{2}LSD$_{0.05}$

[‡] Least significant difference (LSD) at 0.05 level

^{1}LSD$_{0.05}$ for comparison of means within a column with different season at same year and tillage

^{2}LSD$_{0.05}$ for comparison of means within a column with different year at same tillage and tillage

^{3}LSD$_{0.05}$ for comparison of means within a column with different tillage at the same year and season.

Table 4. Effect of tillage, burning, residue level, and season on the density of grass weed species, red sprangletop (LEFFI), and prickly sida (SIDSP) in 2006 in a wheat-soybean, double-crop system in the Mississippi River Delta region of eastern Arkansas.

Year-season	Tillage	Burning	Residue	Grasses	LEFFI	SIDSP
				Plants m^{-2}		
2006-early	CT	Burn	High	71aA[†]	43aA	11a
			Low	44aB*	24aB*	
		No burn	High	73aA*	35aA	4a
			Low	74aA*	43aA*	
	NT	Burn	High	68aB	53aB x	13b
			Low	167aA	137aA x	
		No burn	High	47aA	25aA	4a
			Low	41aA	22aA	
2006-late	CT	Burn	High	25bA	0bA	4b*
			Low	30aA	1aA	
		No burn	High	32bA	0bA	3a
			Low	20bA	0bA	
	NT	Burn	High	68aA	0bA	21a
			Low	47aB	0bA	
		No burn	High	10bA	0aA	3a
			Low	22aA	0aA	
[‡] $^{1}LSD_{0.05}$				35	29	6
$^{2}LSD_{0.05}$				17	14	-
$^{3}LSD_{0.05}$				21	16	2
$^{4}LSD_{0.05}$				181	22	25

[†] Means of different season within a column followed by different lower case letters are significant different using $^{1}LSD_{0.05}$

Means of different residue within a column followed by different upper case letters are significant different using $^{2}LSD_{0.05}$

Means of different tillage within a column of similar season followed by an asterisk (*) are significant different using $^{3}LSD_{0.05}$

Means of different burning within a column of similar season-tillage-residue combination followed by an 'x' are significant different using $^{4}LSD_{0.05}$

[‡] Least significant difference (LSD) at 0.05 level

$^{1}LSD_{0.05}$ for comparison of means within a column with different season at the same tillage and burning

$^{2}LSD_{0.05}$ for comparison of means within a column with different burning at the same tillage and season

$^{3}LSD_{0.05}$ for comparison of means within a column with different tillage at the same or different burning and season

$^{4}LSD_{0.05}$ for comparison of means within a column with different burning at the same tillage, residue, and season

- Not applicable

Table 5. Effect of tillage, burning, residue level, and season on the density of grass weed species, red sprangletop (LEFFI), and prickly sida (SIDSP) in 2007 in a wheat-soybean, double-crop system, in the Mississippi River Delta region of eastern Arkansas.

Year-season	Till	Burning	Residue	Grasses	LEFFI	ALLCA	SIDSP
				Plants m^{-2}			
2007-early	CT	Burn	High	99aA*†	31aA	0aA	7a*
			Low	96aA	32aA	0aA	
		No burn	High	100aA*	32aA	0aA	7a
			Low	88aA*	16aB	0aA	
	NT	Burn	High	139aA	18aB	0aA	10a
			Low	82aB	43aA	0bA	
		No burn	High	63aA	18aA	0aA	6a
			Low	56aA	21aA	0aA	
2007-late	CT	Burn	High	4bA	4aA	3aA*	3a
			Low	1bA	1bA	0aB*	
		No burn	High	1bA	1bA	0aA	1a
			Low	2bA	0aa	< 1aA	
	NT	Burn	High	2bA	2aA	< 1aB	4a
			Low	13bA	13bA	8aA	
		No burn	High	3bA	2aA	0aA	1a
			Low	2bA	2aA	0aA	
‡^{1}LSD$_{0.05}$				35	29	3	6
^{2}LSD$_{0.05}$				17	14	1	-
^{3}LSD$_{0.05}$				21	16	2	2
^{4}LSD$_{0.05}$				181	22	9	25

†Means of different season within a column followed by different lower case letters are significant different using ^{1}LSD$_{0.05}$

Means of different residue within a column followed by different upper case letters are significant different using ^{2}LSD$_{0.05}$

Means of different tillage within a column of similar season followed by an asterisk (*) are significant different using ^{3}LSD$_{0.05}$

Means of different burning within a column of similar season-tillage-residue combination followed by an 'x' are significant different using ^{4}LSD$_{0.05}$

‡ Least significant difference (LSD) at 0.05 level

^{1}LSD$_{0.05}$ for comparison of means within a column with different season at the same tillage and burning

^{2}LSD$_{0.05}$ for comparison of means within a column with different burning at the same tillage and season

^{3}LSD$_{0.05}$ for comparison of means within a column with different tillage at the same burning and season

^{4}LSD$_{0.05}$ for comparison of means within a column with different burning at the same tillage, residue, and season

\- Not applicable

Table 6. Analysis of variance summary of the effects of tillage, residue burning, residue level, year, and season [early (pre-) and late (postherbicide applications)] on densities of total large crabgrass (DIGSA), goosegrass (ELEIN), red sprangletop (LEFFI), fall panicum (PANDI), and cheat (BROSE) that occurred in 2006 and 2007 during the soybean growing season in the Mississippi River Delta region of eastern Arkansas. Only interactions terms that were significant for at least one of the five weed groups tested are reported. All other interactions were not significant at the 0.05 level.

Source of variation	df[†]	DIGSA	ELEIN	LEFFI	PANDI	BROSE
				P		
Tillage	1	0.017	0.004	ns[‡]	ns	ns
Burning	1	ns	0.043	0.014	ns	ns
Residue	1	ns	ns	ns	ns	ns
Year	1	ns	ns	ns	ns	ns
Season	1	0.001	0.001	0.001	0.003	0.001
Till*burn	1	ns	ns	0.005	ns	ns
Till*residue	1	ns	ns	0.027	0.015	ns
Till*year	1	0.016	ns	ns	ns	ns
Burn*year	1	ns	0.009	ns	ns	ns
Till*season	1	0.024	0.034	ns	ns	ns
Burn*season	1	ns	ns	0.008	ns	ns
Year*season	1	0.001	0.001	0.001	0.001	0.001
Till*burn*year	1	ns	ns	0.004	ns	ns
Till*residue*year	1	ns	ns	ns	0.010	ns
Till*burn*season	1	ns	ns	0.0086	ns	ns
Till*residue*season	1	ns	ns	0.034	ns	ns
Till*year*season	1	0.039	0.037	0.048	ns	ns
Till*burn*year*season	1	ns	ns	0.008	ns	ns
Till*burn*residue*yr*season	1	ns	ns	0.030	ns	ns

[†] degrees of freedom (df)

[‡] not significant (ns)

Table 7. Analysis of variance summary of the effects of tillage, residue burning, residue level, year, and season [early (pre-) and late (postherbicide applications)] on densities of total carpetweed (MOLVE), henbit (LAMAM), pitted morningglory (IPOLA), prickly sida (SIDSP), and smooth pigweed (AMACH) that occurred in 2006 and 2007 during the soybean growing season in the Mississippi River Delta region of eastern Arkansas. Only interactions terms that were significant for at least one of the five weed groups tested are reported. All other interactions were not significant at the 0.05 level.

Source of variation	df[†]	MOLVE	LAMAM	IPOLA	SIDSP	AMACH
				P		
Tillage	1	0.038	0.042	ns[‡]	ns	ns
Burning	1	ns	ns	ns	ns	ns
Residue	1	ns	ns	ns	ns	ns
Year	1	ns	ns	ns	ns	ns
Season	1	0.001	0.001	ns	0.006	0.001
Till*burn	1	ns	ns	ns	0.018	ns
Till*residue	1	ns	ns	ns	0.024	0.024
Till*year	1	0.048	0.042	ns	ns	ns
Till*season	1	0.001	ns	ns	ns	ns
Year*season	1	0.001	0.001	ns	0.019	0.001
Till*residue*year	1	ns	ns	ns	ns	0.013
Till*year*season	1	0.001	ns	ns	0.049	ns
Residue*year*season	1	ns	ns	ns	0.021	ns
Till*burn*residue*year	1	ns	ns	0.047	ns	ns
Till*burn*year*season	1	ns	ns	ns	0.045	ns

[†] degrees of freedom (df)

[‡] not significant (ns)

Table 8. Effect of tillage, burning, and residue levels on the pitted morningglory (IPOLA) density in 2006 and 2007 in the Mississippi River Delta region of eastern Arkansas.

Year	Tillage	Burning	Residue	IPOLA
				plants m^{-2}
2006	CT	Burn	High	7aA[†]
			Low	10aA
		No burn	High	14aA
			Low	10aA
	NT	Burn	High	7aA*
			Low	< 1aA*
		No burn	High	3aA
			Low	5aA
2007	CT	Burn	High	2bA
			Low	1bA
		No burn	High	2bA
			Low	3bA
	NT	Burn	High	3aA
			Low	2aA
		No burn	High	6aA
			Low	8aA
[1]LSD[‡]$_{0.05}$				4
[2]LSD$_{0.05}$				5
[3]LSD$_{0.05}$				28

[†] Means of different year within a column followed by different lower case letters are significant different using [1]LSD$_{0.05}$

Means of different burning within a column followed by different upper case letters are significant different using [3]LSD$_{0.05}$

Means of different tillage within a column and similar year-burning-residue combination followed by an asterisk (*) are significant different using [2]LSD$_{0.05}$

[‡] Least significant difference (LSD) at 0.05 level.

[1]LSD$_{0.05}$ is for comparison of means with different year at same level of tillage, burning, and residue-level

[2]LSD$_{0.05}$ is for comparison of means with different residue at same level of tillage, burning, and year

[3]LSD$_{0.05}$ is for comparison of means with different burning at same level of tillage, residue, and year

Table 9. Summary of wheat residue-levels on the soil surface of the no-tillage/no-burn treatment combinations before soybean planting in 2006 and 2007.

Residue level	2006	2007
	Mg ha^{-1}	
Low	8.7	6.2
High	14.7	9.8

Table 10. Summary of soybean yields under tillage [conventional tillage (CT) and no-tillage (NT)]-burn-residue-level treatment combinations during the weed assessment period in 2006 and 2007 in the Mississippi River Delta region of eastern Arkansas.

			Soybean yield	
Tillage	Burning	Residue	2006	2007
			Mg ha^{-1}	
CT	Burn	Low	2.57	1.96
	No-burn	High	2.57	2.13
	Burn	Low	2.23	1.72
	No-burn	High	2.15	2.02
NT	Burn	Low	2.29	1.97
	No-burn	High	2.39	1.86
	Burn	Low	1.79	1.98
	No-burn	High	2.09	2.07

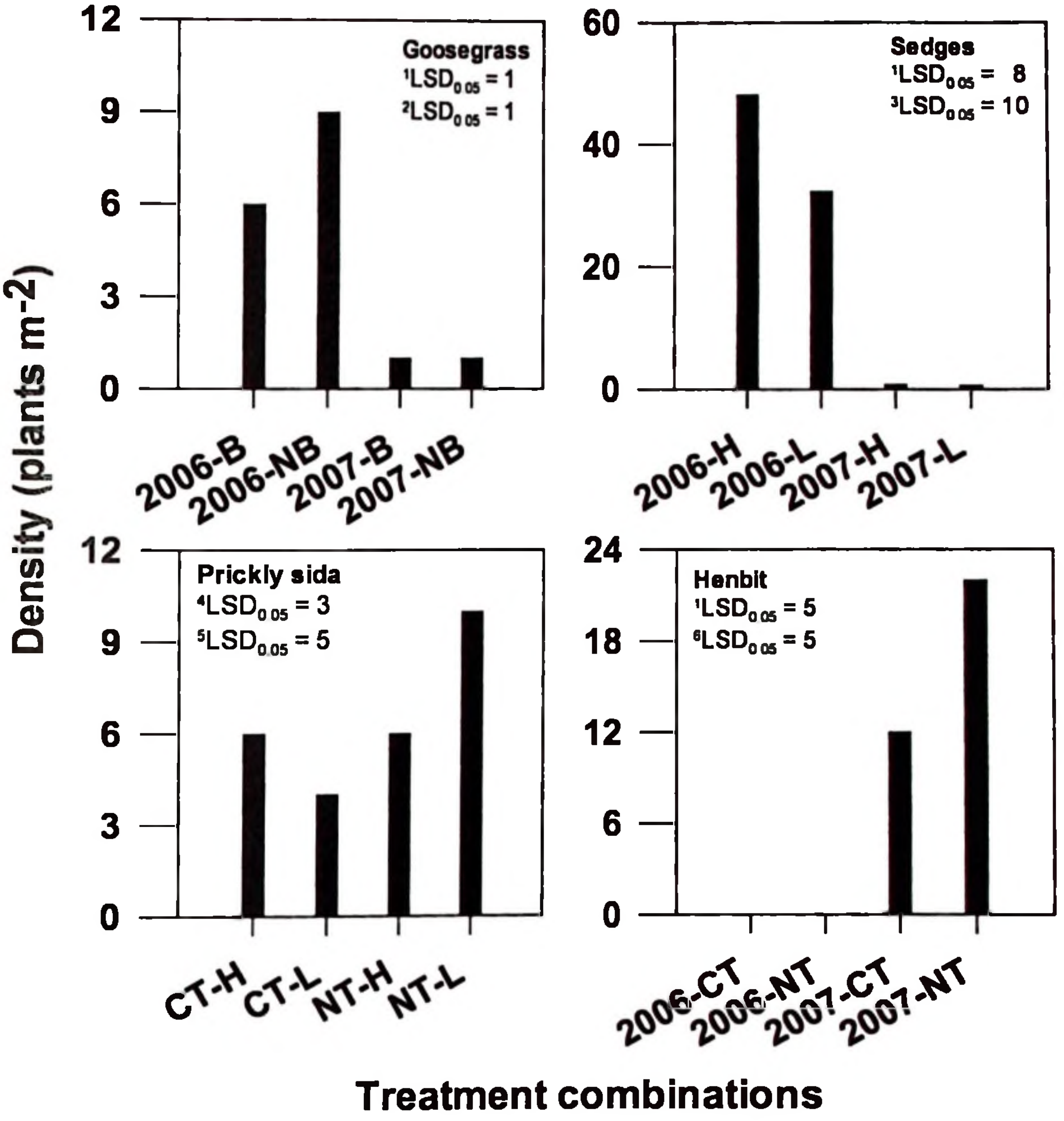

Figure 1. Effect of tillage [conventional tillage (CT) and no-tillage (NT)], burning [burn (B) and no burn (NB)], and residue level [low (L) and high (H)] on the density of goosegrass, sedges, prickly sida, and henbit in 2006 and 2007 in a wheat-soybean, double-crop production system in the Mississippi River Delta region of eastern Arkansas. $LSD_{0.05}$ is least significant difference at the 0.05 level. $^1LSD_{0.05}$ is for comparison of means of goosegrass, sedges, and henbit between years at the same burning, residue level and tillage, respectively; $^2LSD_{0.05}$ is for comparison of means of goosegrass under different burning; $^3LSD_{0.05}$ is for comparison of sedges under different residue level; $^4LSD_{0.05}$ is for comparison of means of prickly sida under different residue level at the same level of tillage; $^5LSD_{0.05}$ is for comparison of means of prickly sida under different tillage; $^6LSD_{0.05}$, is for comparison of means of henbit under different tillage level.

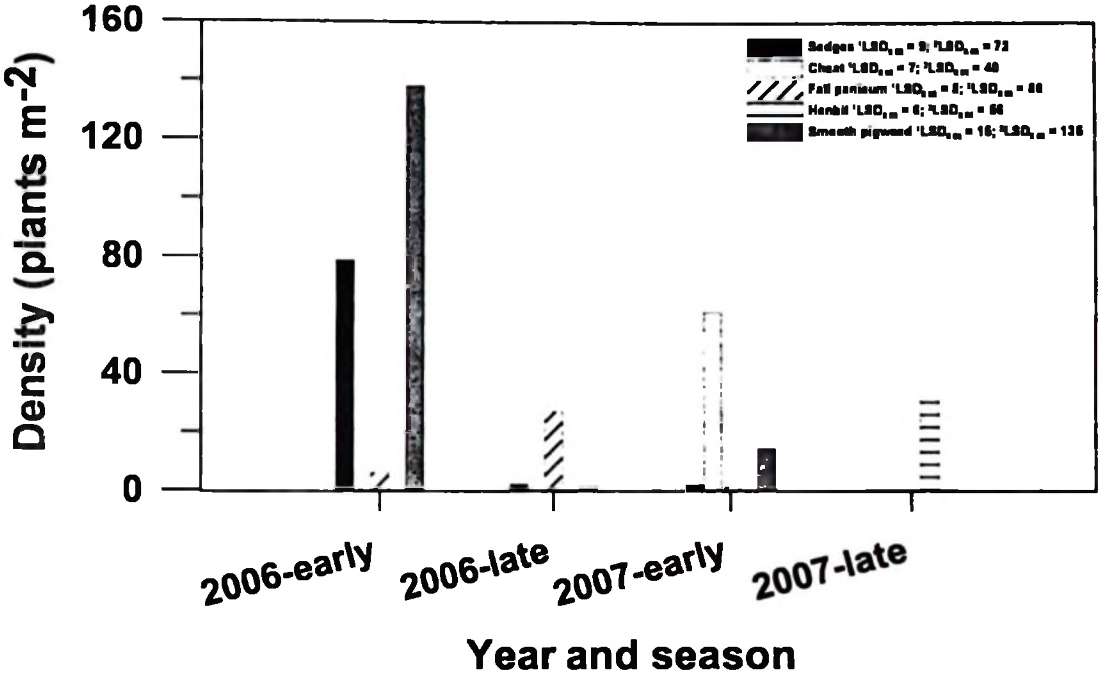

Figure 2. Effect of season [pre- (early) and postherbicide (late) application] on the population density of sedges, cheat, fall panicum, henbit, and smooth pigweed in 2006 and 2007 in a wheat-soybean, double-crop production system in the Mississippi River Delta region of eastern Arkansas. LSD$_{0.05}$ is the least significant difference at the 0.05 level. ^{1}LSD$_{0.05}$ is for comparison of means of similar bars with different seasons in the same year; ^{2}LSD$_{0\,05}$ is for comparison of similar bars with different years in the same or different season.

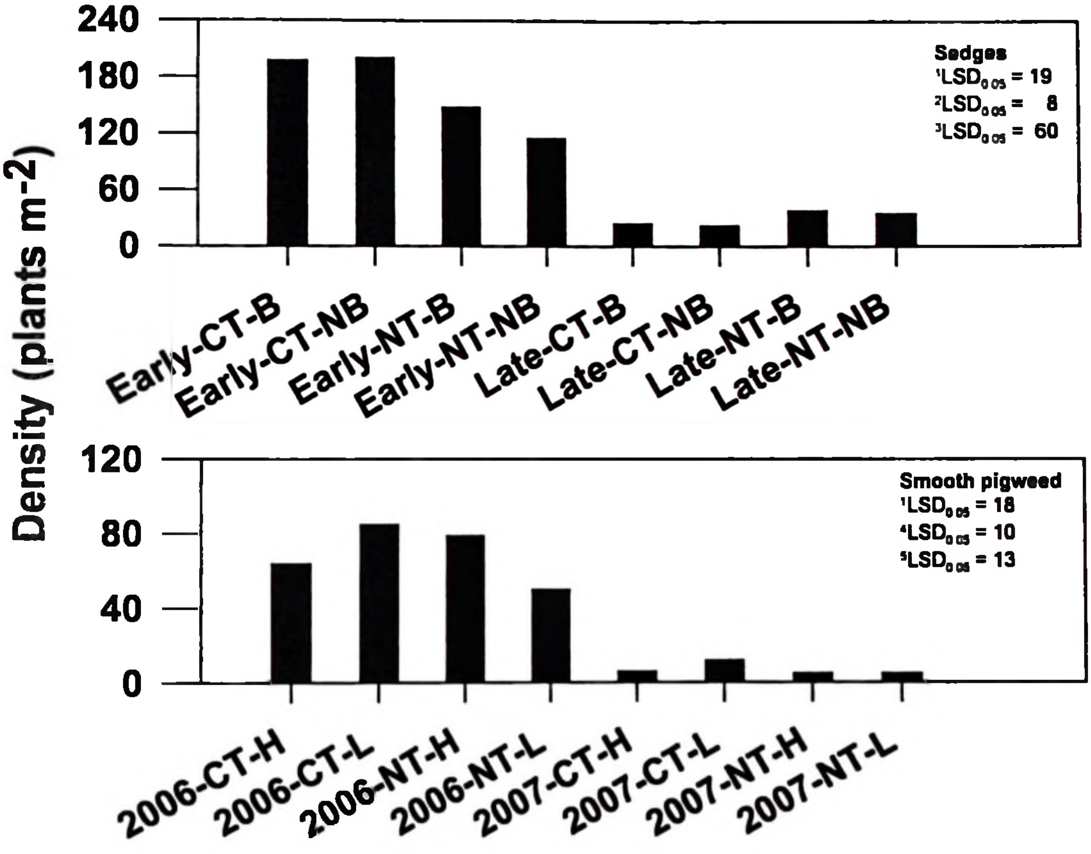

Figure 3. Effect of tillage [conventional tillage (CT) and no-tillage (NT)], burning [burn (B) and no burn (NB)], and residue level [low (L) and high (H)] on the density of sedges and smooth pigweed in early and late in the soybean growing season in 2006 and 2007, in a wheat-soybean, double-crop production system in the Mississippi River Delta region of eastern Arkansas. LSD$_{0.05}$ is the least significant difference at the 0.05 level. ^{1}LSD$_{0.05}$, is for comparison of means of sedges and smooth pigweed with different seasons and year, respectively, at the same burning and residue level, respectively and same tillage; ^{2}LSD$_{0.05}$ is for comparison of means of sedges with different tillage at same level of burning and season; ^{3}LSD$_{0.05}$ is for comparison of means of sedges with different burning level; ^{4}LSD$_{0.05}$ is for comparison of smooth pigweed with different residue; ^{5}LSD$_{0.05}$, is for comparison of means of smooth pigweed with different tillage at same residue and year level.

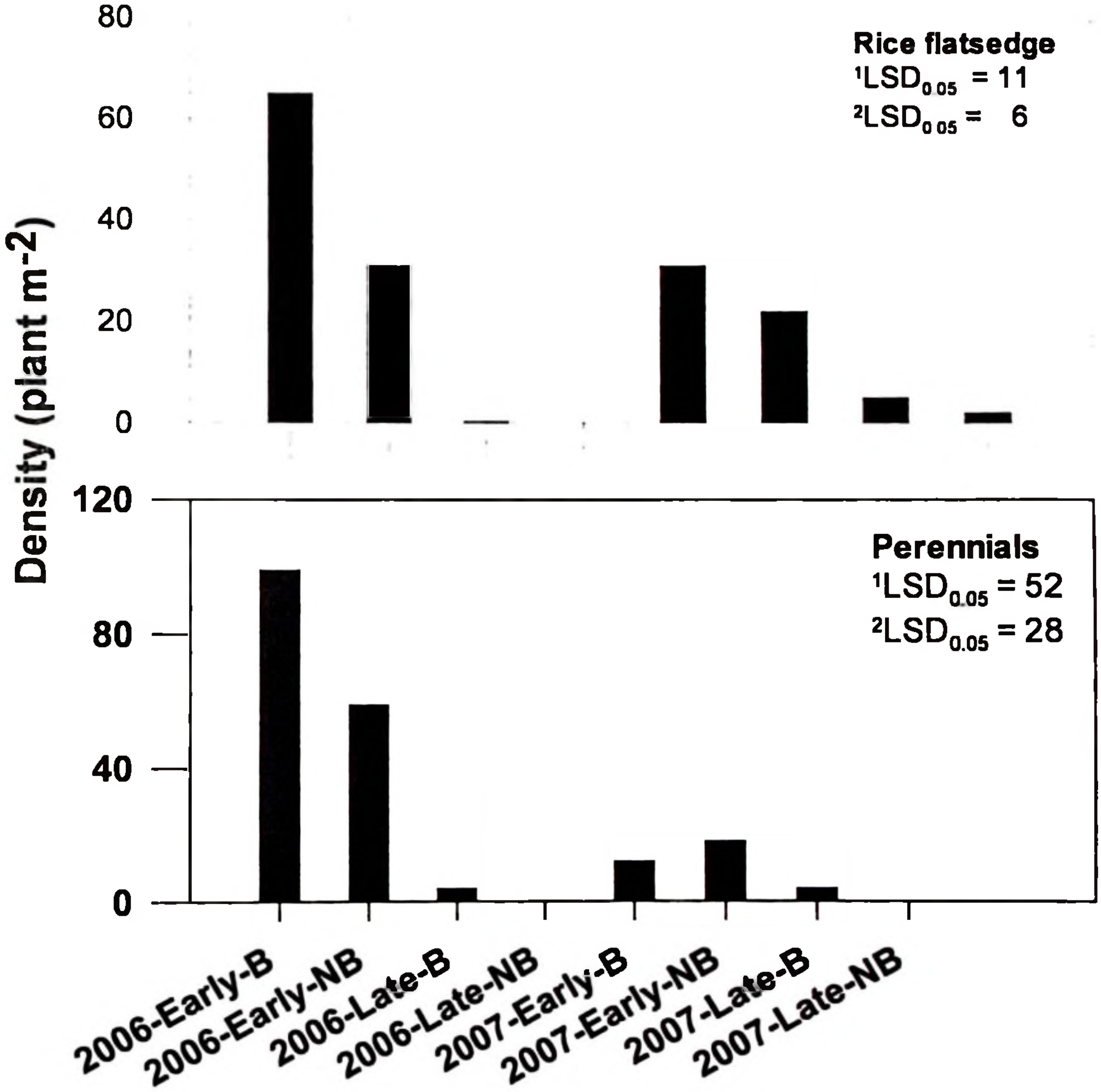

Figure 4. Effect of wheat residue burning [burn (B) and no burn (NB)] and season [pre- (early) and postherbicide (late) application] on rice flatsedge and perennial weed density in 2006 and 2007 in a wheat-soybean, double-crop system in the Mississippi River Delta region of eastern Arkansas. $LSD_{0.05}$ is least significant difference at the 0.05 level. $^1LSD_{0.05}$ is for comparison of means with different year-season combinations at same burning level; $^2LSD_{0.05}$ is for comparison of means with different burning at the same year-season combination.

CHAPTER FOUR

Residue Management Practice Effects on Soil Penetration Resistance in a Wheat-soybean Double-crop Production System

Abstract

Improving long-term agricultural sustainability will require appropriate soil and residue management practices. Soil cone index (CI) is an important physical property relating to soil and crop productivity, particularly in intensive cropping systems. A study was initiated in 2001 to evaluate the effect of alternative residue management practices on soil penetration resistance (PR) in a wheat (*Triticum aestivum* L.)-soybean [*Glycine max* (L.) Merr.] double-cropped system in the Mississippi River Delta region of eastern Arkansas. Residue management treatments consisted of tillage [conventional (CT) and no-tillage (NT)], residue burning (burn and no burn), and residue level (low and high, achieved through application of different fertilizer-N rates). Soil PR, as measured by the cone index (CI), was determined at 0.05-m intervals to a depth of 0.4 m in 2003, after one, and in 2006, after four complete cropping cycles, using a hand pushed penetrometer. The whole-field CI increased with depth in both years. Tillage, burning, and residue level generally did not affect CI in the top 0.2-m in either year. In both years, soil CI was consistently lower under burning than non-burning at all depth below 0.2 m. Compared to after only one year, four years of NT soybean resulted in a 35 % increase in CI at the 0.05-m depth. Soil CI was reduced at the 0.4-m depth under NT and non-burning, but increased somewhat under CT and non-burning after 4 years. Being aware of the potential effects of alternative residue management on soil physical and hydraulic properties and root growth in relation to soil penetration resistance will be necessary to ensure future sustainability of soil management practices.

***Keywords*:** residue, burning, tillage, wheat, soybean, compaction

1. Introduction

Improving soil and residue management practices are key factors in improving soil quality for agricultural production. Soil penetration resistance (PR), also commonly referred to as cone index (CI), is an important soil-quality-related parameter that influences and/or is influenced by water infiltration, gas fluxes, nutrient availability, root penetration, and hence crop growth and yield potential. Increased soil resistance to penetration is an indication of soil compaction. Soil compaction is a major problem for producers in intensely cropped areas (Williams and Weil, 2004) because intensive cropping systems generally require more cultural operations, which result in a greater frequency of vehicle and implement passage and greater opportunity for additional compaction to occur. Recently, Chan and Barchia (2007) concluded that soil compaction controlled earthworm populations in south-eastern Australia, where both earthworm density and biomass in the top 7.5 cm decreased significantly as soil bulk density increased (i.e., soil compaction increased) over the range of ~ 1.2 to 1.55 Mg m^{-3}.

Double- or multi-crop systems are among the most intensive cropping systems, particularly in the mid-southern and southeastern United States and elsewhere, due to the harvest of more than one crop per year. Busscher et al. (2000) projected that 50 % of the total soybean planted area in the southeastern United States is grown in a wheat (*Triticum aestivum* L.)-soybean [*Glycine max* (L.) Merr.] double-crop system. Scott et al. (1998) estimated that 25 to 40 % of the production area in the mid-southern and southeastern United States is double-cropped with a small grain such as wheat. In Arkansas, where more than 1.2 million ha of soybean are grown annually (NASS-USDA, 2007), the wheat-soybean double-crop system is popular and accounts for approximately 30 % of the planted soybean area (ASPB, 2007). On average, wheat-soybean double-cropping has constituted about 11 % of the soybean area in Missouri for the past five years (NASS-USDA, 2007). As the demand for soybean potentially increases for use in bio-diesel fuel production (Ash et al., 2006), the amount of land area in a wheat-soybean double-crop production system will likely increase.

The wheat-soybean double-crop system is particularly advantageous for producers because two crops are produced with diverse potential uses for food, seed-oil products, animal feed, and recently developed bio-diesel for fuel. Multiple crops with diverse uses help producers spread production risks as the two crops have different market demands. In addition, double-cropping contributes to increased crop residues for soil organic matter enrichment, reduced erosion due to winter soil cover, and can lead to increased total production per unit land area (Lewis and Phillips, 1976). However, the double-cropping system demands careful management as it requires more intense land use, labor, machinery, and capital investment.

To meet the additional challenges and expenses encountered in double-cropping, many growers have adopted no-tillage (NT). The development of herbicides, planting equipment (Lewis and Phillips, 1976), narrow row spacing (Frederick et al., 1998), herbicide-resistant soybean, early maturing cultivars, which minimize yield differences between NT and conventional tillage (CT) practices, has stimulated expansion of the double-cropping system. No-tillage aids in timely planting of soybean following wheat, reduces labor and fuel requirements, conserves soil moisture critical for planting and summer growth, and controls wind and water erosion (Lewis and Phillips, 1976).

Tillage practices have been reported to cause significant variations in soil PR at various soil depths in double-crop systems. A 2-yr study in a loamy sand in South Carolina revealed that disking loosened the top 5 to 15 cm of the soil profile under a wheat-soybean double-crop system (Busscher et al., 2000). However, disking resulted in the formation of a hard pan just below the loosened zone and 60 kPa greater resistance to penetration than without disking (Busscher et al., 2000). Raper et al. (2005) reported that, with similar soil moisture in the top 0.3 m, hard-pan formation occurred at a shallower depth (0.21 m) under CT than under NT (0.34 m) in a silt-loam soil under continuous soybean in Mississippi. In a winter wheat-sorghum [*Sorghum bicolor* (L.) Moench] rotation on a clay loam in Texas, Unger (1996) reported similar penetration resistance between CT and NT. However, the traffic-furrow position had a greater mean CI (0.93 MPa) in the 0.05 to 0.25 m depth compared to the non-traffic-furrow position (0.70 MPa) in the same soil depth interval. Data from these studies suggest that wheel traffic is the major cause of hard-pan formation and increased PR. Furthermore, a study comparing NT and periodic tillage after long-term NT in wheat-soybean double-crop system in Kentucky showed that the average PR in the top 0.3 m of a silt loam was 35% greater in NT (1.24 MPa) than in tilled soil (0.99 MPa) (Diaz-Zorita et al., 2004). However, penetration resistances in both tillage treatments were less than the critical levels for normal root growth of 2.0 to 2.5 MPa (Taylor et al., 1966). Ehlers et al. (1983) reported that the critical CI for root growth is 3.6 MPa for tilled and 4.6 to 5.1 MPa for untilled loess topsoil with 80 % silt content under field moisture conditions. The differences in CI critical levels for root growth under tilled and untilled were explained as being due to the build up of a continuous pore system in untilled soil created by earthworms and roots from preceding crops (Ehlers et al., 1983; Williams and Weil, 2004).

Soil compaction has both direct and indirect negative effects on crop growth. Soil compaction impairs crop growth primarily through restricting the plant's capacity to capture resources, resulting in reduced nutrient and water uptake, hence decreased interception of photosynthetic active radiation (Ehlers et al., 1983; Sadras et al., 2005). Indirectly, compaction reduces the rate of nitrogen mineralization, symbiotic fixation, and increases the rate of denitrification, hence affecting most of the nitrogen budget (Lipiec and Stepniewski, 1995).

Regardless of tillage method used, residue management still poses great challenges in the wheat-soybean double-crop system. Thus, many producers in the mid-southern and southeastern United States choose to burn wheat residue soon after harvesting to facilitate timely planting of soybean (Sanford, 1982). However, burning has been reported to decrease soil C, N, aggregate stability, water infiltration (Wuest et al., 2005; Murphy et al., 2006), and extractable soil P, S, Ca, and Mg compared to leaving residue in tact on the soil surface (Murphy et al., 2006). Results from other studies have shown that burning results in emissions of N, C, and S gases due to high temperatures during combustion, which favor volatilization of the gaseous forms of these elements (Boubel et al., 1969; Caldwell et al., 2002; Murphy et al., 2006). While surface residues have been reported to reduce machine-induced compaction in forest soils (Ess et al., 1998), retaining crop residues in agricultural fields have produced varied results with regard to soil compaction. Ess et al. (1998) reported no significant reduction of machine-induced compaction due to the presence of above-ground residue in a silt loam in

Virginia. However, compaction was reduced due to the reinforcing effect of the undisturbed root network within the soil (Ess et al., 1998). In contrast, a laboratory study by Guerif (1979) showed that incorporation of undecayed wheat straw reduced compactibility of a clay soil. Maiorana et al. (2001) compared burning and the incorporation of crop residue with different N fertilizers in a silty-clay Vertisol in southern Italy, but was unable to show any clear effect on soil penetration resistance.

Soil PR is influenced by several soil physical properties including soil moisture content, bulk density, and texture. Soil moisture content (Vaz et al., 2001), degree of saturation, and matric potential (Whalley et al., 2005) have been shown to be inversely related to soil PR. Thus, it is essential that the soil moisture status is characterized along with PR measurements (Vaz and Hopman, 2001). Unger (1996) reported a significant increase in PR with decreasing water content, but no significant relationship between PR and soil bulk density in an irrigated, expanding clay loam in Texas. Whalley at al. (2005) reported increased PR with increased bulk density in a sandy loam despite a relatively small change in moisture content. A simultaneous measurement of PR and volumetric water content using a combined cone penetrometer – time domain reflectometry (TDR) device in a silty clay loam in California revealed that PR tends to increase as soil bulk density increases at similar water contents (Vaz and Hopman, 2001). It was further determined that the effect of soil bulk density on PR decreases as the water content increases, and that PR increases exponentially with decreasing water content (Ehlers et al., 1983; Vaz and Hopman, 2001). Therefore, it is likely that any management practices influencing soil moisture storage will also affect penetration resistance.

Similar to the effects of soil water content, soil particle-size distribution also affects soil PR. Grunwald et al. (2001) reported negative, though non-significant, correlations between CI and silt and clay contents, and a positive correlation between CI and sand content. Brye et al. (2005) determined that at a shallow depth (5 cm), CI was significantly positively correlated with silt content, but negatively correlated with clay content, while at 10-cm depth CI was significantly negatively correlated with silt and positively correlated with sand content. Kumar et al. (2006) reported CI decrease linearly with increasing clay content and increased CI with increasing silt and sand contents. However, Whalley et al. (2005) reported greater PR in a clay soil than in a sandy loam at the same degree of saturation. It appears that different proportions of particle sizes (i.e., different soil textural classes) are likely to have a greater effect on CI than the content of individual soil separates.

Changes in CI below the plow layer, like many soil properties, due to changes in management practices are expected to occur slowly and vary with time. Wilkins et al. (2002) reported greater CI after one year of NT than CT, and that the CI under NT decreased and approached that of CT after prolonged NT in a wheat-fallow cropping system on a silt loam in Oregon. In contrast, results from other studies have shown increased CI in NT for both short- and long-term field studies under continuous corn (*Zea mays* L.; Hill, 1990; Larney and Kladivko, 1989) and under winter wheat-spring pea (*Pisum sativum* L.), and -spring barley (*Hordeum vulgare* L.) rotation (Hammel, 1989). However, the longer-term effects of alternative residue management practices, particularly those associated with the popular wheat-soybean double-crop system in the mid-southern United States, on soil PR are still relatively unknown.

Soil PR has been shown to affect soybean and wheat yields, as well as other soil properties beneficial for plant growth. Busscher et al. (2000) reported an average soybean and wheat yield decrease of 1.31 and 1.63 Mg ha^{-1}, respectively, for each megapascal increase in mean profile CI above their minimum mean profile CI of 0.82 MPa. Therefore, reducing soil PR can likely alleviate potential yield reductions. Unger (1996) also reported greater hydraulic conductivity and lower PR in the top 3.5 cm than in the 10 to 13.5 cm depth.

One way to reduce soil PR is periodic deep tillage. Deep tillage resulted in 34% lower soil strength when compared to CT without deep tillage (Busscher et al., 2000). However, deep tillage is relatively expensive, as it requires large tractors and more fuel and labor per unit area than when deep tillage is not conducted (Karlen et al., 1991). In addition, significant yield increases may stimulate producers to think that annual deep tillage is necessary (Busscher et al., 2000). Frequent deep tillage has been reported to reduce overall economic benefit of the wheat-soybean double-cropped system when compared to NT (Diaz-Zorita et al., 2004). It is evident that alternative soil and residue management practices and their potential effects on soil PR need to be evaluated in long-term double-crop production systems.

Therefore, the objective of this study was to evaluate the effect of alternative residue management practices on soil PR in a wheat-soybean double-cropped system. It was hypothesized that in the short-term, soil PR would increase under NT and residue burning compared to CT and when residue is left unburned. In addition, it was hypothesized that near-surface soil PR under NT one year after management-practice change would be greater than after four years of consistent management (i.e., soil PR would tend to decrease over time under NT).

2. Materials and methods

2.1. *Study site description*

A long-term study was initiated in Fall 2001 at the University of Arkansas' Cotton Branch Experiment Station (CBES), Marianna, (N 34^0, 44', 2.26"; W 90^0, 45' 51.56"; Cordell et al., 2006) in the Mississippi River Delta region of eastern Arkansas. The study was conducted on a Calloway silt loam (fine-silty, mixed, active, thermic Aquic Fraglossudalf; Gray and Catlett, 1966; USDA-NRCS-SSS, 2007). This soil would be most similar to a Dystric Planosol under the Food and Agriculture Organization's international soil classification scheme (FAO, 2007). The regional climate is relatively warm and wet with a 30-yr mean annual temperature minimum of -2.4^{0}C in January and maximum of 32.8^{0}C in July and mean annual precipitation of 128.2 cm (Brye et al., 2006).

2.2. *Experimental design*

The study consisted of three residue management treatments, tillage (CT and NT), residue burning (burn and no burn), and residue level (low and high, achieved through application of different fertilizer-N rates), arranged in a split-strip plot factorial experimental design (Brye et al., 2006). Tillage treatments were arranged as randomized complete block design with three replications. Burn treatments were arranged as strips across the tillage treatment with two replications. Residue-level treatments represented a split plot within the tillage-burn combinations. A total of 48 plots, 3-m wide by 6-m long, comprised the entire study area (Cordell et al., 2006; Brye et al., 2006).

2.3. Field management

Prior to Fall 2001, the study site was managed as a non-double-cropped soybean system using CT (Cordell et al., 2006). Initial field preparations in Fall 2001 included 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. Each Fall, wheat (cultivars 'Coker 9663' for 2001 to 2004 and 'Coker 9553' for 2005 and 2006) was drill seeded with a 19-cm row spacing. In early March 2002 through 2004, all plots were broadcast fertilized with 101 kg N ha^{-1} as urea. To obtain different levels of wheat residue, 24 high-residue plots were broadcast fertilized in late March at approximately the late-jointing stage (Fehr et al., 1971) with an additional 101 kg N ha^{-1}. In Fall 2004, a wheat stand was not achieved due to prolonged wet soil conditions, thus no N fertilization occurred in Spring 2005. In Spring 2006, the high-residue plots received an initial broadcast application of 56 kg N ha^{-1} as urea in late February followed by a split application of an additional 56 kg N ha^{-1} at the late-jointing stage in late-March. The low-residue plots received no N fertilization in Spring 2006. Wheat was harvested in approximately early June each year.

After each wheat harvest, the remaining above-ground wheat stubble was mowed to a height of < 3 cm from the soil surface. Mowing is not a standard practice in the mid-southern United States, but was conducted to ensure a uniform, residue-covered plot surface into which the subsequent soybean crop could be planted. After mowing, above-ground residue was collected from within 0.25-m^2 metal frame, dried at 55^{0}C for 3 days and weighed. The burn treatment was imposed followed by imposition of the tillage treatment, which consisted of disking twice followed by seedbed smoothing with a soil conditioner prior to soybean planting. In approximately mid-June each year, glyphosate-resistant soybean (cultivars 'Pioneer 95B32' maturity group 5.3 for 2002 through 2005 and 'Armor 54-03' maturity group 5.4 for 2006) was drill seeded with a 19-cm row spacing. Plots were furrow-irrigated on an as-needed basis throughout the 2003 and 2004 soybean growing seasons. However, prior to the 2005 growing season, the study area was split in half to impose an irrigated versus dry-land soybean comparison, thus 24 plots were left non-irrigated and watered periodically by natural rainfall only. Soybean was harvested in late-October to early November each year. Additional details regarding field management between Fall 2001 and Fall 2004 are described in Cordell et al. (2006) and Brye et al. (2006).

2.4. Soil sampling and measurements

Soil PR measurements (i.e., measurement of CI) were conducted in early March 2003 and late February 2006, after one and four crop rotation cycles, respectively. Soil PR measurements were conducted at two points in each plot from the 0.05- to 0.4-m depth at 0.05-m intervals using a hand-pushed, recording penetrometer (The Investigator, Spectrum Technologies, Plainfield, IL, 60544, U.S.A.; Brye et al., 2005). The penetrometer's cone angle was 20^0, base diameter was 0.013 m, and shaft diameter was 0.009 m (Brye et al., 2005). Similar to Brye et al. (2005), all PR measurements were conducted by the same operator to maintain an approximately uniform insertion rate of

1.7 m min^{-1}. Duplicate measurements per plot were averaged for one PR profile per plot for statistical analysis purposes.

Since the study area had been consistently and uniformly managed for several years prior to initiation of the long-term study in Fall 2001, it was assumed that soil PR was reasonably uniform across the study area. Therefore, differences in soil PR after one (2003) and four years (2006) of alternative residue management were assumed attributable to treatment effects rather than inherent spatial differences in soil PR throughout the study area.

Immediately after and adjacent to each PR measurement, volumetric soil water content was measured in the 0-0.06 m depth using a Theta Probe (Model TH20, Dynamax, Inc., Houston, TX, USA). In a previous study, (Cordell et al., 2006; Brye et al., 2006), soil samples had been collected from the top 0.1 m in each plot, oven-dried at 70°C for 48 hr, ground and sieved to pass a 2-mm mesh screen for particle-size analysis by the hydrometer method (Arshad et al., 1996). In 2006, soil samples were also collected in the 0 to 0.4 m depth, weighed, oven-dried at 70°C for 48 hr, and re-weighed to determine gravimetric soil water content. The same 0 to 0.4 m soil samples were also prepared as described above for particle-size analysis. Daily rainfall was manually recorded on-site throughout the duration of the study period.

After wheat harvest and before soybean planting each year, 10 to 15 soil cores were collected from the top 0.1 from each plot, combined into one sample per plot, dried for 48 hr at 70°C, and ground to pass through a 2-mm mesh screen. Soil organic matter (SOM) was then determined by weight-loss-on-ignition after 2 hr at 360 °C. In early August each year, approximately 8 weeks after soybean planting, a single 4.8-cm diameter core soil sample was collected from 0 to 10 cm depth in each plot, oven dried at 70 ^{0}C for 48 hr and weighed for bulk density determination.

2.5. Statistical analysis

The effects of residue level, burning, and tillage on soil particle-size distributions, soil water contents, and CI by depth separately were determined by analysis of variance (ANOVA) using SAS (Version 9.1, SAS Institute, Cary, NC). Treatment effects on CI were determined separately by sample date (i.e., after one and four rotation cycles) and on the CI difference between the two sample dates determined by subtracting the 2003 CI from the 2006 CI on a plot-by-plot basis. When appropriate, means were separated using the least significant difference (LSD) at $\alpha = 0.05$.

3. Results and discussion

3.1. Soil particle-size distribution and water content

Since CI is known to be dependent on soil texture and water content (Voorhees and Walker, 1977; Kasim et al., 1986; Grunwald et al., 2001; Vaz et al., 2001), it is important to demonstrate reasonable spatial and temporal uniformity with these soil properties such that observed differences in CI are largely attributable to treatment differences rather than inherent difference in soil particle-size distribution and/or water content at the time of measurement.

Though residue management practices would not have affected soil particle-size distributions, there were several apparent significant treatment effects on soil particle-size distribution in the top 0.1 m (Table 1) meaning that these generally minor variations were initial spatial differences throughout the 0.3-ha study area prior to imposing any actual treatments. However, mean sand, silt, and clay contents in the top 0.1 m differed by less than 0.03, 0.05, and 0.04 g g^{-1}, respectively, among the eight treatment combinations and averaged 0.16, 0.73, and 0.11g g^{-1}, respectively, throughout the entire study area (Brye et al., 2006). Except for a significant apparent burn effect ($P = 0.013$) on clay content, sand, silt, and clay contents in the top 0.4 m did not differ among treatments (Table 1) and averaged 0.20, 0.64, and 0.16 g g^{-1}, respectively, across the entire study area. The clay content in the top 0.4 m was 0.035 g g^{-1} greater under the pre-assigned burn than under the no-burn treatment. This slight, but significant, difference in clay was likely present at the on-set of the study prior to imposing the burn treatment.

Though a few differences in particle-size distribution existed among treatments, absolute differences were small and likely had minimal impact on penetration resistance under uniform moisture conditions. Furthermore, since soil properties, including particle-size distribution, water contents, and penetration resistance, are known to be spatially variable even within short distances, it is unrealistic to expect the soil properties within a 0.3-ha area to be exactly spatially uniform and non-varying.

Whole-field mean volumetric soil water contents in the top 0.06 m averaged 0.31 [standard error (SE) = 0.004] and 0.41 (SE = 0.004) m^3 m^{-3} in 2003 and 2006, respectively, but differed slightly ($P < 0.01$) between sample dates. In 2003, volumetric soil water contents in the top 0.06 m differed ($P = 0.023$) between tillage treatments (Table 2), but the water content difference was only 2 % (v/v). In 2006, residue level significantly ($P = 0.022$) affected volumetric soil water contents in the top 0.06 m (Table 2), but the water content difference was only 1 % (v/v). Though 2003 data are unavailable, gravimetric soil water contents in the top 0.4 m did not differ among treatments in 2006 (Table 2) and averaged 0.25 g g^{-1} across the entire study area. However, the study site received 18.6 and 18.7 cm of rainfall in the 45 days prior to conducting the PR measurements in 2003 and 2006, respectively; thus we reasonably assumed that the soil water contents in the top 0.4 m on the two sample dates were as similar as could be expected. Despite the few, though minimal, differences in particle-size distribution in the top 0.1 m and a slight spatial variation in clay content in the top 0.4 m, soil particle-size distributions throughout the study area were also as homogeneous as could be expected in the 0.4-m profile through which PR measurements were conducted. Therefore, we were confident that differences in CI were actual treatment effects rather than due to temporal differences in soil profile water content or large spatial variations in particle-size distribution.

3.2. *Treatment effects on cone index*

In 2003, after 1 year of alternative residue management, the whole-field CI increased with depth and ranged from a low of 903 kPa at the 0.05-m depth to a high of 2625 kPa at the 0.4-m depth (Fig. 1). Similar CI trends with depth have been reported in other studies (Brye et al., 2005; Williams and Weil, 2004; Unger, 1995; Hill, 1990). Except for greater CI ($P = 0.010$) at the 0.05-m depth under the high than the low residue-level treatment, neither tillage, burning, nor residue level affected CI in the top 0.15 m (Table 3; Fig. 2). Although greater root densities under the high than low fertilizer rate were expected to leave more root channels after decomposition, which generally provides less resistance for root growth in otherwise compacted soil (Ehlers et al., 1983; William and Weil, 2004), lower resistance may not have been realized yet after only one year.

Roots have also been reported to increase soil shear strength (Waldron, 1977; Waldron and Dakessian, 1981). Since soil shear strength is directly correlated to penetration resistance (Marshall and Tokunaga, 2006), although not measured directly, it is likely that a greater undecomposed root density due to the greater N fertilizer rate in the high residue-level treatment resulted in a greater CI measured by penetrometer. However, Ess et al. (1998) reported reduced machine-induced soil compaction due to a reinforcing effect of the undisturbed cover crop root network in a silt-loam soil.

Neither tillage nor residue level affected CI in the 0.2- to 0.35-m depth interval in 2003 after only 1 year of alternative residue management (Table 3; Fig. 2). However, there were significant tillage x burn ($P = 0.008$) and tillage x residue level ($P = 0.036$) interactions on CI at the 0.4-m depth (Table 3). At either tillage treatment, non-burning had higher CI than burn at 0.4-m depth. Also, CI under NT was greater than under CT at any residue level at the 0.4 m depth. Since tillage was not expected to have had any direct effect at this depth, differences in CI between burn treatments might be due to deeper rooting, higher root decomposition rates, and greater moisture content under burning than non-burning (Verkler et al., 2008).

In contrast to tillage and residue level, burning significantly ($P < 0.05$) affected CI in the 0.2- to 0.35-m depth interval (Table 3; Fig. 2). Soil CI was consistently greater under the no-burn than under the burn treatment at and below the 0.2-m depth, and the difference between treatments tended to increase with depth. The numerically lower CI under non-burning near the soil surface was likely due to steady additions to the SOM pool (Table 4). However, the lower CI under burning than non-burning at deeper depths (Fig. 2) was somewhat unexpected.

The presence of wheat residue on the soil surface has been shown to negatively affect early-season seedling development and crop growth (Sanford, 1982; Cordell et al., 2006) presumably due to reduced light penetration and the physical barrier the residue provides. Therefore, removal of surface residues by burning may have favored quicker and deeper rooting, which in turn may have reduced subsurface CI from increased SOM due to decaying roots. By a similar mechanism, Williams and Weil (2004) suggested that the creation of biopores as previous crop roots decayed could reduce soil compaction. Similarly, for two consecutive soybean growing seasons (2005 and 2006) in the same plots as used in this study, Verkler et al. (2008) reported that soil water contents at the 0.075-m depth were consistently greater under the burn than under the non-burn treatment and suggested that burning stimulated root decomposition, such that old, decayed root channels acted as preferential flow paths for quicker and deeper water infiltration. In addition, the presence of wheat residue, such as in a non-burned situation, has been reported to cause allelopathic effects on wheat (Wu et al., 2001) and soybean (Caviness et al., 1986) and reduced soil temperature (Horton et al., 1994). Reduced soil temperature would not have likely resulted in any negative effect of seed germination or seedling establishment in the Mississippi River Delta region of eastern Arkansas due to the already relatively warm air temperatures at the time of double-crop soybean planting (i.e., early to mid-June), but potential allelopathic effects may have had a negative impact on both wheat and soybean root growth.

In 2006, after 4 years of alternative residue management, the whole-field CI was numerically greater at all depths in the top 0.2 m than that in 2003, but numerically smaller at all depths below 0.2 m than that in 2003 (Fig. 1). Similar to 2003, whole-field CI in 2006 was smallest at the 0.05-m depth (1120 kPa). However, in contrast to 2003, whole-field CI in 2006 was greatest at the 0.15-m depth (2780 kPa), which is approximately the depth to the traffic-induced tillage pan present throughout the study area. Though the study area was divided into two to facilitate imposition of an irrigated versus dryland soybean comparison prior to the 2005 growing season, the only potential ramification this would have had on the study results would have been potentially increased variability in penetration resistance making significant inference potentially more difficult to achieve. Furthermore, this potential added variability was only in place for 1 of the 3-year duration of consistent management between measurements, all of which were conducted at the same time of the year and under as similar soil profile water content conditions as could reasonably be expected to minimize any potential additional variability.

In contrast to 2003 where CI was unaffected by tillage in the top 0.15 m (Table 3), CI was greater ($P = 0.003$) under NT than CT at the 0.05-m depth in 2006 (Table 5; Fig. 2), which was likely due to the numerically greater 0- to 0.1-m bulk density under NT than CT (Table 4). Similar results have been reported by Hammel (1989) who observed that, although tillage effects on CI do not always correspond well to bulk density, high CI under NT corresponded to similarly high BD in a silt-loam soil under a winter wheat-spring pea and barley rotation in Idaho. Four years of NT soybean resulted in a 35 % increase in CI at the 0.05-m depth compared to after only one year of NT soybean, while there was a negligible 2 % decrease in CI under CT. Similar to 2003, CI was unaffected by tillage between the 0.2- and 0.35-m depth interval, however CI was also unaffected by tillage at the 0.4-m depth in 2006 (Table 5). Similar to 2003, CI was unaffected by residue level in the 0.1-, 0.25-, 0.3-, and 0.35-m depths in 2006 (Table 5). In contrast to 2003, CI was also unaffected by residue level in the 0.05- and 0.4-m depths in 2006 (Table 5). Also in contrast to 2003, there were significant unexplainable three-way interactions ($P < 0.05$) on CI at the 0.15- and 0.2-m depths in 2006 (Table 5). However, similar to 2003 after only 1 year, CI was consistently lower ($P < 0.05$) under burning than non-burning at all depths at and below 0.25 m in 2006 after 4 years of consistent alternative residue management (Table 5; Fig. 2). In contrast, Maiorana et al. (2001) reported no clear effects of burning on soil CI.

Results show that, in the particular silt-loam Alfisol evaluated in this study, the soil depth at which CI is great enough to potentially limit root growth (i.e., ~ 2000 kPa and above; Taylor et al., 1966) is 0.15 m, the approximate depth of the traffic-induced tillage pan. Therefore, these soils have a relatively shallow root zone for optimal crop production, which is likely to negatively affect soil moisture availability in the case of drought conditions or under dryland soybean production due to restricted root growth and nodulation (Buttery et al., 1998). However, CI below the 0.15-m depth is likely to be agronomically insignificant during periods of adequate rainfall and/or under irrigated production practices.

In contrast to Busscher et al. (2000) who observed a significant, indirect relationship between soybean yield and mean profile CI, irrigated soybean yield was uncorrelated with mean profile CI. In this study soybean was irrigated 4 times under irrigation treatment during the season as per needed basis and irrigated soybean yield was also uncorrelated with mean CI for the 0.1- and 0.15-m depths only (Fig. 3), which approximately represents the top and bottom of the traffic-induced tillage pan present throughout the study area.

3.3. *Treatment effects on the change in cone index*

Penetration resistance is a similar soil property to soil carbon (C) in that both are known to vary spatially and temporally. Apparent year-year changes in penetration resistance or soil C are generally meaningless because of high variability tending to mask potential treatment effects. Therefore, for measured changes in CI and/or soil C to be considered accurate and representative of true treatment effects, several years of elapsed time are generally required. Thus, the 3-year duration of consistent management between measurements should be sufficiently adequate to demonstrate actual treatment effects without the added burden of dealing with inordinately large variability due to the too short duration between observations.

Despite several, though generally inconsistent, treatment effects on CI after both 1 and 4 years of alternative residue management, except for a consistent burn effect below 0.2 m, the 3-year change in CI in the agronomically significant zone > 0.15 m was affected ($P = 0.002$) by only tillage at the 0.05-m depth (Table 6). Between 2003 and 2006, CI increased by 454 kPa under NT, while CI under CT did not change. The lack of a change in CI under CT was expected since the same tillage operations (i.e., disking twice followed by soil conditioning) was used throughout the study period to uniformly loosen and manipulate the surface soil. Although 4 years of NT increased CI, CI at 0.05-

m depth in both years (Fig. 2) was below the suggested 2000-kPa-CI root-limiting threshold indicating that crop growth has likely not been limited due to compaction under NT (Table 2).

The 3-year change in CI was also affected by burning at the 0.35-m depth (P = 0.045) and had a tillage x burn interaction (P = 0.012) at the 0.4-m depth (Table 6). The 3-year change in CI was represented by a greater decrease in CI under non-burning than under burning at 0.35-m depth. Although both burning and non-burning resulted in decreased CI over the 3 year period, the greater reduction under non-burning than burning may have been due to greater addition of SOM deeper in the soil profile. Whole-field SOM in the top 0.1 m increased by 15 % from 2003 to 2006 (Table 4). At the 0.4-m depth, the CT/non-burn treatment combination resulted in increased CI, while the burn with either NT or CT decreased CI. The NT/non-burn treatment combination resulted in greatest reduction of CI at 0.4-m depth, which may be due to a combination of reduced traffic compaction, and increased SOM over time compared to under CT and burning. The change in CI was unaffected by any other treatment or interaction at any other depth (Table 6).

It is likely that significant treatment differences in CI at any single point in time and the temporal change in CI will continue to at least persist and will likely increase with increasing duration of the wheat-soybean double-crop production system. At some point in the future the soil compaction, as measured by increasing CI, under NT may result in a significant negative impact on seedling establishment, rooting, growth, and/or potentially yield. However, it is not yet known after what duration, or whether it will occur at all in the wheat-soybean double-crop production system, will the potential effects of soil compaction due to alternative residue management practices manifest themselves on crop growth and production. Considering the current significant area devoted to soybean production in the mid-south and south-eastern United States and the likely potential for this area to increase in response to the recent developments and growing interest in bio-fuels as an alternative energy source, further research is needed to ascertain the potential long-term positive and negative effects on soil properties and crop growth and production under alternative residue management practices.

4. Conclusions

Alternative residue management practices in a wheat-soybean double-crop system in the Mississippi River Delta region of the mid-Southern United States had variable effects on soil PR at both 1 and 4 years of consistent treatment. The high-residue-level treatment increased CI in the top 0.05 m after one complete cropping cycle, but decreased CI after 4 years of alternative residue management, presumably due to the enrichment of SOM from root decomposition. Although NT increased CI in the top 0.05 m after 4 years of residue management, the CI under NT was below the critical CI for root growth and crop yield. Burning resulted in an unexpectedly lower soil CI in the 0.2- to 0.35-m depth after 1 and 4 years of residue management, which may have been due to favorable effects of residue removal on root elongation and decomposition. Results show that NT and non-burning have similar effect on CI as CT and burning below the 0.05-m depth within the first 4 years of altered management, and therefore will not likely negatively affect root growth and nutrient availability to soybean or wheat. However, NT and non-burning will have the added long-term advantages of increased surface SOM enrichment and erosion control. The NT/non-burn treatment combination is also likely to have improved whole-profile soil moisture storage capability. Further research on potential long-term effect of alternative residue management on soil penetration resistance, as well as on CI-related soil properties such as hydraulic conductivity, infiltration rate, and root growth, will still be needed to improve the sustainability of alternative residue management practices.

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Table 1

Analysis of variance summary of the effects of tillage (till), burning (burn), and residue level (residue) on soil particle-size distribution in the 0 to 0.1 and 0 to 0.4 m depth intervals at the Cotton Branch Experiment Station, Marianna, eastern Arkansas

		Depth (m)					
		0 - 0.1			0 - 0.4		
Source of variation	df	Sand	Silt	Clay	Sand	Silt	Clay
		P					
Till	1	0.018	0.079	0.033	0.801	0.154	0.374
Burn	1	0.568	< 0.001	0.001	0.183	0.047	0.013
Residue	1	0.037	0.001	0.529	0.230	0.997	0.181
Till*Burn	1	0.981	0.003	0.027	0.872	0.663	0.879
Till*Residue	1	0.629	0.090	0.119	0.530	0.552	0.792
Burn*Residue	1	0.834	0.211	0.311	0.276	0.175	0.862
Till*Burn*Residue	1	0.407	0.028	0.033	0.954	0.348	0.505

df, degrees of freedom

Table 2
Analysis of variance summary of the effects of tillage (till), burning (burn), and residue level (residue) on soil water contents at the time of 2003 and 2006 penetration resistance measurements at Cotton Branch Experiment Station, Marianna, eastern Arkansas

		Water content		
		0 to 0.06 m (m^3 m^{-3})		0 to 0.4 m (g g^{-1})
Source of variation	df	2003	2006	2006
		P		
Till	1	0.023	0.097	0.084
Burn	1	0.988	0.139	0.442
Residue	1	0.496	0.022	0.115
Till*Burn	1	0.585	0.485	0.210
Till*Residue	1	0.673	0.315	0.786
Burn*Residue	1	0.551	0.895	0.360
Till*Burn*Residue	1	0.956	0.792	0.051

df, degrees of freedom

Table 3

Analysis of variance summary of the effects of tillage (till), burning (burn), and residue level (residue) on soil penetration resistance between the 0.05- and 0.40-m depths after one year of alternative residue management (i.e., 2003) at the Cotton Branch Experiment Station, Marianna, eastern Arkansas

		Soil depth (m)							
Source of variation	df	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40
		P							
Till	1	0.059	0.688	0.592	0.784	0.386	0.663	0.627	0.010
Burn	1	0.227	0.933	0.316	0.044	0.002	0.003	0.001	<0.001
Residue	1	0.010	0.281	0.584	0.866	0.722	0.984	0.663	0.213
Till*burn	1	0.355	0.323	0.152	0.149	0.381	0.231	0.191	0.008
Till*residue	1	0.356	0.586	0.058	0.797	0.093	0.408	0.361	0.036
Burn*residue	1	0.713	0.549	0.524	0.233	0.141	0.388	0.231	0.468
Till*burn*residue	1	0.383	0.949	0.985	0.776	0.117	0.169	0.317	0.170

df, degrees of freedom

Table 4

Summary of soil organic matter (SOM) concentrations and bulk density (BD) in the 0- to 10-cm depth after 1 (2003) and 4 years (2006) of alternative residue management as affected by tillage [conventional (CT) and no-tillage (NT)], burning (burn and no Burn), and wheat residue level (low and high) at the Cotton Branch Experiment Station, Marianna, eastern Arkansas. Treatment means are reported (n = 24) with standard errors in parentheses

	SOM (g kg^{-1})		BD (g cm^{-3})	
Treatment	2003	2006	2003	2006
Tillage				
CT	19.4 (0.9)	23.1 (0.6)	1.27 (0.01)	1.22 (0.01)
NT	19.7 (0.8)	22.7 (0.7)	1.31 (0.01)	1.23 (0.01)
Burning				
Burn	18.9 (0.7)	22.4 (0.5)	1.31 (0.01)	1.22 (0.01)
No burn	20.2 (0.9)	23.5 (0.8)	1.28 (0.01)	1.23 (0.01)
Residue level				
Low	19.6 (1.0)	22.4 (0.7)	1.29 (0.01)	1.22 (0.01)
High	19.5 (0.6)	23.4 (0.6)	1.29 (0.01)	1.24 (0.01)

Table 5

Analysis of variance summary of the effects of tillage (till), burning (burn), and residue level (residue) on soil penetration resistance between the 0.05- and 0.40-m depths after 4 years of alternative residue management (i.e., 2006) at the Cotton Branch Experiment Station, Marianna, eastern Arkansas

		Soil depth (m)							
Source of variation	df	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40
		P							
Till	1	0.003	0.054	0.045	0.135	0.739	0.356	0.385	0.707
Burn	1	0.237	0.014	0.133	0.112	0.047	0.003	0.003	0.002
Residue	1	0.846	0.780	0.148	0.055	0.493	0.341	0.165	0.184
Till*Burn	1	0.908	0.253	0.499	0.127	0.358	0.188	0.463	0.320
Till*Residue	1	0.104	0.052	0.019	0.689	0.277	0.249	0.235	0.951
Burn*Residue	1	0.348	0.284	0.188	0.524	0.999	0.900	0.926	0.136
Till*Burn*Residue	1	0.634	0.197	0.016	0.047	0.149	0.150	0.295	0.132

df, degrees of freedom

Table 6

Analysis of variance summary of the effects of tillage (till), burning (burn), and residue level (residue) on the change in soil penetration resistance between the 0.05- and 0.40-m depths from 2003 to 2006 after 3 years of consistent alternative residue management at the Cotton Branch Experiment Station, Marianna, eastern Arkansas

		Soil depth (m)							
Source of variation	df	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40
		P							
Till	1	0.002	0.691	0.088	0.231	0.789	0.735	0.584	0.031
Burn	1	0.126	0.315	0.772	0.323	0.203	0.187	0.045	0.169
Residue	1	0.084	0.284	0.168	0.218	0.532	0.414	0.173	0.499
Till*burn	1	0.706	0.585	0.181	0.763	0.300	0.835	0.352	0.012
Till*residue	1	0.078	0.784	0.388	0.640	0.756	0.917	0.673	0.120
Burn*residue	1	0.517	0.850	0.165	0.172	0.393	0.289	0.097	0.225
Till*burn*residue	1	0.971	0.611	0.109	0.225	0.944	0.742	0.960	0.506

df, degrees of freedom

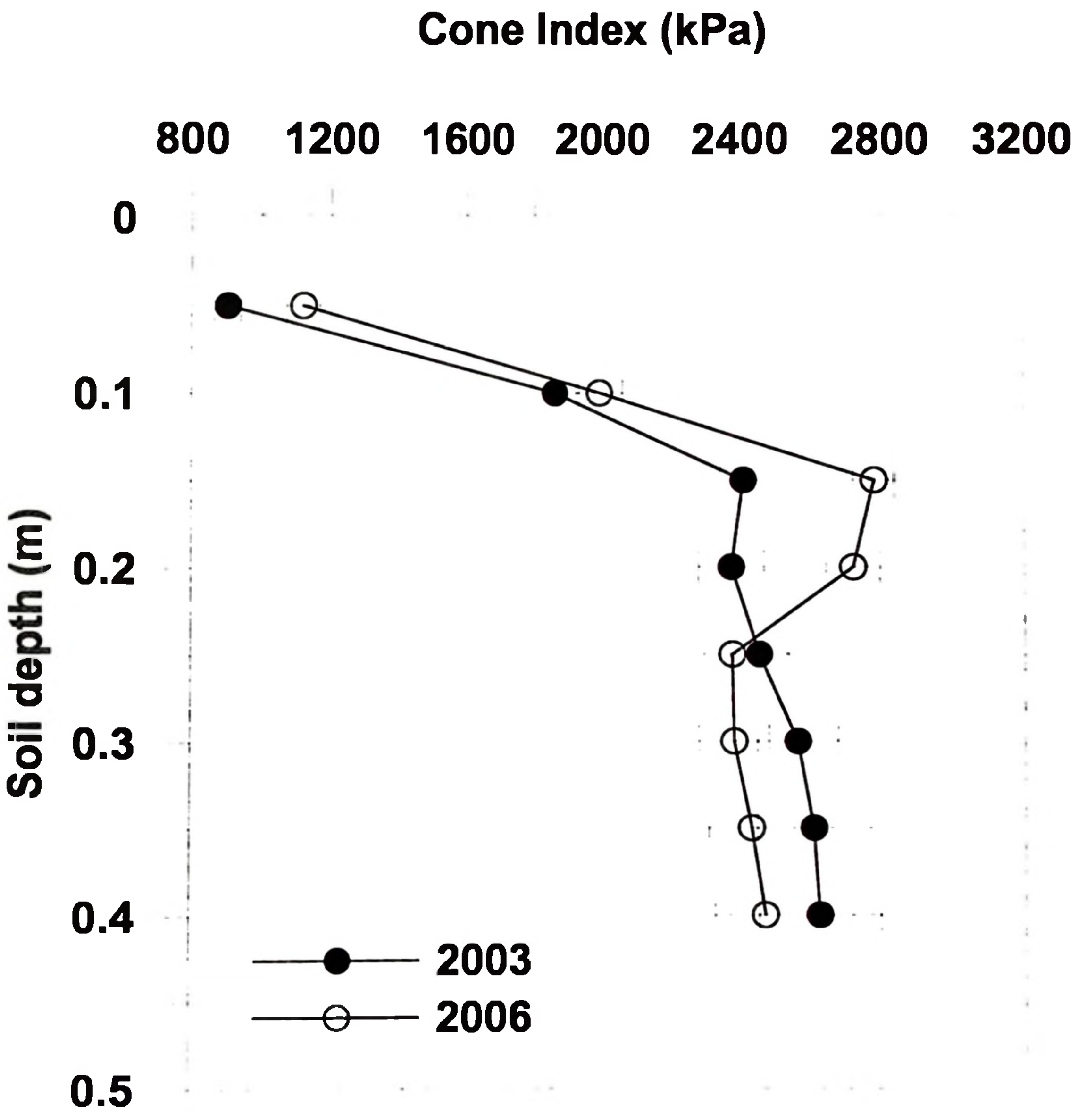


Fig. 1. Whole-field mean (n = 48 per sample date) cone index profile after one (2003) and four (2006) years of alternative residue management practices at the Lon Mann Cotton Research Station, Marianna, eastern Arkansas. Lines connecting the data points are for graphical depiction of the profile and do not imply any statistical significance.

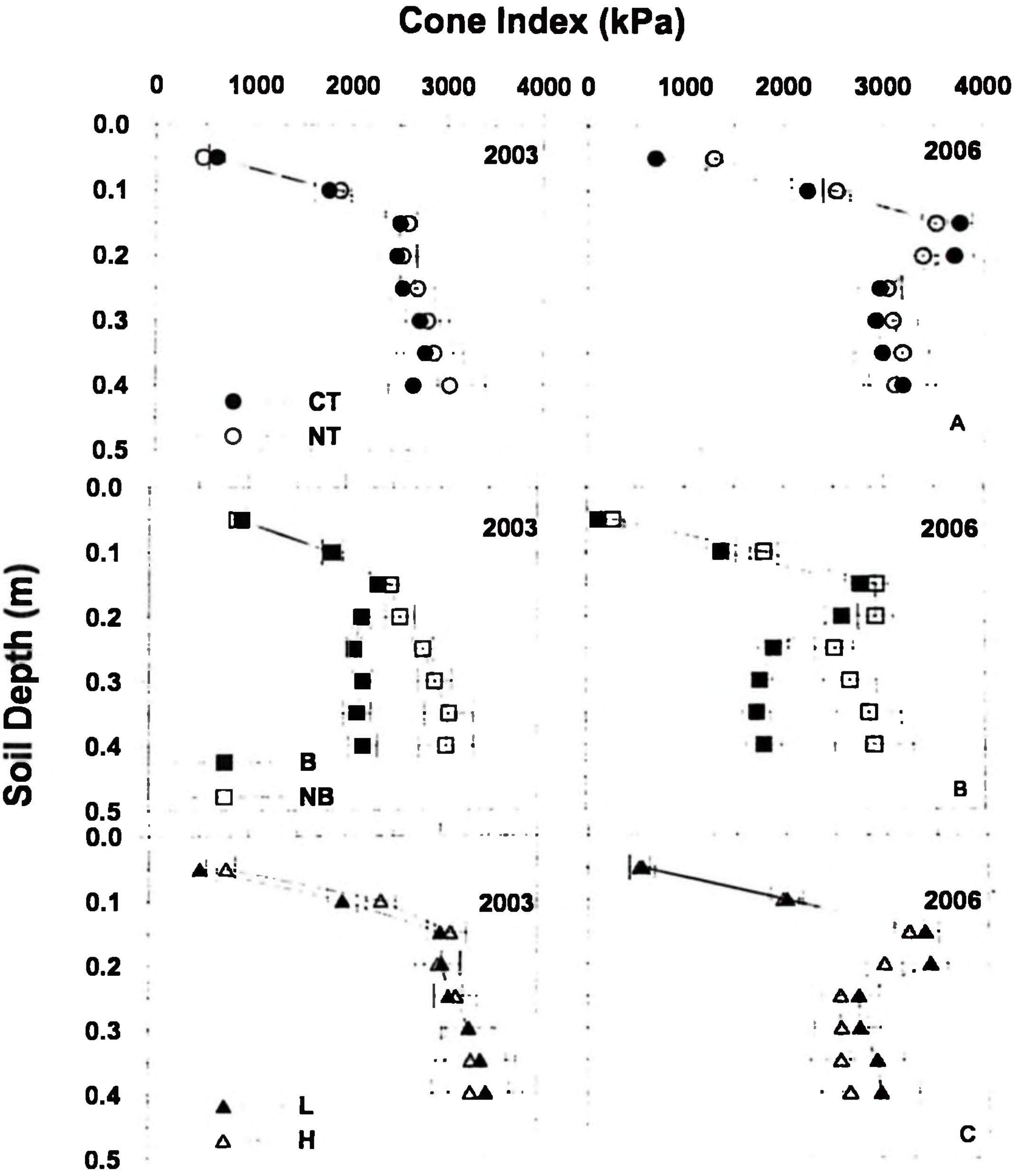


Fig. 2. Summary of the mean (n = 24 per treatment) cone index profiles for tillage [A; conventional (CT) and no-tillage (NT)], burning (B; Burn and No Burn), and residue level [C; Low (L) and High (H)] after one (2003) and four (2006) years of alternative residue management practices at the Lon Mann Cotton Research Station, Marianna, eastern Arkansas. Lines connecting the data points are for graphical depiction of the profile and do not imply any statistical significance.

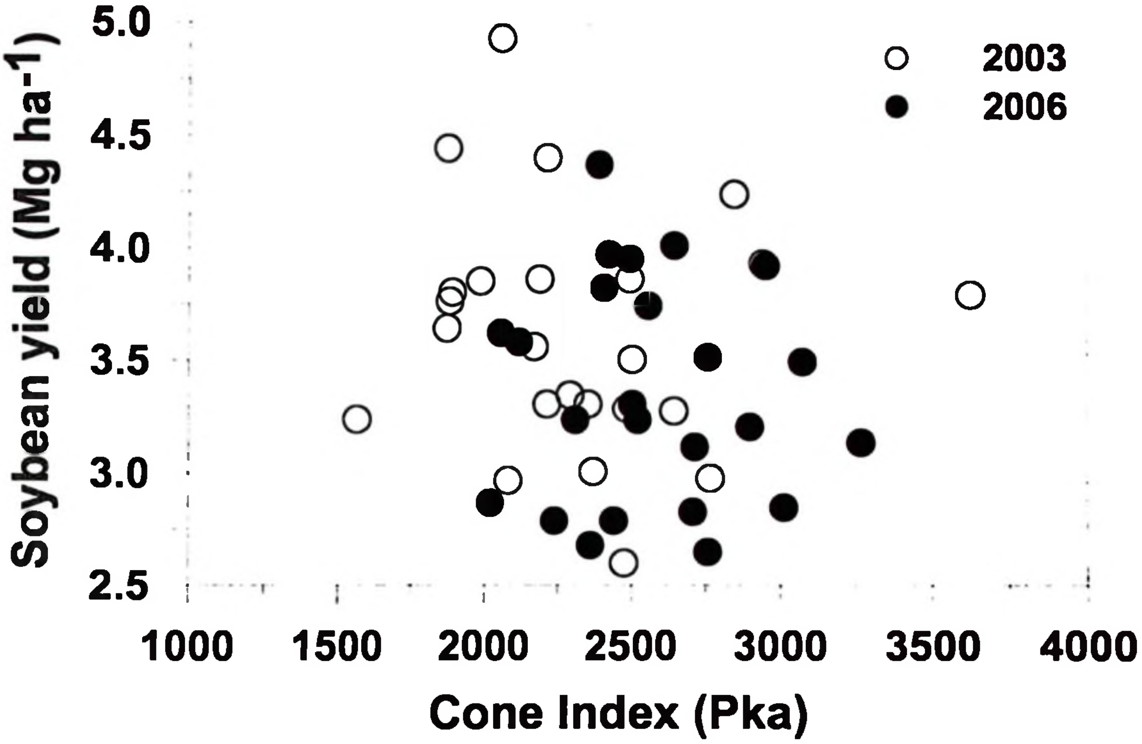


Fig. 3. Relationship between irrigated soybean yield, reported at 13% moisture, and the mean cone index for the 0.1- and 0.15-m depth intervals for 2003 and 2006.

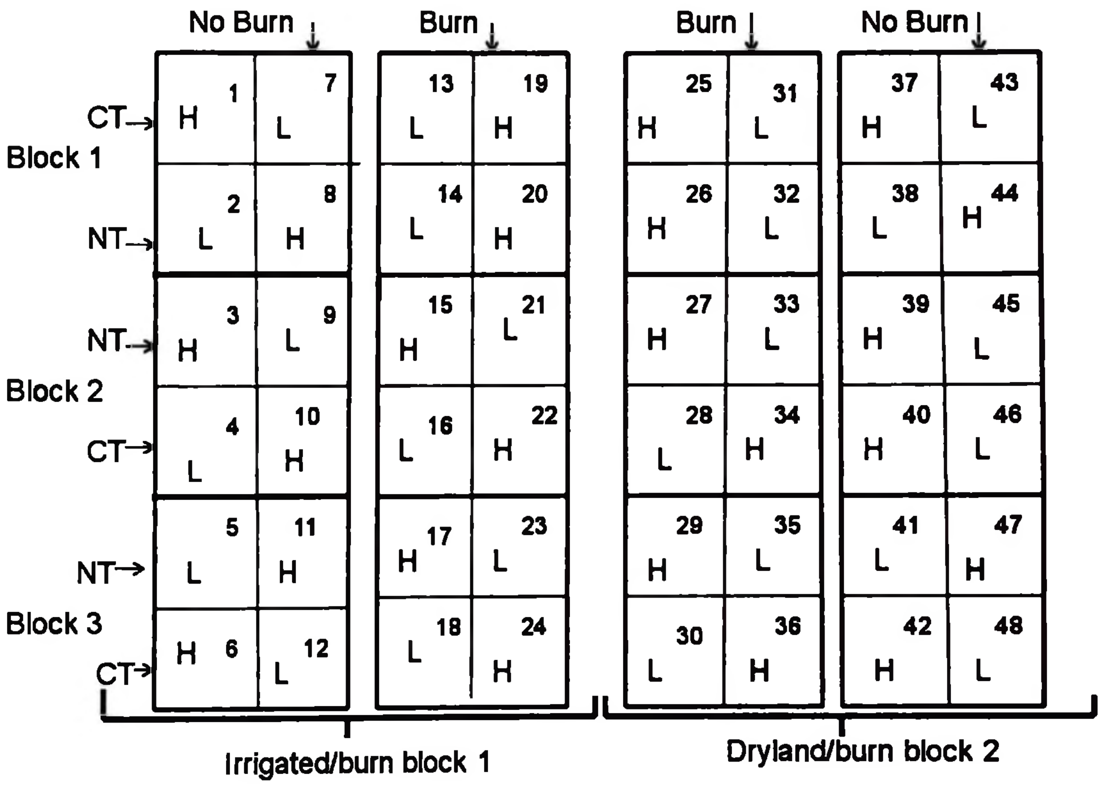
OVERALL CONCLUSIONS

The results from this study indicated that non-burning and high wheat residue has a greater rate of soil C sequestration in eastern Arkansas soils regardless of tillage compared to burning and low-residue level. All treatments resulted in similar soybean yields trend, and the soybean yield trend appears to be influenced by growing-season rainfall distribution and soil physical conditions. No-tillage, no burning and high-residue level treatments under both irrigated and dry-land conditions appeared to contribute significantly to the suppression of most weed species without reducing herbicide efficiency. The high-residue-level treatment increased CI in the top 0.05 m after one complete cropping cycle, but decreased CI after 4 years of alternative residue management, presumably due to the enrichment of SOM from root decomposition. Burning resulted in an unexpectedly lower soil CI in the 0.2- to 0.35-m depth after 1 and 4 years of residue management, which may have been due to favorable effects of residue removal on root elongation and decomposition. The management practices with NT were more profitable than the traditional CT practice even when the fertilizer and diesel costs continue to increase. Therefore, NT and non-burning with any residue level have great potential to improve soil quality, reduce weed pressure in the soybean growing season, and maintain profitability in the wheat-soybean double-crop production system. This study can serve as a base line for future weed assessments to determine potential weed species shift after a greater duration of consistent alternative residue management practices in a wheat-soybean, double crop system in the Mississippi River Delta region of eastern Arkansas. Further research on potential long-term effect of alternative residue management on soil penetration resistance, as well as on CI-related soil properties such as hydraulic conductivity, infiltration rate, and root growth, will still be needed to improve the sustainability of alternative residue management practices.

APPENDIX 1. Plot plan

The study plot plan for wheat residue management practices from 2002 to 2007.

Numbers within plots are plot numbers.



CT - conventional tillage

NT - no-tillage

H - high residue level/high N rate

L - low residue level/low N rate

APPENDIX 2. SAS programs used for statistical analyses

A. Chapter 2. ANCOVA full models

```
Title 'Amuri, N: Analysis of Co variance with all trt combn without irrigation';

Data asa;
length trtcode1 trtcode2 trtcode3 trtcode4 $15;
infile 'cbes_longterm soil_NT_BD rep.csv' firstobs=5 delimiter= ",";
input obs year plot tblock bblock rep tillage$ burning$ residue$ Irrig$ soyyld whtyld Resicover BD pH EC
Po K Ca Mg Na S Fe Mn Zn Cu OM TN TC CNratio OMcont TNcont TCcont;
year2=year*year;
Year3=year2*year;
trtcode1=substr(tillage,1,2)||'-'||compress(substr(burning,1,2));
trtcode2=substr(tillage,1,2)||'-'||substr(residue,1,1);
trtcode3=compress(substr(burning,1,2))||'-'||substr(residue,1,1);
trtcode4=substr(tillage,1,2)||'-'||substr(residue,1,1)||'_'||compress(substr(burning,1,2));
label obs='observation #'
year='year'
plot='plot #'
tblock='tillage block'
bblock='burning block'
rep='replication'
tillage='tillage'
burning='burning'
residue='residue level'
Irrig='Irrigation'
soyyld='soybean yield (Mg/ha)'
whtyld='wheat yield (Mg/ha)'
Resicover='residue cover(kg/ha)'
BD='bulk density (g/cm3)'
pH='pH'
EC='Electrical conductivity (dS/m)'
Po='phosphorus content (kg/ha)'
K='potassium content (kg/ha)'
Ca='calcium content (kg/ha)'
Mg='magnesium content (kg/ha)'
Na='sodium content (kg/ha)'
S='sulfur content (kg/ha)'
Fe='iron content (kg/ha)'
Mn='manganese content (kg/ha)'
Zn='zince content (kg/ha)'
Cu='copper content (kg/ha)'
OM='organic matter conc (g/kg)'
TC='total carbon (g/kg)'
TN='total nitrogen conc (g/kg)'
CNratio='C:N ratio'
OMcont='organic matter content (kg/m2)'
TNcont='Total Nitrogen content (kg/m2)'
TCcont='Total carbon content (kg/m2)'
trtcode='treatment code'
year2='year square'
year3='year cube';
run;
Proc sort data=asa;
```

```
by rep tillage burning residue year;
quit;

title2 'initial data listing';
proc print data=asa;
id rep tillage burning residue Irrig trtcode1 trtcode2 trtcode3 trtcode4;
var plot year soyyld whtyld BD pH EC Po K Ca Mg Na S Fe Mn Zn Cu OM TN TC CNratio OMcont
TNcont TCcont;
Quit;

title3 'Initial plots all data';
proc plot data=asa hpercent=50 vpercent=70;
plot (BD pH EC Po K Ca Mg Na S Fe Mn Zn Cu OMcont TCcont TNcont)*year;
Run;

Title3 'Full Reg model Analysis of cov with all possible combinations (all lines)';
proc glm data=asa;
class tillage burning residue rep;
model soyyld whtyld BD pH EC Po K Ca Mg Na S Fe Mn Zn Cu CNratio OMcont TNcont TCcont=
tillage   burning    residue
tillage*burning    tillage*residue     burning*residue
tillage*burning*residue
year
tillage*year      burning*year      residue*year
tillage*burning*year    tillage*residue*year       burning*residue*year
tillage*burning*residue*year
rep(tillage burning residue)       year*rep(tillage burning residue);
random rep(tillage burning residue)/test;
id tillage burning residue ;

output out=new residual=resid stdr=se_resid student=sresid p=pred cookd=cookd;
quit;
```

```
Title 'Amuri. N: Analysis of Covariance with all trt combn (nested rep with irrigation)';

Data asa;
length trtcode4 $15;
infile 'cbes_longterm soil_NT_BD rep_irrg.csv' firstobs=5 delimiter= ",";
input obs year plot tblock bblock rep tillage$ burning$ residue$ Irrig$ soyyld whtyld Resicover BD pH EC
Po K Ca Mg Na S Fe Mn Zn Cu OM TN TC CNratio OMcont TNcont TCcont;
year2=year*year;
Year3=year2*year;
trtcode4=substr(tillage,1,2)||'-'||substr(residue,1,1)||'_'||substr(burning,1,2)||'-'||compress((substr(Irrig,1,2)));
label obs='observation #'
year='year'
plot='plot #'
tblock='tillage block'
bblock='burning block'
rep='replication'
tillage='tillage'
burning='burning'
residue='residue level'
Irrig='Irrigation'
soyyld='soybean yield (Mg/ha)'
whtyld='wheat yield (Mg/ha)'
Resicover='residue cover(kg/ha)'
BD='bulk density (g/cm3)'
pH='pH'
EC='Electrical conductivity (dS/m)'
Po='phosphorus content (kg/ha)'
K='potassium content (kg/ha)'
Ca='calcium content (kg/ha)'
Mg='magnesium content (kg/ha)'
Na='sodium content (kg/ha)'
S='sulfur content (kg/ha)'
Fe='iron content (kg/ha)'
Mn='manganese content (kg/ha)'
Zn='zincc content (kg/ha)'
Cu='copper content (kg/ha)'
OM='organic matter conc (g/kg)'
TC='total carbon (g/kg)'
TN='total nitrogen conc (g/kg)'
CNratio='C:N ratio'
OMcont='organic matter content (kg/m2)'
TNcont='Total Nitrogen content (kg/m2)'
TCcont='Total carbon content (kg/m2)'
trtcode='treatment code'
year2='year square'
year3='year cube';
run;

Proc sort data=asa;
by rep tillage burning residue year;
quit;

title2 'initial data listing';
proc print data=asa;
id plot year rep tillage burning residue Irrig trtcode4;
```

```
var  soyyld whtyld BD pH EC Po K Ca Mg Na S Fe Mn Zn Cu OM TN TC CNratio OMcont TNcont
TCcont;
Quit;
proc means data=asa mean stderr;
Class year Irrig;
var pH K Fe Mn Zn TCcont BD soyyld;
quit;


Title3 'Fullmodel-1 Analysis of cov with all possible combinations (all lines)';
proc glm data=asa;
class tillage Irrig burning residue rep;
model soyyld whtyld BD pH EC Po K Ca Mg Na S Fe Mn Zn Cu CNratio OMcont TNcont TCcont=
tillage| Irrig | burning |residue|year|rep(tillage burning residue);
random rep(tillage burning residue)/test;
id tillage burning residue ;
output out=new residual=resid stdr=se_resid student=sresid p=pred cookd=cookd;
quit;
```

B. Chapter 2. ANCOVA Reduced models

```
Title 'Amuri, N: OM &TC Analysis of Co variance with all trt combn without irrigation';

Data asa;
length trtcode1 trtcode2 trtcode3 trtcode4 $15;
infile 'cbes_longterm soil_NT_BD rep.csv' firstobs=5 delimiter= ",";
input obs year plot tblock bblock rep tillage$ burning$ residue$ Irrig$ soyyld whtyld Resicover BD pH EC
Po K Ca Mg Na S Fe Mn Zn Cu OM TN TC CNratio OMcont TNcont TCcont;
year2=year*year;
Year3=year2*year;
trtcode1=substr(tillage,1,2)||'-'||compress(substr(burning,1,2));
trtcode2=substr(tillage,1,2)||'-'||substr(residue,1,1);
trtcode3=compress(substr(burning,1,2))||'-'||substr(residue,1,1);
trtcode4=substr(tillage,1,2)||'-'||substr(residue,1,1)||'_'||compress(substr(burning,1,2)):
label obs='observation #'
year='year'
plot='plot #'
tblock='tillage block'
bblock='burning block'
rep='replication'
tillage='tillage'
burning='burning'
residue='residue level'
Irrig='Irrigation'
soyyld='soybean yield (Mg/ha)'
whtyld='wheat yield (Mg/ha)'
Resicover='residue cover(kg/ha)'
BD='bulk density (g/cm3)'
pH='pH'
EC='Electrical conductivity (dS/m)'
Po='phosphorus content (kg/ha)'
K='potassium content (kg/ha)'
Ca='calcium content (kg/ha)'
Mg='magnesium content (kg/ha)'
Na='sodium content (kg/ha)'
S='sulfur content (kg/ha)'
Fe='iron content (kg/ha)'
Mn='manganese content (kg/ha)'
Zn='zince content (kg/ha)'
Cu='copper content (kg/ha)'
OM='organic matter conc (g/kg)'
TC='total carbon (g/kg)'
TN='total nitrogen conc (g/kg)'
CNratio='C:N ratio'
OMcont='organic matter content (kg/m2)'
TNcont='Total Nitrogen content (kg/m2)'
TCcont='Total carbon content (kg/m2)'
trtcode='treatment code'
year2='year square'
year3='year cube';
run;
```

```
Proc sort data=asa;
by rep tillage burning residue year;
quit;

title2 'initial data listing';
proc print data=asa;
id rep tillage burning residue Irrig trtcode1 trtcode2 trtcode3 trtcode4;
var plot year /*soyyld whtyldBD pH EC Po K Ca Mg Na S Fe Mn Zn Cu OM TN TC*/ CNratio OMcont
TNcont TCcont;
Quit;

title3 'Initial plots all data';
proc plot data=asa hpercent=50 vpercent=70;
plot (BD pH EC Po K Ca Mg Na S Fe Mn Zn Cu OMcont TCcont TNcont)*year;
Run;

proc means data=asa mean stderr;
class residue year;
var TCcont;
quit;

Title3 'Reduced Reg model-1 Analysis of cov with all possible combinations (all lines)';
proc glm data=asa;
class tillage burning residue rep;
model /*CNratio*/ OMcont TNcont TCcont= tillage   burning    residue
tillage*burning    tillage*residue     burning*residue
tillage*burning*residue
year
/*tillage*year*/     burning*year     residue*year
/*tillage*burning*year    tillage*residue*year        /*burning*residue*year
tillage*burning*residue*year*/
rep(tillage burning residue)       year*rep(tillage burning residue);
random rep(tillage burning residue)/test;
id tillage burning residue ;
output out=new residual=resid stdr=se_resid student=sresid p=pred cookd=cookd;
quit;

Title3 'Reduced model for OM- Analysis of cov with till by resdidue intercepts (4 lines)';
proc glm data=asa;
class tillage burning residue rep;
model OMcont= /*tillage   burning    residue*/
/*tillage*burning    tillage*residue     /*burning*residue
tillage*burning*residue*/
year
/*tillage*year     burning*year     residue*year
/*tillage*burning*year    tillage*residue*year        /*burning*residue*year
tillage*burning*residue*year*/
rep(tillage burning residue)       year*rep(tillage burning residue);
random rep(tillage burning residue)/test;
id tillage burning residue ;

 *INTERCEPTS*/
estimate 'common intercept tillage-CT&NT' intercept 1;
 *estimate 'B001 tillage  CT' intercept 1 tillage 1 0;
estimate 'B002 tillage  NT' intercept 1 tillage 0 1;*/
```

```
estimate 'common intercept burning=B&NB' intercept 1;
/*estimate 'B003 burning=B' intercept 1 burning 1 0;
estimate 'B004 burning=NB' intercept 1 burning 0 1;*/

estimate 'common intercept residue=H&L' intercept 1;
/*estimate 'B005 residue=H' intercept 1 residue 1 0;
estimate 'B006 residue=H' intercept 1 residue 0 1;

estimate 'B021 CT-H' intercept 1 tillage 1 0 residue 1 0
                    tillage*residue 1 0 0 0;
estimate 'B022 CT-L' intercept 1 tillage 1 0 residue 0 1
                    tillage*residue 0 1 0 0;
estimate 'B023 NT-H' intercept 1 tillage 0 1 residue 1 0
                    tillage*residue 0 0 1 0;
estimate 'B024 NT-L' intercept 1 tillage 0 1 residue 0 1
                    tillage*residue 0 0 0 1;

/*SLOPES*/
Estimate 'common slope for all' year 1;

output out=newOM residual=resid stdr=se_resid student=sresid p=pred cookd=cookd;
quit;
proc sort data=newOM;
by tillage residue burning ; quit;
data newOM;
set newOM;
if tillage='CT' then sresid1=sresid; else sresid1=.; if tillage='NT' then sresid2=sresid; else sresid2=.;
if burning='B' then sresid3=sresid; else sresid3=.; if burning='NB' then sresid4=sresid; else sresid4=.;
if residue='H' then sresid5=sresid; else sresid3=.;if residue='L' then sresid6=sresid; else sresid4=.;
label resid='Residual'
se_resid='standard error of residual'
sresid='studentized residual'
pred='predicted'
cookd='cooks distance'
sresid1='CT student resid'
sresid2='NT student resid'
sresid3='B student resid'
sresid4='NB student resid'
sresid5='H student resid'
sresid6='L student resid'
run;
proc sort data=newOM;
by tillage residue; quit;
/*proc sort data=newpH;
by residue;quit;*/

proc print data=newOM label noobs;
by tillage residue;
id tillage residue;
var year Omcont sresid1 sresid2 sresid3 sresid4 sresid5 sresid6 cookd;
quit;

proc plot data=newOM hpercent=50 vpercent=70;
plot sresid*year/vref=0 vaxis=-6 to 6 by 1;

proc sort data=newOM; by tillage burning residue; quit;
```

```
Proc plot data=newOM hpercent=50 vpercent=70; /*by burning:*/
plot (sresid1 sresid2  sresid3 sresid4 sresid5 sresid6)*year/vref=0 vaxis=-6 to 6 by 1;
Quit;

/*proc sort data=newOM; by residue: quit:
Proc plot data=newOM hpercent=50 vpercent=70: /*by residue:
plot (sresid3 sresid4)*year/vref=0 vaxis=-6 to 6 by 1;
Quit:*/

Title3 'Reduced model for TC- Analysis of cov with till by resdidue intercepts (4 lines)';
proc glm data=asa;
class tillage burning residue rep;
model  TCcont= /*tillage  burning   /*residue
tillage*burning   tillage*residue     /*burning*residue
tillage*burning*residue*/
year
/*tillage*year*/     burning*year     residue*year
/*tillage*burning*year    tillage*residue*year       burning*residue*year
tillage*burning*residue*year*/
rep(tillage burning residue)       year*rep(tillage burning residue);
random rep(tillage burning residue)/test;
id tillage burning residue ;

/*INTERCEPTS*/

estimate 'common intercept all' intercept 1;
/*estimate 'B001 tillage=CT' intercept 1 tillage 1 0:
estimate 'B002 tillage=NT' intercept 1 tillage 0 1;*/

/*estimate 'common intercept burning=B&NB' intercept 1;
estimate 'B003 burning=B' intercept 1 burning  1 0:
estimate 'B004 burning=NB' intercept 1 burning 0 1:*/

/*estimate 'common intercept residue=H&L' intercept 1:
estimate 'B005 residue=H' intercept 1 residue  1 0:
estimate 'B006 residue=H' intercept 1 residue  0 1:

estimate 'B021 CT-H' intercept 1 tillage 1 0 residue 1 0
                    tillage*residue 1 0 0 0:
estimate 'B022 CT-L' intercept 1 tillage 1 0 residue 0 1
                    tillage*residue 0 1 0 0:
estimate 'B023 NT-H' intercept 1 tillage 0 1 residue 1 0
                    tillage*residue 0 0 1 0:
estimate 'B024 NT-L' intercept 1 tillage 0 1 residue 0 1
                    tillage*residue 0 0 0 1:*/

/*SLOPES
Estimate 'common slope for all' year 1:*/
estimate 'B103 burning=B' year 1 burning*year  1 0:
estimate 'B104 burning=NB' year 1 burning*year 0 1;

estimate 'B105 residue=H' year 1 year*residue  1 0;
estimate 'B106 residue=L' year 1 year*residue  0 1;

output out=newTC residual=resid stdr=se_resid student=sresid p=pred cookd=cookd:
quit;
```

```
proc sort data=newTC;
by tillage burning residue : quit;
data newTC;
set newTC;
if tillage='CT' then sresid1=sresid; else sresid1=.; if tillage='NT' then sresid2=sresid; else sresid2=.;
if burning='B' then sresid3=sresid; else sresid3=.; if burning='NB' then sresid4=sresid; else sresid4=.;
if residue='H' then sresid5=sresid; else sresid3=.;if residue='L' then sresid6=sresid; else sresid4=.;
label resid='Residual'
se_resid='standard error of residual'
sresid='studentized residual'
pred='predicted'
cookd='cooks distance'
sresid1='CT student resid'
sresid2='NT student resid'
sresid3='B student resid'
sresid4='NB student resid'
sresid5='H student resid'
sresid6='L student resid';
run;
proc sort data=newTC;
by tillage burning residue; quit;

proc print data=newTC label noobs;
by tillage burning residue;
id tillage burning residue;
var year TCcont sresid1 sresid2 sresid3 sresid4 sresid5 sresid6 cookd;
quit;

proc plot data=newTC hpercent=50 vpercent=70;
plot sresid*year/vref=0 vaxis=-6 to 6 by 1;

proc sort data=newTC; by tillage burning residue; quit;
Proc plot data=newTC hpercent=50 vpercent=70; /*by burning;*/
plot (sresid1 sresid2 sresid3 sresid4 sresid5 sresid6)*year/vref=0 vaxis=-6 to 6 by 1;
Quit;
```

```
Title 'Amuri. N: Analysis of Co variance with all trt combn (nested rep no irrigtn)';

Data asa;
length trtcode1 trtcode2 trtcode3 trtcode4 $15;
infile 'cbes_longterm soil_NT_BD rep.csv' firstobs=5 delimiter= ",";
input obs year plot tblock bblock rep tillage$ burning$ residue$ Irrig$ soyyld whtyld Resicover BD pH EC
Po K Ca Mg Na S Fe Mn Zn Cu OM TN TC CNratio OMcont TNcont TCcont;
year2=year*year;
Year3=year2*year;
trtcode1=substr(tillage,1,2)||'-'||compress(substr(burning,1,2));
trtcode2=substr(tillage,1,2)||'-'||substr(residue,1,1);
trtcode3=compress(substr(burning,1,2))||'-'||substr(residue,1,1);
trtcode4=substr(tillage,1,2)||'-'||substr(residue,1,1)||'_'||compress(substr(burning,1,2));
label obs='observation #'
year='year'
plot='plot #'
tblock='tillage block'
bblock='burning block'
rep='replication'
tillage='tillage'
burning='burning'
residue='residue level'
Irrig='Irrigation'
soyyld='soybean yield (Mg/ha)'
whtyld='wheat yield (Mg/ha)'
Resicover='residue cover(kg/ha)'
BD='bulk density (g/cm3)'
pH='pH'
EC='Electrical conductivity (dS/m)'
Po='phosphorus content (kg/ha)'
K='potassium content (kg/ha)'
Ca='calcium content (kg/ha)'
Mg='magnesium content (kg/ha)'
Na='sodium content (kg/ha)'
S='sulfur content (kg/ha)'
Fe='iron content (kg/ha)'
Mn='manganese content (kg/ha)'
Zn='zinc content (kg/ha)'
Cu='copper content (kg/ha)'
OM='organic matter conc (g/kg)'
TC='total carbon (g/kg)'
TN='total nitrogen conc (g/kg)'
CNratio='C:N ratio'
OMcont='organic matter content (kg/m2)'
TNcont='Total Nitrogen content (kg/m2)'
TCcont='Total carbon content (kg/m2)'
trtcode='treatment code'
year2='year square'
year3='year cube';
run;

Proc sort data=asa;
by rep tillage burning residue year;
quit;
```

```
title2 'initial data listing';
proc print data=asa;
id rep tillage burning residue Irrig trtcode1 trtcode2 trtcode3 trtcode4;
var plot year /*soyyld whtyldBD pH EC Po K Ca Mg Na S Fe Mn Zn Cu OM TN TC*/ CNratio OMcont
TNcont TCcont;
Quit;

title3 'Initial plots all data';
proc plot data=asa hpercent=50 vpercent=70;
plot (BD pH EC Po K Ca Mg Na S Fe Mn Zn Cu OMcont TCcont TNcont)*year;
Run;
proc means data=asa mean stderr;
class year;
var Ca;
quit;

Title3 'Reduced Reg model-1 Analysis of covariance with all possible combinations (deleted some lines)';
proc glm data=asa;
class tillage burning residue rep;
model pH EC Po K Ca Mg = tillage   burning    residue
tillage*burning   tillage*residue    burning*residue
tillage*burning*residue
year
tillage*year    burning*year     residue*year
/*tillage*burning*year   tillage*residue*year      burning*residue*year
tillage*burning*residue*year*/
rep(tillage burning residue)       year*rep(tillage burning residue);
random rep(tillage burning residue)/test;
id tillage burning residue ;
output out=new residual=resid stdr=se_resid student=sresid p=pred cookd=cookd;
quit;

Title3 'Reduced Reg model pH Analysis of cov with significant combinations only (reduced lines)';
proc glm data=asa;
class tillage burning residue rep;
model pH = /*tillage*/   burning /*   residue
tillage*burning   tillage*residue    burning*residue
/*tillage*burning*residue*/
year
/*tillage*year     burning*year     /*residue*year
tillage*burning*year   tillage*residue*year      burning*residue*year
tillage*burning*residue*year*/
rep(tillage burning residue)       year*rep(tillage burning residue);
random rep(tillage burning residue)/test;
id tillage burning residue ;

/*INTERCEPTS*/
estimate 'B003 burning=B' intercept 1 burning  1 0;
estimate 'B004 burning=NB' intercept 1 burning 0 1;

/*SLOPE*/
estimate 'common slope for all trt' year 1;
output out=newpH residual=resid stdr=se_resid student=sresid p=pred cookd=cookd;
quit;
proc sort data=newpH;
by tillage residue burning ; quit;
```

```
data newpH;
set newpH;
if tillage='CT' then sresid1=sresid; else sresid1=.; if tillage='NT' then sresid2=sresid; else sresid2=.;
if burning='B' then sresid3=sresid; else sresid3=.; if burning='NB' then sresid4=sresid; else sresid4=.;
if residue='H' then sresid5=sresid; else sresid5=.;if residue='L' then sresid6=sresid; else sresid4=.;
label resid='Residual'
se_resid='standard error of residual'
sresid='studentized residual'
pred='predicted'
cookd='cooks distance'
sresid1='CT student resid'
sresid2='NT student resid'
sresid3='B student resid'
sresid4='NB student resid'
sresid5='H student resid'
sresid6='L student resid'
run;
proc sort data=newpH;
by tillage burning residue; quit;
/*proc sort data=newpH;
by residue;quit;*/

proc print data=newpH label noobs;
by tillage burning residue;
id tillage burning residue;
var year pH sresid1 sresid2 sresid3 sresid4 sresid5 sresid6 cookd;
quit;

proc plot data=newpH hpercent=50 vpercent=70;
plot sresid*year/vref=0 vaxis=-6 to 6 by 1;

proc sort data=newpH; by tillage burning residue; quit;
Proc plot data=newpH hpercent=50 vpercent=70; /*by burning;*/
plot (sresid1 sresid2  sresid3 sresid4 sresid5 sresid6)*year/vref=0 vaxis=-6 to 6 by 1;
Quit;


Title3 'Reduced ancov model EC  with significant combinations only (reduced lines)';
proc glm data=asa;
class tillage burning residue rep;
model EC = /*tillage   burning  /*  residue
tillage*burning   tillage*residue    burning*residue
/*tillage*burning*residue*/
year
/*tillage*year     burning*year     /*residue*year
tillage*burning*year   tillage*residue*year      burning*residue*year
tillage*burning*residue*year*/
rep(tillage burning residue)       year*rep(tillage burning residue);
random rep(tillage burning residue)/test;
id tillage burning residue :
output out=new residual=resid stdr=se_resid student=sresid p=pred cookd=cookd;
quit;

Title3 'Reduced Reg model EC Analysis (1 lines)';
proc reg data=asa;
model EC = year;
```

```
output out=newEC2 residual=resid stdr=se_resid student=sresid p=pred cookd=cookd;
quit;
data newEC2;
set newEC2;
label resid='Residual'
se_resid='standard error of residual'
sresid='studentized residual'
pred='predicted'
cookd='cooks distance';
run;

proc sort data=newEC2;
by tillage burning residue;
quit;

proc print data=newEC2 label noobs;
var year EC cookd sresid;
quit;

proc plot data=newEC2 hpercent=50 vpercent=70;
plot sresid *year/vref=0 vaxis=-6 to 6 by 1;

proc sort data=newEC2;
by tillage;
quit;
proc plot data=newEC2 hpercent=50 vpercent=70;
by tillage ;
plot sresid *year/vref=0 vaxis=-6 to 6 by 1;
Quit;
proc sort data=newEC2;
by burning;
quit;
proc plot data=newEC2 hpercent=50 vpercent=70;
by burning;
plot sresid *year/vref=0 vaxis=-6 to 6 by 1;
Quit;
proc sort data=newEC2;
by residue;
quit;

proc plot data=newEC2 hpercent=50 vpercent=70;
by residue;
plot sresid *year/vref=0 vaxis=-6 to 6 by 1;
Quit;

Title3 'Reduced Reg model Phosphorus Analysis of cov with all possible combinations (4 lines)';
proc glm data=asa;
class tillage burning residue rep;
model Po = /*tillage*/  burning   /*residue
/*tillage*burning   tillage*residue    /* burning*residue
tillage*burning*residue*/
year
tillage*year      /*burning*year*/     residue*year
/*tillage*burning*year   tillage*residue*year      burning*residue*year
tillage*burning*residue*year*/
rep(tillage burning residue)       year*rep(tillage burning residue);
```

```
random rep(tillage burning residue)/test;
id tillage burning residue ;
/*INTERCEPTS*/
estimate 'B003 burning=B' intercept 1 burning  1 0;
estimate 'B004 burning=NB' intercept 1 burning 0 1;

estimate 'common intercept for tillage&residue' intercept 1;

/*SLOPE*/
estimate 'B101 tillage=CT' year 1 tillage*year  1 0;
estimate 'B102 tillage=NT' year 1 tillage*year  0 1;

estimate 'Common slope for burning' year 1;

estimate 'B103 residue=H' year 1 residue*year  1 0;
estimate 'B104 residue=L' year 1 residue*year  0 1;

output out=newPo residual=resid stdr=se_resid student=sresid p=pred cookd=cookd;
quit;
proc sort data=newPo;
by tillage residue burning ; quit;
data newPo;
set newPo;
if tillage='CT' then sresid1=sresid; else sresid1=.; if tillage='NT' then sresid2=sresid; else sresid2=.;
if burning='B' then sresid3=sresid; else sresid3=.; if burning='NB' then sresid4=sresid; else sresid4=.;
if residue='H' then sresid5=sresid; else sresid3=.;if residue='L' then sresid6=sresid; else sresid4=.;
label resid='Residual'
se_resid='standard error of residual'
sresid='studentized residual'
pred='predicted'
cookd='cooks distance'
sresid1='CT student resid'
sresid2='NT student resid'
sresid3='B student resid'
sresid4='NB student resid'
sresid5='H student resid'
sresid6='L student resid'
run;
proc sort data=newPo;
by tillage burning residue; quit;

proc print data=newPo label noobs;
by tillage burning residue;
id tillage burning residue;
var year pH sresid1 sresid2 sresid3 sresid4 sresid5 sresid6 cookd;
quit;

proc plot data=newPo hpercent=50 vpercent=70;
plot sresid*year/vref=0 vaxis=-6 to 6 by 1;

proc sort data=newPo; by tillage burning residue; quit;
Proc plot data=newPo hpercent=50 vpercent=70; /*by burning;*/
plot (sresid1 sresid2  sresid3 sresid4 sresid5 sresid6)*year/vref=0 vaxis=-6 to 6 by 1;
Quit;

Title3 'Reduced ancov model K  (1 lines)';
```

```
proc glm data=asa;
class tillage burning residue rep;
model K = /*tillage   burning   /* residue
tillage*burning   tillage*residue   /* burning*residue
tillage*burning*residue*/
year
/*tillage*year*    burning*year    /* residue*year
tillage*burning*year   tillage*residue*year    burning*residue*year
tillage*burning*residue*year*/
rep(tillage burning residue)      year*rep(tillage burning residue);
random rep(tillage burning residue)/test;
id tillage burning residue ;
output out=newK residual=resid stdr=se_resid student=sresid p=pred cookd=cookd;
quit;

Title3 'Reduced Reg model K Analysis (1 lines)';
proc reg data=asa;
model K = year;
output out=newK2 residual=resid stdr=se_resid student=sresid p=pred cookd=cookd;
quit;
data newK2;
set newK2;
label resid='Residual'
se_resid='standard error of residual'
sresid='studentized residual'
pred='predicted'
cookd='cooks distance';
run;

proc sort data=newK2;
by tillage burning residue;
quit;

proc print data=newK2 label noobs;
var year K cookd sresid;
quit;

proc plot data=newK2 hpercent=50 vpercent=70;
plot sresid *year/vref=0 vaxis=-6 to 6 by 1;

proc sort data=newK2;
by tillage;
quit;
proc plot data=newK2 hpercent=50 vpercent=70;
by tillage ;
plot sresid *year/vref=0 vaxis=-6 to 6 by 1;
Quit;
proc sort data=newK2;
by burning;
quit;
proc plot data=newK2 hpercent=50 vpercent=70;
by burning;
plot sresid *year/vref=0 vaxis=-6 to 6 by 1;
Quit;
proc sort data=newK2;
by residue;
```

```
quit;

proc plot data=newK2 hpercent=50 vpercent=70;
by residue;
plot sresid *year/vref=0 vaxis=-6 to 6 by 1;
Quit;

Title3 'Reduced ancova model Ca (1)';
proc glm data=asa;
class tillage burning residue rep;
model Ca = /*tillage  burning*/ /* residue
tillage*burning  tillage*residue  burning*residue
/*tillage*burning*residue*/
year
/*tillage*year   burning*year   residue*year
/*tillage*burning*year  tillage*residue*year   burning*residue*year
tillage*burning*residue*year*/
rep(tillage burning residue)    year*rep(tillage burning residue);
random rep(tillage burning residue)/test;
id tillage burning residue ;
output out=new residual=resid stdr=se_resid student=sresid p=pred cookd=cookd;
quit;

Title3 'Reduced Reg model Ca Analysis (1 lines)';
proc reg data=asa;
model Ca = year;
output out=newCa2 residual=resid stdr=se_resid student=sresid p=pred cookd=cookd;
quit;
data newCa2;
set newCa2;
label resid='Residual'
se_resid='standard error of residual'
sresid='studentized residual'
pred='predicted'
cookd='cooks distance';
run;

proc sort data=newCa2;
by tillage burning residue;
quit;

proc print data=newCa2 label noobs;
var year Ca cookd sresid;
quit;

proc plot data=newCa2 hpercent=50 vpercent=70;
plot sresid *year/vref=0 vaxis=-6 to 6 by 1;

proc sort data=newCa2;
by tillage;
quit;
proc plot data=newCa2 hpercent=50 vpercent=70;
by tillage ;
plot sresid *year/vref=0 vaxis=-6 to 6 by 1;
Quit;
proc sort data=newCa2;
```

```
by burning;
quit;
proc plot data=newCa2 hpercent=50 vpercent=70;
by burning;
plot sresid *year/vref=0 vaxis=-6 to 6 by 1;
Quit;
proc sort data=newCa2;
by residue;
quit;

proc plot data=newCa2 hpercent=50 vpercent=70;
by residue;
plot sresid *year/vref=0 vaxis=-6 to 6 by 1;
Quit;

Title3 'Reduced ancova model Mg Analysis of cov with burning intercepts(2 lines)';
proc glm data=asa;
class tillage burning residue rep;
model Mg = /*tillage*/  burning   /*residue
tillage*burning   tillage*residue    burning*residue
tillage*burning*residue*/
year
/*tillage*year     burning*year     /*residue*year
tillage*burning*year   tillage*residue*year      burning*residue*year
tillage*burning*residue*year*/
rep(tillage burning residue)       year*rep(tillage burning residue);
random rep(tillage burning residue)/test;
id tillage burning residue ;
/*INTERCEPTS*/
estimate 'B003 burning=B' intercept 1 burning  1 0;
estimate 'B004 burning=NB' intercept 1 burning 0 1;

/*SLOPE*/
estimate 'common slope for all trt' year 1;
output out=newMg residual=resid stdr=se_resid student=sresid p=pred cookd=cookd;
quit;
proc sort data=newMg;
by tillage residue burning ; quit;
data newMg;
set newMg;
if tillage='CT' then sresid1=sresid; else sresid1=.; if tillage='NT' then sresid2=sresid; else sresid2=.;
if burning='B' then sresid3=sresid; else sresid3=.; if burning='NB' then sresid4=sresid; else sresid4=.;
if residue='H' then sresid5=sresid; else sresid3=.;if residue='L' then sresid6=sresid; else sresid4=.;
label resid='Residual'
se_resid='standard error of residual'
sresid='studentized residual'
pred='predicted'
cookd='cooks distance'
sresid1='CT student resid'
sresid2='NT student resid'
sresid3='B student resid'
sresid4='NB student resid'
sresid5='H student resid'
sresid6='L student resid'
run;
proc sort data=newMg;
```

```
by tillage burning residue; quit;
/*proc sort data=newpH;
by residue;quit;*/

proc print data=newMg label noobs;
by tillage burning residue;
id tillage burning residue;
var year pH sresid1 sresid2 sresid3 sresid4 sresid5 sresid6 cookd;
quit;

proc plot data=newMg hpercent=50 vpercent=70;
plot sresid*year/vref=0 vaxis=-6 to 6 by 1;

proc sort data=newMg; by tillage burning residue; quit;
Proc plot data=newMg hpercent=50 vpercent=70; /*by burning;*/
plot (sresid1 sresid2  sresid3 sresid4 sresid5 sresid6)*year/vref=0 vaxis=-6 to 6 by 1;
Quit;


Title3 'Reduced Reg model OM with nested rep (1 lines)';
proc reg data=asa;
model OMcont = year;
output out=newOM2 residual=resid stdr=se_resid student=sresid p=pred cookd=cookd;
quit;
data newOM2;
set newOM2;
label resid='Residual'
se_resid='standard error of residual'
sresid='studentized residual'
pred='predicted'
cookd='cooks distance';
run;

proc sort data=newOM2;
by tillage burning residue;
quit;

proc print data=newOM2 label noobs;
var year OM cookd sresid;
quit;

proc plot data=newOM2 hpercent=50 vpercent=70;
plot sresid *year/vref=0 vaxis=-6 to 6 by 1;

proc sort data=newOM2;
by tillage;
quit;
proc plot data=newOM2 hpercent=50 vpercent=70;
by tillage ;
plot sresid *year/vref=0 vaxis=-6 to 6 by 1;
Quit;
proc sort data=newOM2;
by burning;
quit;
proc plot data=newOM2 hpercent=50 vpercent=70;
by burning;
```

```
plot sresid *year/vref=0 vaxis=-6 to 6 by 1;
Quit;
proc sort data=newOM2;
by residue;
quit;

proc plot data=newOM2 hpercent=50 vpercent=70;
by residue;
plot sresid *year/vref=0 vaxis=-6 to 6 by 1;
Quit;
```

```
Title 'Amuri, N: Analysis of Co variance with all trt combn without irrigation';

Data asa;
length trtcode1 trtcode2 trtcode3 trtcode4 S15;
infile 'cbes_longterm soil_NT_BD rep.csv' firstobs=5 delimiter= ",";
input obs year plot tblock bblock rep tillageS burningS residueS IrrigS soyyld whtyld Resicover BD pH EC
Po K Ca Mg Na S Fe Mn Zn Cu OM TN TC CNratio OMcont TNcont TCcont;
year2=year*year;
Year3=year2*year;
trtcode1=substr(tillage,1,2)||'-'||compress(substr(burning,1,2));
trtcode2=substr(tillage,1,2)||'-'||substr(residue,1,1);
trtcode3=compress(substr(burning,1,2))||'-'||substr(residue,1,1);
trtcode4=substr(tillage,1,2)||'-'||substr(residue,1,1)||'_'||compress(substr(burning,1,2));
label obs='observation #'
year='year'
plot='plot #'
tblock='tillage block'
bblock='burning block'
rep='replication'
tillage='tillage'
burning='burning'
residue='residue level'
Irrig='Irrigation'
soyyld='soybean yield (Mg/ha)'
whtyld='wheat yield (Mg/ha)'
Resicover='residue cover(kg/ha)'
BD='bulk density (g/cm3)'
pH='pH'
EC='Electrical conductivity (dS/m)'
Po='phosphorus content (kg/ha)'
K='potassium content (kg/ha)'
Ca='calcium content (kg/ha)'
Mg='magnesium content (kg/ha)'
Na='sodium content (kg/ha)'
S='sulfur content (kg/ha)'
Fe='iron content (kg/ha)'
Mn='manganese content (kg/ha)'
Zn='zince content (kg/ha)'
Cu='copper content (kg/ha)'
OM='organic matter conc (g/kg)'
TC='total carbon (g/kg)'
TN='total nitrogen conc (g/kg)'
CNratio='C:N ratio'
OMcont='organic matter content (kg/m2)'
TNcont='Total Nitrogen content (kg/m2)'
TCcont='Total carbon content (kg/m2)'
trtcode='treatment code'
year2='year square'
year3='year cube';
run;

Proc sort data=asa;
by tillage burning residue year;
quit;

title2 'initial data listing';
```

```
proc print data=asa;
id tillage burning residue Irrig trtcode1 trtcode2 trtcode3 trtcode4;
var plot year soyyld whtyld BD /*pH EC Po K Ca Mg Na S Fe Mn Zn Cu OM TN TC CNratio OMcont
TNcont TCcont*/;
Quit;

title3 'Initial plots all data';
proc plot data=asa hpercent=50 vpercent=70;
plot (soyyld whtyld BD /*pH EC Po K Ca Mg Na S Fe Mn Zn Cu OMcont TCcont TNcont* )*year;
Run;

Proc sort data=asa;
by tillage year;
quit;

title3 'average BD for graph plots';
proc means data=asa mean stderr;
var BD;
by tillage year;
quit;
Proc sort data=asa;
by year;
quit;

proc means data=asa mean stderr;
var soyyld;
by year;
quit;

Title3 'Full model Ancova with all possible combinations (all lines)';
proc glm data=asa;
class tillage burning residue rep;
model soyyld /*whtyld*/ BD = /*tillage burning residue year rep(tillage burning residue);*/
tillage burning residue
tillage*burning tillage*residue burning*residue
tillage*burning*residue
year year2
tillage*year burning*year residue*year
tillage*year2 burning*year2 residue*year2

tillage*burning*year   tillage*residue*year   burning*residue*year
tillage*burning*year2  tillage*residue*year2   burning*residue*year2

tillage*burning*residue*year
tillage*burning*residue*year2

rep(tillage burning residue)   year*rep(tillage burning residue)  year2*rep(tillage burning residue);
random rep(tillage burning residue);
id tillage burning residue ;


output out=new residual=resid stdr=se_resid student=sresid p=pred cookd=cookd;
quit;

title3 'Soy yield reduced model all slopes and intercepts are same-one line';
proc reg data=asa;
```

```
model soyyld=year year2;
output out=newsoy residual=resid stdr=se_resid student=sresid p=pred cookd=cookd;
quit;
proc sort data=newsoy;
by tillage burning residue;
data newsoy;
set newsoy;

proc print data=newsoy label noobs;
by tillage burning residue;
id tillage burning residue;
var year year2 BD sresid cookd;
quit;

proc sort data=newsoy;
by tillage; quit;

proc plot data=newsoy hpercent=50 vpercent=70;
by tillage ;
plot (sresid)*year/vref=0 vaxis=-6 to 6 by 1;
plot (sresid)*year2/vref=0 vaxis=-6 to 6 by 1;
Quit;

proc sort data=newsoy;
by burning; quit;
proc plot data=newsoy hpercent=50 vpercent=70;
by burning;
plot (sresid)*year/vref=0 vaxis=-6 to 6 by 1;
plot (sresid)*year2/vref=0 vaxis=-6 to 6 by 1;
Quit;

proc sort data=newsoy;
by residue; quit;
proc plot data=newsoy hpercent=50 vpercent=70;
by  residue;
plot (sresid)*year/vref=0 vaxis=-6 to 6 by 1;
plot (sresid)*year2/vref=0 vaxis=-6 to 6 by 1;
Quit;

Title3 'Bulk density reduced model Analysis of cov with all possible combinations (all lines)';
proc glm data=asa;
class tillage burning residue rep;
model BD =
tillage /*burning residue*/
/*tillage*burning tillage*residue /*burning*residue
tillage*burning*residue*/
year year2
tillage*year /*burning*year residue*year*/
tillage*year2 /*burning*year2 residue*year2

tillage*burning*year   tillage*residue*year   burning*residue*year*/
/*tillage*burning*year2  tillage*residue*year2   burning*residue*year2*

/*tillage*burning*residue*year
tillage*burning*residue*year2*/
```

```
rep(tillage burning residue)  year*rep(tillage burning residue)  year2*rep(tillage burning residue);
random rep(tillage burning residue);
id tillage burning residue ;

/*INTERCEPTS*/
estimate 'common intercept B001 for all trt' intercept 1;
/*estimate 'B001 tillage=CT' intercept 1 tillage 1 0;
estimate 'B002 tillage=NT' intercept 1 tillage 0 1;

estimate 'B003 burning=B' intercept 1 burning  1 0;
estimate 'B004 burning=NB' intercept 1 burning 0 1;

estimate 'B005 residue=H' intercept 1 residue  1 0;
estimate 'B006 residue=H' intercept 1 residue  0 1;

/*SLOPES*/
estimate 'slope 1 B101 tillage=CT' year 1 year*tillage 1 0;
estimate 'slope 1 B102 tillage=NT' year 1 year*tillage 0 1;

estimate 'common slope1 B103 for burning and residue' year 1 ;
/*estimate 'slope1 B103 burning=B' year 1 year*burning  1 0;
estimate 'slope 1 B104 burning=NB' year 1 year*burning 0 1;

estimate 'slope 1 B105 residue=H' year 1 year*residue  1 0;
estimate 'slope 1 B106 residue=L' year 1 year*residue  0 1;*/


estimate 'slope2 B201 tillage=CT' year2 1 year2*tillage 1 0;
estimate 'slope2 B202 tillage=NT' year2 1 year2*tillage 0 1;

estimate 'common slope2 B103 for burning and residue' year 2 ;
/*estimate 'slope2 B203 burning=B' year 1 year*burning  1 0;
estimate 'slope2 B204 burning=NB' year 1 year*burning 0 1;

estimate 'slope2 B205 residue=H' year 1 year*residue  1 0;
estimate 'slope2 B206 residue=L' year 1 year*residue  0 1;



/*CONSTRASTS*/
/*contrast 'Intercept CT vs NT' tillage 1 -1;
contrast 'Intercept CT-B vs CT-NB' burning 1 -1 tillage*burning 1 -1 0 0;*/

contrast 'Slope1 CT vs NT' tillage 1 -1 tillage*year 1 -1;
contrast 'Slope2 CT vs NT' tillage 1 -1 tillage*year2 1 -1;

/*contrast 'Slope CT-B vs CT-NB' burning*year 1 -1 tillage*burning*year 1 -1 0 0;*/

output out=newBD residual=resid stdr=se_resid student=sresid p=pred cookd=cookd;
quit;
proc sort data=newBD;
by tillage burning residue;
data newBD;
set newBD;
if tillage='CT' then sresid1=sresid; else sresid1=.; if tillage='NT' then sresid2=sresid; else sresid2=.;
if burning='NB' then sresid3=sresid; else sresid3=.;if burning='B' then sresid4=sresid; else sresid4=.;
```

```
if residue='H' then sresid5=sresid; else sresid5=.; if residue='L' then sresid6=sresid; else sresid6=.;
label resid='Residual'
se_resid='standard error of residual'
sresid='studentized residual'
pred='predicted'
cookd='cooks distance'
sresid1='CT student resid'
sresid2='NT student resid'
sresid3='NB student resid'
sresid4='B student resid'
sresid5='H student resid'
sresid6='L student resid';
run;

proc print data=newBD label noobs;
by tillage burning residue;
id tillage burning residue;
var year year2 BD sresid1 sresid2  sresid3 sresid4 cookd sresid5 sresid6;
quit;

proc plot data=newBD hpercent=50 vpercent=70;
plot (sresid1 sresid2 sresid3 sresid4 sresid5 sresid6)*year/vref=0 vaxis=-6 to 6 by 1;
plot (sresid1 sresid2 sresid3 sresid4 sresid5 sresid6)*year2/vref=0 vaxis=-6 to 6 by 1;
Quit;
```

```
Title 'Amuri, N: Analysis of Covariance with all trt combn (nested rep with irrigation)';

Data asa;
length trtcode4 $15;
infile 'cbes_longterm soil_NT_BD rep_irrg.csv' firstobs=5 delimiter= ",";
input obs year plot tblock bblock rep tillage$ burning$ residue$ Irrig$ soyyld whtyld Resicover BD pH EC
Po K Ca Mg Na S Fe Mn Zn Cu OM TN TC CNratio OMcont TNcont TCcont;
year2=year*year;
Year3=year2*year;
trtcode4=substr(tillage,1,2)||'-'||substr(residue,1,1)||'_'||substr(burning,1,2)||'-'||compress((substr(Irrig,1,2)));
label obs='observation #'
year='year'
plot='plot #'
tblock='tillage block'
bblock='burning block'
rep='replication'
tillage='tillage'
burning='burning'
residue='residue level'
Irrig='Irrigation'
soyyld='soybean yield (Mg/ha)'
whtyld='wheat yield (Mg/ha)'
Resicover='residue cover(kg/ha)'
BD='bulk density (g/cm3)'
pH='pH'
EC='Electrical conductivity (dS/m)'
Po='phosphorus content (kg/ha)'
K='potassium content (kg/ha)'
Ca='calcium content (kg/ha)'
Mg='magnesium content (kg/ha)'
Na='sodium content (kg/ha)'
S='sulfur content (kg/ha)'
Fe='iron content (kg/ha)'
Mn='manganese content (kg/ha)'
Zn='zince content (kg/ha)'
Cu='copper content (kg/ha)'
OM='organic matter conc (g/kg)'
TC='total carbon (g/kg)'
TN='total nitrogen conc (g/kg)'
CNratio='C:N ratio'
OMcont='organic matter content (kg/m2)'
TNcont='Total Nitrogen content (kg/m2)'
TCcont='Total carbon content (kg/m2)'
trtcode='treatment code'
year2='year square'
year3='year cube';
run;

Proc sort data=asa;
by tillage Irrig burning residue year;
quit;

title2 'initial data listing';
proc print data=asa;
id plot year rep tillage burning residue Irrig trtcode4;
```

```
var  soyyld whtyld BD pH EC Po K Ca Mg Na S Fe Mn Zn Cu /*OM TN TC*/ CNratio OMcont TNcont
TCcont;
Quit;
proc sort data=asa; by Irrig; quit;
proc means data=asa;
Class Irrig;
var TCcont soyyld;
quit;*/

Title3 'means for Fig plots';
proc means data=asa mean stderr;
class year Irrig;
var pH K Mg Fe Mn Zn TCcont;
quit;

Title3 'means for Fig plots';
proc means data=asa mean stderr;
class year Irrig burning;
var Ca Mg;
quit;

Title3 'Reduced model Analysis of cov with all possible combinations (all lines)';
proc glm data=asa;
class tillage Irrig burning residue rep;
model pH EC Po K Fe Mn Zn TCcont=
/*tillage*/  Irrig /* burning  residue
/*tillage*Irrig  tillage*burning  Irrig*burning   tillage*residue  Irrig*residue   burning*residue
tillage*Irrig*burning   tillage*Irrig*residue  tillage*burning*residue
tillage*irrig*burning*residue*/
year
/*year*tillage*/  year*irrig  /*year*burning  year*residue
year*tillage*Irrig  year*tillage*burning  year*Irrig*burning   year*tillage*residue
year*Irrig*residue  year*burning*residue
year*tillage*Irrig*burning   year*tillage*Irrig*residue  year*tillage*burning*residue
year*tillage*irrig*burning*residue*/
rep(tillage Irrig burning residue)  year*rep(tillage Irrig burning residue );
random rep(tillage burning residue Irrig)/test;
id tillage burning residue irrig;

/*INTERCEPTS*/
estimate 'B005 Irrig=I' intercept 1 Irrig  1 0;
estimate 'B006 Irrig=NI' intercept 1 Irrig 0 1;

/*SLOPE*/
/*estimate 'common slope for all trt' year 1;*/
estimate 'slope B105 Irrig=I' year 1 year*Irrig  1 0;
estimate 'slope B106 Irrig=NI' year 1 year*Irrig 0 1;

output out=newAll residual=resid stdr=se_resid student=sresid p=pred cookd=cookd;
quit;
proc sort data=newAll;
by tillage Irrig residue burning ; quit;
data newAll;
set newAll;
if tillage='CT' then sresid1=sresid; else sresid1=.; if tillage='NT' then sresid2=sresid; else sresid2=.;
if Irrig='I' then sresid3=sresid; else sresid3=.;if Irrig='NI' then sresid4=sresid; else sresid4=.;
```

```
if burning='B' then sresid5=sresid; else sresid5=.; if burning='NB' then sresid6=sresid; else sresid6=.;
if residue='H' then sresid7=sresid; else sresid7=.;if residue='L' then sresid8=sresid; else sresid8=.;
label resid='Residual'
se_resid='standard error of residual'
sresid='studentized residual'
pred='predicted'
cookd='cooks distance'
sresid1='CT' student resid'
sresid2='NT' student resid'
sresid3='Irr student resid'
sresid4='NI student resid'
sresid5='B student resid'
sresid6='NB student resid'
sresid7='H student resid'
sresid8='L student resid'
run;
proc sort data=newAll;
by tillage burning residue Irrig; quit;
/*proc sort data=newpH;
by residue;quit;*/

proc print data=newAll label noobs;
by tillage Irrig burning residue;
id tillage Irrig  burning residue;
var year pH EC Po K Fe Mn Zn TCcont sresid1 sresid2 sresid3 sresid4 sresid5 sresid6 sresid7 sresid8
cookd;
quit;

proc plot data=newAll hpercent=50 vpercent=70;
plot sresid*year/vref=0 vaxis=-6 to 6 by 1;

proc sort data=newAll; by tillage Irrig burning residue; quit;
Proc plot data=newAll hpercent=50 vpercent=70; /*by burning;*/
plot (sresid1 sresid2  sresid3 sresid4 sresid5 sresid6 sresid7 sresid8)*year/vref=0 vaxis=-6 to 6 by 1;
Quit;

Title3 'Reduced model-1 Ca Analysis of cov with all possible combinations (all lines)';
proc glm data=asa;
class tillage Irrig burning residue rep;
model  Ca  =
/*tillage*/   Irrig   burning /* residue
tillage*Irrig   tillage*burning*/   Irrig*burning   /* tillage*residue  Irrig*residue   burning*residue
tillage*Irrig*burning    tillage*Irrig*residue   tillage*burning*residue
tillage*irrig*burning*residue*/
year
/*year*tillage*/   year*Irrig   year*burning   /* year*residue
year*tillage*Irrig   year*tillage*burning*/   year*Irrig*burning    /*year*tillage*residue
year*Irrig*residue   year*burning*residue
year*tillage*Irrig*burning    year*tillage*Irrig*residue   year*tillage*burning*residue
year*tillage*irrig*burning*residue*/
rep(tillage Irrig burning residue)   year*rep(tillage Irrig burning residue );
random rep(tillage burning residue Irrig)/test;
id tillage burning residue irrig;

/*INTERCEPTS*/
estimate 'B005 Irrig 1' intercept 1 Irrig  1 0;
```

```
estimate 'B006 Irrig=NI' intercept 1 Irrig 0 1;


estimate 'B011 I-B' intercept 1  Irrig 1 0 burning 1 0
                    Irrig*burning 1 0 0 0;
estimate 'B012 I-NB' intercept 1 Irrig 1 0 burning 0 1
                    Irrig*burning 0 1 0 0;
estimate 'B013 NI-B' intercept 1 Irrig 0 1 burning 1 0
                    Irrig*burning 0 0 1 0;
estimate 'B014 NI-NB' intercept 1 Irrig 0 1 burning 0 1
                    Irrig*burning 0 0 0 1;

/*SLOPE*/
/*estimate 'common slope for all trt' year 1;*/
estimate 'B111 year I-B' year 1 Irrig*year 1 0 burning*year 1 0
                    Irrig*burning*year 1 0 0 0;
estimate 'B112 year I-NB' year 1 Irrig*year 1 0 burning*year 0 1
                    Irrig*burning*year 0 1 0 0;
estimate 'B113 year NI-B'  year 1 Irrig*year 0 1 burning*year 1 0
                    Irrig*burning*year 0 0 1 0;
estimate 'B114 year NI-NB' year 1 Irrig*year 0 1 burning*year 0 1
                    Irrig*burning*year 0 0 0 1;
/*CONTRASTS*/
contrast 'Intercept I vs NI' Irrig 1 -1;

contrast 'Intercept I-B vs I-NB' burning 1 -1 Irrig*burning 1 -1 0 0;
contrast 'Intercept NI-B vs NI-NB' burning 1 -1 Irrig*burning  0 0 1 -1;
contrast 'Intercept I-B vs NI-B' Irrig 1 -1 Irrig*burning 1 0 -1 0;
contrast 'Intercept I-NB vs NI-NB' Irrig 1 -1 Irrig*burning 0 1 0 -1;

contrast 'Slope I-B vs I-NB' burning*year 1 -1 Irrig*burning*year 1 -1 0 0;
contrast 'Slope NI-B vs NI-NB' burning*year 1 -1 Irrig*burning*year  0 0 1 -1;
contrast 'Slope I-B vs NI-B' Irrig*year 1 -1 Irrig*burning*year 1 0 -1 0;
contrast 'Slope I-NB vs NI-NB' Irrig*year 1 -1 Irrig*burning*year 0 1 0 -1;

output out=newCa residual=resid stdr=se_resid student=sresid p=pred cookd=cookd;
quit;
proc sort data=newCa;
by tillage Irrig residue burning ; quit;
data newCa;
set newCa;
if tillage='CT' then sresid1=sresid; else sresid1=.; if tillage='NT' then sresid2=sresid; else sresid2=.;
if Irrig='I' then sresid3=sresid; else sresid3=.;if Irrig='NI' then sresid4=sresid; else sresid4=.;
if burning='B' then sresid5=sresid; else sresid5=.; if burning='NB' then sresid6=sresid; else sresid6=.;
if residue='H' then sresid7=sresid; else sresid7=.;if residue='L' then sresid8=sresid; else sresid8=.;
label resid='Residual'
se_resid='standard error of residual'
sresid='studentized residual'
pred='predicted'
cookd='cooks distance'
sresid1='CT student resid'
sresid2='NT student resid'
sresid3='Irr student resid'
sresid4='NI student resid'
sresid5='B student resid'
sresid6='NB student resid'
```

```
sresid7='H student resid'
sresid8='L student resid'
run;
proc sort data=newCa;
by tillage burning residue Irrig; quit;

proc print data=newCa label noobs;
by tillage Irrig burning residue;
id tillage Irrig  burning residue;
var year pH EC Po K Fe Mn Zn TCcont sresid1 sresid2 sresid3 sresid4 sresid5 sresid6 sresid7 sresid8
cookd;
quit;

proc plot data=newCa hpercent=50 vpercent=70;
plot sresid*year/vref=0 vaxis=-6 to 6 by 1;

proc sort data=newCa; by tillage Irrig burning residue; quit;
Proc plot data=newCa hpercent=50 vpercent=70; /*by burning;*/
plot (sresid1 sresid2  sresid3 sresid4 sresid5 sresid6 sresid7 sresid8)*year/vref=0 vaxis=-6 to 6 by 1;
Quit;

Title3 'Reduced model-1 Mg Analysis of cov with all possible combinations (all lines)';
proc glm data=asa;
class tillage Irrig burning residue rep;
model  Mg  =
/*tillage*/  Irrig burning  /* residue
tillage*Irrig  tillage*burning*/  Irrig*burning  /* tillage*residue  Irrig*residue   burning*residue
tillage*Irrig*burning   tillage*Irrig*residue  tillage*burning*residue
tillage*irrig*burning*residue*/
year
/*year*tillage*/  year*irrig  /*year*burning  year*residue
year*tillage*Irrig  year*tillage*burning  year*Irrig*burning   /*year*tillage*residue
year*Irrig*residue  year*burning*residue
year*tillage*Irrig*burning   year*tillage*Irrig*residue  year*tillage*burning*residue
year*tillage*irrig*burning*residue*/
rep(tillage Irrig burning residue)   year*rep(tillage Irrig burning residue );
random rep(tillage burning residue Irrig)/test;
id tillage burning residue irrig;

/*INTERCEPTS*/
/*estimate 'common intercept for all trt' intercept 1;*/
estimate 'B005 Irrig=I' intercept 1 Irrig  1 0;
estimate 'B006 Irrig=NI' intercept 1 Irrig 0 1;

estimate 'B011 I-B' intercept 1  Irrig 1 0 burning 1 0
                    Irrig*burning 1 0 0 0;
estimate 'B012 I-NB' intercept 1 Irrig 1 0 burning 0 1
                    Irrig*burning 0 1 0 0;
estimate 'B013 NI-B' intercept 1 Irrig 0 1 burning 1 0
                    Irrig*burning 0 0 1 0;
estimate 'B014 NI-NB' intercept 1 Irrig 0 1 burning 0 1
                    Irrig*burning 0 0 0 1;
/*SLOPE*/
/*estimate 'common slope for Irrig-burn combns' year 1;*/
estimate 'slope B105 Irrig=I' year 1 year*Irrig  1 0;
estimate 'slope B106 Irrig=NI' year 1 year*Irrig 0 1;
```

```
/*CONTRASTS*/
contrast 'Intercept I-B vs I-NB' burning 1 -1 Irrig*burning 1 -1 0 0;
contrast 'Intercept NI-B vs NI-NB' burning 1 -1 Irrig*burning  0 0 1 -1;
contrast 'Intercept I-B vs NI-B' Irrig 1 -1 Irrig*burning 1 0 -1 0;
contrast 'Intercept I-NB vs NI-NB' Irrig 1 -1 Irrig*burning 0 1 0 -1;

contrast 'sLOPE I vs NI' Irrig*year 1 -1;

output out=newMg residual=resid stdr=se_resid student=sresid p=pred cookd=cookd;
quit;
proc sort data=newMg;
by tillage Irrig residue burning ; quit;
data newMg;
set newMg;
if tillage='CT' then sresid1=sresid; else sresid1=.; if tillage='NT' then sresid2=sresid; else sresid2=.;
if Irrig='I' then sresid3=sresid; else sresid3=.;if Irrig='NI' then sresid4=sresid; else sresid4=.;
if burning='B' then sresid5=sresid; else sresid5=.; if burning='NB' then sresid6=sresid; else sresid6=.;
if residue='H' then sresid7=sresid; else sresid7=.;if residue='L' then sresid8=sresid; else sresid8=.;
label resid='Residual'
se_resid='standard error of residual'
sresid='studentized residual'
pred='predicted'
cookd='cooks distance'
sresid1='CT student resid'
sresid2='NT student resid'
sresid3='Irr student resid'
sresid4='NI student resid'
sresid5='B student resid'
sresid6='NB student resid'
sresid7='H student resid'
sresid8='L student resid'
run;
proc sort data=newMg;
by tillage burning residue Irrig; quit;
/*proc sort data=newpH;
by residue;quit;*/

proc print data=newMg label noobs;
by tillage Irrig burning residue;
id tillage Irrig  burning residue;
var year pH EC Po K Fe Mn Zn TCcont sresid1 sresid2 sresid3 sresid4 sresid5 sresid6 sresid7 sresid8
cookd;
quit;

proc plot data=newMg hpercent=50 vpercent=70;
plot sresid*year/vref=0 vaxis=-6 to 6 by 1;

proc sort data=newMg; by tillage Irrig burning residue; quit;
Proc plot data=newMg hpercent=50 vpercent=70; /*by burning;*/
plot (sresid1 sresid2  sresid3 sresid4 sresid5 sresid6 sresid7 sresid8)*year/vref=0 vaxis=-6 to 6 by 1;Quit;
```

C. Chapter 2 ANOVA for residue level

```
title 'Amuri. N: ANOVA FOR CBES DATA 2007';
option ls=132 ps=70;
data all;
  infile 'cbes resid SOy06&07.csv' firstobs = 3 delimiter = ",";
  input plot tblock bblock till$ burn$ fert$ irrig$ soyyld07 soyyld06 res07 res06;

  label plot = 'Plot number'
       tblock = 'Tillage block'
       irrig = 'irrigation'
       till = 'Tillage'
       burn = 'Burn'
       fert = 'Residue level (H/L)'
       res07 = 'wheat residue level (kg/ha)'
            soyyld07 = 'soybean yield (Mg/ha 13%MC)';
run;
proc sort data = all; by till irrig burn;
quit;
title2 'INITIAL DATA LISTING';
proc print data = all noobs label; by tblock till irrig;
  id tblock irrig till;
  var burn fert plot soyyld07 soyyld06 res07 res06;
quit;
title2 'Descriptive statistics';
proc means data=all mean stderr;
class irrig till burn fert;
var soyyld07 soyyld06 ;
  quit;
title2 'Means of residue level in NT and no burn only';
proc sort data=all; by till burn fert; quit;
 proc means data=all mean stderr;
class till burn fert;
var res06 res07;
quit;

title2 'Cotton Branch 2007 all';
 proc glm data = all;
  class tblock bblock till burn fert;
  model soyyld07 /*whyld*/ res07 res06 /*bd07 pH07 EC07
   P07 K07 Ca07 Mg07 S07 Na07 Fe07 Mn07 Zn07 Cu07 OM07 N07 C07 CNRatio07 OMc07 Nc07
Cc07*/
           = tblock till     tblock*till
            bblock burn     bblock*burn
            till*burn      tblock*bblock*till*burn
            fert          tblock*bblock*fert
            till*fert      tblock*bblock*till*fert
            burn*fert      tblock*bblock*burn*fert
            till*burn*fert ;
 random tblock tblock*till  bblock bblock*burn      tblock*bblock*till*burn
      tblock*bblock*fert  tblock*bblock*till*fert  tblock*bblock*burn*fert
   / test;
 means till / lsd lines E = tblock*till;
 means burn / lsd lines E = bblock*burn;
 means fert / lsd lines E = tblock*bblock*fert;
 means till*burn*fert/lsd; quit;
```

D. Chapter 2 ANOVA for greenhouse experiment

```
title '2007 Soil Incubation: To determine rate of wheat residue decomposition
      and its impact to soil properties as affected by tillage and residue level';

data GH;
Infile 'GH all.csv' firstobs=3 delimiter=",";
Input obs sampleID Till$ Res$ Time$ MB_C grvMC pH EC Pho K Ca Mg S Na
     Fe Mn Zn Cu B OM TN TC CN;
Label sampleID='Sample ID'
              Till='Simulated tillage'
              Res='Residue level'
              Time='Incubation time (weeks)'
     MB_C='Microbial C biomass (ug/g)'
              grvMC='gravimetric moisture content (%)';/*Initial biomass C and GrvMC i.e time0 are not
included*/
    /* CN ='C:N ratio':*/
Run;
proc sort data=GH;
by obs Time Till Res sampleID;
quit;

Title3 'Initial data listing';
Proc print data=GH noobs label;
id obs sampleID Time Till Res;
var   MB_C grvMC pH EC Pho K Ca Mg S Na Fe Mn Zn Cu B OM TN TC CN;
quit;
 title3 'descriptive statistics';
 proc means data=GH stderr;
 class Time Till Res;
 var MB_C grvMC OM TN TC;
 quit;

title3 'Analysis of variance: No covariance';
proc glm data=GH;
class  Time Till Res;
Model MB_C grvMC pH EC Pho K Ca Mg S Na Fe Mn Zn Cu B OM TN TC CN
              = Time| Till| Res;

 means Time / lsd ;
 means Till / lsd ;
 means Res / lsd ;
 means Time*Till/lsd ;
 means Time*Res/lsd;
 quit;
```

```
title 'Amuri N. Total C regression analysis for CT-high residue level';
data TC;
infile 'TC_Time_Till_Res_reg.csv' firstobs=2 delimiter=",";
input time CTH CTHSE CTL CTLSE CTO CTOSE NTH NTHSE NTL NTLSE NTO NTOSE;
label time='time of incubation (wk)';
CTH='total C (kg C m-2)under CT-high';
run;

proc print data=TC;
var time CTH CTHSE CTL CTLSE CTO CTOSE NTH NTHSE NTL NTLSE NTO NTOSE;
quit;

proc reg data=TC;
model CTH = time;
quit;




title 'Amuri N: GH soil incubation temperature and RH data summary';

data GH;
Infile 'GH_Temp_RHsas.csv' firstobs=2 delimiter=",";
Input obs yr mo$ wk date doy hr volt intemp airtemp RH esat eunsat;
label obs='# observation'
yr='year'
mo='month'
wk='week of incubation'
date='date'
doy='Julian day of the year'
hr='hour'
volt='battery volt'
intemp='internal battery temperature (C)'
airtemp='air temperature (C)'
RH='relative humidity (%)';
run;

proc print data=GH;
var obs yr mo wk date doy hr volt intemp airtemp RH esat eunsat;
quit;

proc means data=GH mean;
class yr wk;
var airtemp RH;
quit;
```

E. Chapter 3 ANOVA for weed population density

```
Title 'Amuri N. Effect of tillage, burning, and N rate on weed diversity & population per sq meter';

Data asa;
 /*lengthtrtcode1 trtcode2 trtcode3trtcode4 $15;*/
infile 'weed all per sq m.csv' firstobs=3 delimiter= ",";
input plot tblock till$ bblock burn$ resi$ Irrig$ year season$ soyyld6 soyyld7 barnyd burmd carpt cheat
pursl CLGC
 eclipt EMG FP GG hembit horsew LCG Palmer PMG PS Primro prost redclo RST         RFS SPW sparse
spotted Trumpt Vertch VPW whitclo wonion YWS YNS ;
/*trtcode1=substr(tillage,1,2)||'-'||compress(substr(burning.1,2));
trtcode2=substr(tillage,1,2)||'-'||substr(residue,1,1);
trtcode3=compress(substr(burning.1,2))||'-'||substr(residue.1.1);
trtcode4=substr(tillage,1,2)||'-'||substr(residue,1,1)||'_'||compress(substr(burning.1,2));*/
grasses= (barnyd + burmd + cheat + FP + GG  + LCG + RST);
sedges=(RFS + YNS);
broadl=(barnyd + burmd + carpt + cheat + pursl + CLGC + Primro + eclipt + EMG + FP + GG + + hembit
+
       horsew + LCG + Palmer + PMG + PS + Primro + prost + redclo + RST + RFS + SPW + sparse +
spotted + VPW +
       whitclo + wonion + YNS + YWS)-(grasses + sedges);
perennial=sedges + wonion + YWS + Trumpt;
allweed=grasses + broadl + sedges;
spotted2 =(prost + sparse + spotted);
if year=2006 and season='early' then time='Ea2006';
if year=2006 and season='late' then time='La2006';
if year=2007 and season='early' then time='Ea2007';
if year=2007 and season='late' then time='La2007';

If year=2006 and season='late' then soyyld6=.;
if year=2007 and season='early' then soyyld6=.;
If year=2007 and season='late' then soyyld6=.;

If year=2006 and season='late' then soyyld7=.;
if year=2007 and season='early' then soyyld7=.;
if year=2007 and season='late' then soyyld7=.;

label
year='year'
plot='plot #'
tblock='tillage block'
till='tillage'
burn='burning'
resi='residue level'
barnyd='barnyard geass'
burmd='burmuder grass'
carpt='carpet weed'
cheat='cheat'
pursl='common purslane'
CLGC='cutleaf groundcherry'
Primro='cutleaf primrose'
eclipt='eclipter'
EMG='entire morningglory'
```

```
FP='fall panicum'
GG='goosegrass'
horsew='horseweed'
LCG='large crabgrass'
Palmer='palmer Amaranth'
PMG='pitted morningglory'
PS='prickly sida'
redclo='red clover'
RST='red sprangletop'
RFS='rice flatsedge'
SPW='smooth pigweed'
sparse='sparse spurge'
spotted='spotted spurge'
VPW='virginia pepperweed'
whitclo='white clover'
wonion='wild onion'
YNS='yellow nutsedge'
YWS='yellow woodsorrel'
/*trtcode='treatment code'*/;
if soyyld=0 then soyyld=.;
run;
Proc sort data=asa;
by till Irrig burn resi;
quit;

title2 'initial data listing';
proc print data=asa;
id plot year till bblock time /*Irrig*/ burn resi /*trtcode1 trtcode2 trtcode3 trtcode4*/;
var allweed grasses sedges broadl perennial barnyd burmd carpt cheat pursl CLGC
 eclipt EMG FP GG hembit horsew LCG Palmer PMG PS Primro prost redclo RST          RFS SPW
sparse spotted spotted2 Trumpt Vertch VPW whitclo wonion YWS YNS ;
Quit;

title3 'Revised Repeated experiment season as fixed factor in split plot.year.season. and blocks included in
repeated measurement';
proc glm data=asa;
class tblock bblock till /*Irrig*/ burn resi year season;
model allweed grasses broadl sedges perennial /*barnyd burmd*/ carpt cheat /*pursl CLGC
 eclipt EMG*/ FP GG hembit /*horsew*/ LCG /*Palmer*/ PMG PS Primro /*prost redclo*/ RST   RFS
SPW /*sparse
spotted2 Trumpt*/ Vertch /*VPW whitclo*/ wonion YWS /*YNS*/ =  till|/*Irrig*/|burn|resi|year|season
     tblock    tblock*till
     bblock    bblock*burn
     tblock*bblock*till*burn
    tblock*bblock*till*resi
    tblock*bblock*till*burn*resi


tblock*year  tblock*till*year
bblock*year   bblock*burn*year
tblock*bblock*till*burn*year
tblock*bblock*till*burn*resi*year

Random              tblock tblock*till
      bblock bblock*burn
      tblock*bblock*till*burn
```

```
     tblock*bblock*till*resi
     tblock*bblock*till*burn*resi

     tblock*year  tblock*till*year
     bblock*year  bblock*burn*year
     tblock*bblock*till*burn*year
     tblock*bblock*till*burn*resi*year/test;

means till/lsd lines e=tblock*till;
means burn/lsd lines e=bblock*burn;
means resi/lsd lines e=tblock*bblock*till*resi;
means till*resi;
means year season/lsd lines;
means year*season/ lsd lines;
means resi*year   till*year   burn*year;
means till*burn*resi/lsd lines e=tblock*bblock*till*burn*resi;
means till*resi*year/lsd lines e= tblock*bblock*till*burn*resi*year;
means till*burn*season;
means till*year*season;
means till*resi*season;
means burn*year*season;
means resi*year*season;
means till*burn*resi*year;
means till*burn*resi*year*season;
quit;

title3 'Anova for weeds with 5 way interraction above summarized to 4 way';
proc glm data=asa;
class tblock bblock till /*Irrig*/ burn resi time;
model grasses perennial PS wonion RST Vertch YWS =  till|/*Irrig*/|burn|resi|time
    tblock    tblock*till
    bblock    bblock*burn
    tblock*bblock*till*burn
   tblock*bblock*till*resi
   tblock*bblock*till*burn*resi


tblock*time  tblock*till*time
bblock*time   bblock*burn*time
tblock*bblock*till*burn*time
/*tblock*bblock*till*burn*resi*time*/ ;



Random             tblock tblock*till
     bblock bblock*burn
     tblock*bblock*till*burn
     tblock*bblock*till*resi
     tblock*bblock*till*burn*resi

     tblock*time  tblock*till*time
     bblock*time   bblock*burn*time
     tblock*bblock*till*burn*time
     /*tblock*bblock*till*burn*resi*time*/ /test;

means till*burn*resi*time;
```

```
means burn*time;
means resi*time;
means till*burn*time ;
means till*resi*time;
                    quit;

title2 'soybean yield 2006 and 2007';

proc glm data = asa;
 class tblock bblock till burn resi;
 model soyyld6 soyyld7
        = tblock till    tblock*till
         bblock burn    bblock*burn
         till*burn      tblock*bblock*till*burn
         resi           tblock*bblock*resi
         till*resi      tblock*bblock*till*resi
         burn*resi      tblock*bblock*burn*resi
         till*burn*resi ;
 random tblock tblock*till  bblock bblock*burn     tblock*bblock*till*burn
      tblock*bblock*resi  tblock*bblock*till*resi  tblock*bblock*burn*resi
    / test;
 means till / lsd lines E = tblock*till;
 means burn / lsd lines E = bblock*burn;
 means resi / lsd lines E = tblock*bblock*resi;
 means till*burn*resi;
quit;
```

APPENDIX 3: Chapter 2 raw data for ANCOVA

Soybean and wheat yield (Mg ha^{-1}), surface residue level (Residue) (kg ha^{-1}), bulk density (BD) (g cm^{-3}), and soil pH

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	soybean	wheat	Residue	BD	pH
1	1	1	1	1	1	CT	NB	H	I	5.28	4.11	4496	1.21	7.0
2	1	2	1	1	1	NT	NB	L	I	5.01	4.51	3768	1.24	7.1
3	1	3	2	1	1	NT	NB	H	I	4.78	3.91	3384	1.28	6.9
4	1	4	2	1	1	CT	NB	L	I	6.14	3.60	5208	1.19	6.9
5	1	5	3	1	2	NT	NB	L	I	4.73	3.59	5224	1.18	7.0
6	1	6	3	1	2	CT	NB	H	I	5.81	4.20	1928	1.19	7.0
7	1	7	1	1	2	CT	NB	L	I	5.97	4.31	6276	1.21	7.1
8	1	8	1	1	2	NT	NB	H	I	6.05	4.47	3116	1.25	7.0
9	1	9	2	1	3	NT	NB	L	I	4.64	3.64	3936	1.22	6.9
10	1	10	2	1	3	CT	NB	H	I	3.39	4.02	3972	1.14	6.8
11	1	11	3	1	3	NT	NB	H	I	3.92	3.47	2656	1.19	6.8
12	1	12	3	1	3	CT	NB	L	I	4.93	3.60	3276	1.24	6.9
13	1	13	1	1	1	CT	B	L	I	3.64	3.84	0	1.18	6.8
14	1	14	1	1	1	NT	B	L	I	3.35	3.82	0	1.18	6.8
15	1	15	2	1	1	NT	B	H	I	4.19	2.93	0	1.08	6.7
16	1	16	2	1	2	CT	B	L	I	5.02	3.26	0	1.18	6.7
17	1	17	3	1	2	NT	B	H	I	4.11	3.73	0	1.22	6.5
18	1	18	3	1	3	CT	B	L	I	5.82	3.96	0	1.21	6.5
19	1	19	1	1	1	CT	B	H	I	7.1	4.21	0	1.20	6.9
20	1	20	1	1	3	NT	B	H	I	4.63	4.13	0	1.19	6.7
21	1	21	2	1	2	NT	B	L	I	4.46	3.53	0	1.21	6.7
22	1	22	2	1	2	CT	B	H	I	5.32	3.97	0	1.10	6.8
23	1	23	3	1	3	NT	B	L	I	7.84	3.45	0	1.29	6.7
24	1	24	3	1	3	CT	B	H	I	6.06	4.44	0	1.19	6.8
25	1	25	1	2	4	CT	B	H	I	3.77	4.33	0	1.18	6.6
26	1	26	1	2	4	NT	B	H	I	4.13	3.89	0	1.18	6.5
27	1	27	2	2	5	NT	B	H	I	3.06	3.89	0	1.26	6.5
28	1	28	2	2	4	CT	B	L	I	3.72	3.83	0	1.13	6.6
29	1	29	3	2	6	NT	B	H	I	4.51	3.82	0	1.18	6.5
30	1	30	3	2	5	CT	B	L	I	5.24	3.68	0	1.15	6.7
31	1	31	1	2	6	CT	B	L	I	1.32	4.42	0	1.14	6.5
32	1	32	1	2	4	NT	B	L	I	2.88	4.61	0	1.24	6.6
33	1	33	2	2	5	NT	B	L	I	2.65	4.11	0	1.23	6.6
34	1	34	2	2	5	CT	B	H	I	3.43	4.27	0	1.22	6.7
35	1	35	3	2	6	NT	B	L	I	5.8	4.07	0	1.24	6.7
36	1	36	3	2	6	CT	B	H	I	4.08	4.54	0	1.25	6.6

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	soybean	wheat	Residue	BD	pH
37	1	37	1	2	4	CT	NB	H	I	2.99	4.08	2772	1.22	6.7
38	1	38	1	2	4	NT	NB	L	I	3.12	3.84	3520	1.24	6.7
39	1	39	2	2	4	NT	NB	H	I	3.12	3.83	3944	1.21	6.7
40	1	40	2	2	5	CT	NB	H	I	3.91	3.78	3568	1.23	6.7
41	1	41	3	2	5	NT	NB	L	I	3.75	3.66	4524	1.25	6.7
42	1	42	3	2	6	CT	NB	H	I	1.91	4.23	4084	1.25	6.9
43	1	43	1	2	4	CT	NB	L	I	2.37	3.71	1480	1.23	6.9
44	1	44	1	2	5	NT	NB	H	I	2.43	3.59	1960	1.26	6.9
45	1	45	2	2	6	NT	NB	L	I	2.73	3.55	3056	1.21	7.0
46	1	46	2	2	5	CT	NB	L	I	3	3.99	3880	1.16	6.9
47	1	47	3	2	6	NT	NB	H	I	2.43	4.16	3164	1.23	6.9
48	1	48	3	2	6	CT	NB	L	I	4.96	3.91	2844	1.24	7.1
49	2	1	1	1	1	CT	NB	H	I	3.8	2.74	8736	1.22	7.1
50	2	2	1	1	1	NT	NB	L	I	4.25	2.66	3568	1.30	7.1
51	2	3	2	1	1	NT	NB	H	I	3.87	2.69	4104	1.27	7.0
52	2	4	2	1	1	CT	NB	L	I	2.6	2.30	6488	1.23	7.0
53	2	5	3	1	2	NT	NB	L	I	3.35	2.48	2008	1.21	7.1
54	2	6	3	1	2	CT	NB	H	I	2.98	2.26	7252	1.26	6.9
55	2	7	1	1	2	CT	NB	L	I	3.29	3.67	3732	1.23	7.2
56	2	8	1	1	2	NT	NB	H	I	3.86	3.59	9000	1.30	7.1
57	2	9	2	1	3	NT	NB	L	I	3.81	3.51	5724	1.34	7.1
58	2	10	2	1	3	CT	NB	H	I	2.97	3.36	7296	1.25	6.9
59	2	11	3	1	3	NT	NB	H	I	3.31	3.23	9840	1.32	7.0
60	2	12	3	1	3	CT	NB	L	I	3.65	3.48	4284	1.34	7.0
61	2	13	1	1	1	CT	B	L	I	3.77	4.45	0	1.25	7.1
62	2	14	1	1	1	NT	B	L	I	4.45	4.53	0	1.34	7.1
63	2	15	2	1	1	NT	B	H	I	4.41	4.05	0	1.33	7.1
64	2	16	2	1	2	CT	B	L	I	3.57	4.25	0	1.22	7.0
65	2	17	3	1	2	NT	B	H	I	4.94	4.33	0	1.31	6.8
66	2	18	3	1	3	CT	B	L	I	3.24	3.68	0	1.29	6.9
67	2	19	1	1	1	CT	B	H	I	3.31	3.90	0	1.30	7.1
68	2	20	1	1	3	NT	B	H	I	3.51	4.00	0	1.32	7.1
69	2	21	2	1	2	NT	B	L	I	3.94	3.57	0	1.38	7.2
70	2	22	2	1	2	CT	B	H	I	3.01	3.90	0	1.33	7.0
71	2	23	3	1	3	NT	B	L	I	3.87	3.96	0	1.30	7.1
72	2	24	3	1	3	CT	B	H	I	3.28	4.41	0	1.27	7.1
73	2	25	1	2	4	CT	B	H	I	3.86	4.22	0	1.32	6.9
74	2	26	1	2	4	NT	B	H	I	3.6	7.13	0	1.39	6.9
75	2	27	2	2	5	NT	B	H	I	3.97	3.67	0	1.24	6.9
76	2	28	2	2	4	CT	B	L	I	3.54	3.37	0	1.21	7.0
77	2	29	3	2	6	NT	B	H	I	3.95	4.17	0	1.34	6.8
78	2	30	3	2	5	CT	B	L	I	3.14	3.21	0	1.31	7.0

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	soybean	wheat	Residue	BD	pH
79	2	31	1	2	6	CT	B	L	1	3.41	3.65	0	1.25	6.9
80	2	32	1	2	4	NT	B	L	1	3.77	3.95	0	1.30	6.9
81	2	33	2	2	5	NT	B	L	1	3.97	3.51	0	1.36	6.7
82	2	34	2	2	5	CT	B	H	1	3.83	4.14	0	1.30	6.7
83	2	35	3	2	6	NT	B	L	1	4.08	3.54	0	1.36	6.8
84	2	36	3	2	6	CT	B	H	1	3.56	4.26	0	1.30	6.9
85	2	37	1	2	4	CT	NB	H	1	3.74	3.62	3692	1.19	7.2
86	2	38	1	2	4	NT	NB	L	1	2.96	3.05	4104	1.29	7.1
87	2	39	2	2	4	NT	NB	H	1	3.97	3.75	6060	1.28	7.0
88	2	40	2	2	5	CT	NB	H	1	2.78	3.09	5316	1.26	7.1
89	2	41	3	2	5	NT	NB	L	1	4.3	3.74	4768	1.32	7.1
90	2	42	3	2	6	CT	NB	H	1	3.97	4.07	4700	1.31	7.0
91	2	43	1	2	4	CT	NB	L	1	3.39	2.25	3396	1.30	7.2
92	2	44	1	2	5	NT	NB	H	1	3.65	3.30	4252	1.29	7.3
93	2	45	2	2	6	NT	NB	L	1	3.88	3.11	3460	1.29	7.2
94	2	46	2	2	5	CT	NB	L	1	2.61	3.35	4396	1.22	7.2
95	2	47	3	2	6	NT	NB	H	1	4.01	3.62	3764	1.33	7.1
96	2	48	3	2	6	CT	NB	L	1	3.65	0.00	3716	1.30	7.2
97	3	1	1	1	1	CT	NB	H	1	0.09	2.43	9064	0.98	6.9
98	3	2	1	1	1	NT	NB	L	1	1.02	0.00	4028	1.36	7.0
99	3	3	2	1	1	NT	NB	H	1	1.33	2.91	7564	1.35	6.6
100	3	4	2	1	1	CT	NB	L	1	1.03	3.24	6800	1.31	7.0
101	3	5	3	1	2	NT	NB	L	1	0.88	3.00	8472	1.35	7.0
102	3	6	3	1	2	CT	NB	H	1	0.2	2.64	8068	1.21	6.8
103	3	7	1	1	2	CT	NB	L	1	0.59	2.79	8412	1.19	7.4
104	3	8	1	1	2	NT	NB	H	1	0.83	2.63	8300	1.38	7.0
105	3	9	2	1	3	NT	NB	L	1	0.85	3.00	5320	1.33	7.2
106	3	10	2	1	3	CT	NB	H	1	0.7	2.79	6996	1.23	7.0
107	3	11	3	1	3	NT	NB	H	1	0.97	2.70	14724	1.36	6.8
108	3	12	3	1	3	CT	NB	L	1	0.81	3.04	8712	1.36	6.8
109	3	13	1	1	1	CT	B	L	1	0.76	2.20	0	1.29	7.4
110	3	14	1	1	1	NT	B	L	1	1.27	2.49	0	1.31	7.3
111	3	15	2	1	1	NT	B	H	1	0.92	2.98	0	1.32	7.1
112	3	16	2	1	2	CT	B	L	1	0.86	2.47	0	1.20	7.2
113	3	17	3	1	2	NT	B	H	1	1.04	3.25	0	1.30	7.0
114	3	18	3	1	3	CT	B	L	1	0.63	2.70	0	1.25	6.8
115	3	19	1	1	1	CT	B	H	1	0.76	2.30	0	1.25	7.2
116	3	20	1	1	3	NT	B	H	1	1.22	3.45	0	1.33	7.4
117	3	21	2	1	2	NT	B	L	1	1.32	2.52	0	1.34	7.2
118	3	22	2	1	2	CT	B	H	1	0.31	2.27	0	1.22	7.4

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	soybean	wheat	Residue	BD	pH
119	3	23	3	1	3	NT	B	L	I	1.92	2.81	0	1.35	7.3
120	3	24	3	1	3	CT	B	H	I	0.71	2.95	0	1.27	7.0
121	3	25	1	2	4	CT	B	H	I	0.94	2.40	0	1.33	7.2
122	3	26	1	2	4	NT	B	H	I	1.34	3.49	0	1.34	7.0
123	3	27	2	2	5	NT	B	H	I	0.68	3.62	0	1.30	7.0
124	3	28	2	2	4	CT	B	L	I	0.48	3.04	0	1.30	7.1
125	3	29	3	2	6	NT	B	H	I	0.62	3.06	0	1.38	7.0
126	3	30	3	2	5	CT	B	L	I	0.44	2.84	0	1.30	7.2
127	3	31	1	2	6	CT	B	L	I	0.75	2.40	0	1.24	7.1
128	3	32	1	2	4	NT	B	L	I	1.39	2.95	0	1.33	7.3
129	3	33	2	2	5	NT	B	L	I	0.97	2.58	0	1.37	7.2
130	3	34	2	2	5	CT	B	H	I	0.82	2.42	0	1.29	7.2
131	3	35	3	2	6	NT	B	L	I	0.6	3.01	0	1.28	7.3
132	3	36	3	2	6	CT	B	H	I	0.65	3.07	0	1.27	7.2
133	3	37	1	2	4	CT	NB	H	I	0.84	2.14	7556	1.24	7.3
134	3	38	1	2	4	NT	NB	L	I	1.3	2.04	5720	1.40	7.2
135	3	39	2	2	4	NT	NB	H	I	0.98	3.05	4632	1.39	7.3
136	3	40	2	2	5	CT	NB	H	I	0.84	2.88	5352	1.37	7.3
137	3	41	3	2	5	NT	NB	L	I	0.91	2.55	6020	1.38	7.3
138	3	42	3	2	6	CT	NB	H	I	0.7	1.52	3508	1.34	7.4
139	3	43	1	2	4	CT	NB	L	I	0.91	1.77	4460	1.29	7.3
140	3	44	1	2	5	NT	NB	H	I	1.23	2.64	5964	1.39	7.2
141	3	45	2	2	6	NT	NB	L	I	0.75	2.00	3104	1.37	7.4
142	3	46	2	2	5	CT	NB	L	I	1.12	2.19	6632	1.27	7.4
143	3	47	3	2	6	NT	NB	H	I	0.66	2.94	10396	1.39	7.4
144	3	48	3	2	6	CT	NB	L	I	0.74	2.14	4636	1.33	7.4
145	4	1	1	1	1	CT	NB	H	I	1	0	5360	1.27	7.2
146	4	2	1	1	1	NT	NB	L	I	1.07	0	4316	1.28	7.0
147	4	3	2	1	1	NT	NB	H	I	1.32	0	3516	1.25	7.0
148	4	4	2	1	1	CT	NB	L	I	2.25	0	1308	1.26	7.2
149	4	5	3	1	2	NT	NB	L	I	1.37	0	3476	1.37	7.0
150	4	6	3	1	2	CT	NB	H	I	2.15	0	3928	1.27	7.0
151	4	7	1	1	2	CT	NB	L	I	1.13	0	1424	1.25	7.3
152	4	8	1	1	2	NT	NB	H	I	2.24	0	4296	1.21	7.3
153	4	9	2	1	3	NT	NB	L	I	2.08	0	1260	1.27	7.3
154	4	10	2	1	3	CT	NB	H	I	2.09	0	3472	1.32	7.1
155	4	11	3	1	3	NT	NB	H	I	0.75	0	3832	1.27	7.0
156	4	12	3	1	3	CT	NB	L	I	2.2	0	2460	1.30	7.1
157	4	13	1	1	1	CT	B	L	I	2.01	0	1688	1.22	7.4
158	4	14	1	1	1	NT	B	L	I	2.24	0	3464	1.27	7.2
159	4	15	2	1	1	NT	B	H	I	1.15	0	4528	1.34	7.0

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	soybean	wheat	Residue	BD	pH
160	4	16	2	1	2	CT	B	L	I	1.66	0	1884	1.32	7.3
161	4	17	3	1	2	NT	B	H	I	2.04	0	3956	1.33	7.0
162	4	18	3	1	3	CT	B	L	I	2.24	0	2504	1.32	7.0
163	4	19	1	1	1	CT	B	H	I	2.46	0	2648	1.23	7.1
164	4	20	1	1	3	NT	B	H	I	2.6	0	3740	1.33	7.2
165	4	21	2	1	2	NT	B	L	I	2.01	0	1952	1.28	6.9
166	4	22	2	1	2	CT	B	H	I	2.22	0	1548	1.30	7.1
167	4	23	3	1	3	NT	B	L	I	2.59	0	972	1.36	6.9
168	4	24	3	1	3	CT	B	H	I	3.06	0	3828	1.30	7.0
169	4	25	1	2	1	CT	B	H	NI	1.33	0	3024	1.23	7.0
170	4	26	1	2	1	NT	B	H	NI	0.4	0	3536	1.31	7.1
171	4	27	2	2	2	NT	B	H	NI	1	0	3844	1.33	6.9
172	4	28	2	2	1	CT	B	L	NI	0.96	0	1756	1.32	6.9
173	4	29	3	2	3	NT	B	H	NI	0.59	0	3188	1.31	6.9
174	4	30	3	2	2	CT	B	L	NI	1.13	0	1760	1.35	7.1
175	4	31	1	2	3	CT	B	L	NI	1.62	0	1464	1.13	7.1
176	4	32	1	2	1	NT	B	L	NI	0.83	0	2312	1.35	7.2
177	4	33	2	2	2	NT	B	L	NI	0.72	0	1892	1.21	7.0
178	4	34	2	2	2	CT	B	H	NI	1.03	0	2864	1.25	7.0
179	4	35	3	2	3	NT	B	L	NI	1.29	0	2452	1.26	7.0
180	4	36	3	2	3	CT	B	H	NI	0.99	0	3028	1.21	7.1
181	4	37	1	2	1	CT	NB	H	NI	1.22	0	1936	1.31	7.2
182	4	38	1	2	1	NT	NB	L	NI	0.75	0	2124	1.42	7.2
183	4	39	2	2	1	NT	NB	H	NI	0.52	0	2700	1.31	7.1
184	4	40	2	2	2	CT	NB	H	NI	0.78	0	3796	1.34	7.2
185	4	41	3	2	2	NT	NB	L	NI	0.78	0	2784	1.36	7.3
186	4	42	3	2	3	CT	NB	H	NI	1.11	0	3436	1.32	7.4
187	4	43	1	2	1	CT	NB	L	NI	1.5	0	1060	1.29	7.3
188	4	44	1	2	2	NT	NB	H	NI	0.91	0	4272	1.37	7.2
189	4	45	2	2	3	NT	NB	L	NI	0.78	0	1772	1.32	7.3
190	4	46	2	2	2	CT	NB	L	NI	0.88	0	1688	1.26	7.2
191	4	47	3	2	3	NT	NB	H	NI	0.65	0	2824	1.30	7.2
192	4	48	3	2	3	CT	NB	L	NI	0.19	0	2704	1.30	7.3
193	5	1	1	1	1	CT	NB	H	I	3.12	4.47	11448	1.27	7.6
194	5	2	1	1	1	NT	NB	L	I	2.68	1.99	14456	1.20	7.8
195	5	3	2	1	1	NT	NB	H	I	2.79	4.88	12880	1.18	7.4
196	5	4	2	1	1	CT	NB	L	I	3.24	2.08	10164	1.28	7.7
197	5	5	3	1	2	NT	NB	L	I	2.65	1.73	8668	1.09	7.6
198	5	6	3	1	2	CT	NB	H	I	3.24	4.86	18848	1.26	7.5
199	5	7	1	1	2	CT	NB	L	I	2.85	2.09	9856	1.17	7.8
200	5	8	1	1	2	NT	NB	H	I	2.83	5.02	25560	1.19	7.6

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	soybean	wheat	Residue	BD	pH
201	5	9	2	1	3	NT	NB	L	I	2.79	2.12	9644	1.21	7.5
202	5	10	2	1	3	CT	NB	H	I	3.21	4.99	17280	1.26	7.4
203	5	11	3	1	3	NT	NB	H	I	2.87	4.36	14524	1.22	7.4
204	5	12	3	1	3	CT	NB	L	I	3.5	2.31	3172	1.23	7.5
205	5	13	1	1	1	CT	B	L	I	3.75	2.71	8292	1.27	7.5
206	5	14	1	1	1	NT	B	L	I	3.96	2.84	4536	1.24	7.4
207	5	15	2	1	1	NT	B	H	I	4.02	5.03	10884	1.28	7.4
208	5	16	2	1	2	CT	B	L	I	4.38	2.28	7184	1.24	7.5
209	5	17	3	1	2	NT	B	H	I	3.98	5.04	6892	1.25	7.4
210	5	18	3	1	3	CT	B	L	I	3.63	2.06	3764	1.12	7.2
211	5	19	1	1	1	CT	B	H	I	3.31	4.07	9852	1.30	7.3
212	5	20	1	1	3	NT	B	H	I	3.52	4.27	8180	1.23	7.2
213	5	21	2	1	2	NT	B	L	I	3.14	2.62	4384	1.30	7.3
214	5	22	2	1	2	CT	B	H	I	3.93	4.53	4948	1.20	7.3
215	5	23	3	1	3	NT	B	L	I	3.59	2.03	4232	1.12	7.4
216	5	24	3	1	3	CT	B	H	I	3.83	4.07	5336	1.20	7.1
217	5	25	1	2	1	CT	B	H	NI	2	3.84	8548	1.25	6.9
218	5	26	1	2	1	NT	B	H	NI	0.97	4.12	5824	1.26	6.9
219	5	27	2	2	2	NT	B	H	NI	0.78	4.66	8324	1.27	6.7
220	5	28	2	2	1	CT	B	L	NI	0.89	1.50	3016	1.17	6.7
221	5	29	3	2	3	NT	B	H	NI	1.09	4.86	12876	1.13	6.9
222	5	30	3	2	2	CT	B	L	NI	1.08	1.71	1972	1.17	6.8
223	5	31	1	2	3	CT	B	L	NI	1.68	1.59	3304	1.24	6.9
224	5	32	1	2	1	NT	B	L	NI	0.97	1.68	2740	1.28	7.0
225	5	33	2	2	2	NT	B	L	NI	1.12	1.50	2136	1.21	7.0
226	5	34	2	2	2	CT	B	H	NI	1.04	3.89	7108	1.10	7.0
227	5	35	3	2	3	NT	B	L	NI	0.94	1.53	3752	1.27	7.0
228	5	36	3	2	3	CT	B	H	NI	1.31	3.97	5812	1.16	6.9
229	5	37	1	2	1	CT	NB	H	NI	2.03	4.48	10780	1.25	6.9
230	5	38	1	2	1	NT	NB	L	NI	0.89	1.98	4948	1.26	7.0
231	5	39	2	2	1	NT	NB	H	NI	1.25	3.89	11232	1.27	6.9
232	5	40	2	2	2	CT	NB	H	NI	0.43	3.91	12080	1.27	7.0
233	5	41	3	2	2	NT	NB	L	NI	0.64	2.25	6216	1.24	7.2
234	5	42	3	2	3	CT	NB	H	NI	0.88	3.86	11468	1.30	7.1
235	5	43	1	2	1	CT	NB	L	NI	1.87	2.67	9540	1.19	7.1
236	5	44	1	2	2	NT	NB	H	NI	1.57	3.88	10336	1.29	7.0
237	5	45	2	2	3	NT	NB	L	NI	1.1	2.05	8000	1.27	7.2
238	5	46	2	2	2	CT	NB	L	NI	0.47	2.10	14024	1.22	7.2
239	5	47	3	2	3	NT	NB	H	NI	1.24	3.65	13840	1.28	7.1
240	5	48	3	2	3	CT	NB	L	NI	1.45	1.79	6916	1.20	7.2
241	6	1	1	1	1	CT	NB	H	I	2.78	1.23	9164	1.19	7.7

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	soybean	wheat	Residue	BD	pH
242	6	2	1	1	1	NT	NB	L	I	2.77	1.50	6276	1.12	7.7
243	6	3	2	1	1	NT	NB	H	I	2.68	2.77	10608	1.25	7.5
244	6	4	2	1	1	CT	NB	L	I	2.16	0.64	6688	1.14	7.5
245	6	5	3	1	2	NT	NB	L	I	2.29	1.49	7324	1.22	7.5
246	6	6	3	1	2	CT	NB	H	I	1.82	1.55	9724	1.20	7.5
247	6	7	1	1	2	CT	NB	L	I	2.12	0.71	6544	1.18	7.4
248	6	8	1	1	2	NT	NB	H	I	2.72	2.18	10248	1.21	7.5
249	6	9	2	1	3	NT	NB	L	I	2.72	1.13	6964	1.22	7.2
250	6	10	2	1	3	CT	NB	H	I	2.17	1.75	8372	1.17	7.5
251	6	11	3	1	3	NT	NB	H	I	2.04	2.97	9996	1.17	7.4
252	6	12	3	1	3	CT	NB	L	I	2.18	0.91	5948	1.18	7.3
253	6	13	1	1	1	CT	B	L	I	2.34	0.47	5344	1.19	7.6
254	6	14	1	1	1	NT	B	L	I	2.61	1.52	6420	1.22	7.5
255	6	15	2	1	1	NT	B	H	I	2.46	2.54	8068	1.22	7.4
256	6	16	2	1	2	CT	B	L	I	2.55	0.70	5412	1.20	7.5
257	6	17	3	1	2	NT	B	H	I	2.44	2.70	8092	1.28	7.4
258	6	18	3	1	3	CT	B	L	I	2.58	0.49	4772	1.29	7.3
259	6	19	1	1	1	CT	B	H	I	2.3	0.89	10664	1.22	7.4
260	6	20	1	1	3	NT	B	H	I	2.32	2.18	9612	1.21	7.6
261	6	21	2	1	2	NT	B	L	I	2.68	1.34	7060	1.20	7.5
262	6	22	2	1	2	CT	B	H	I	2.89	1.90	9752	1.15	7.5
263	6	23	3	1	3	NT	B	L	I	2.68	0.86	6368	1.25	7.5
264	6	24	3	1	3	CT	B	H	I	3.22	1.61	10820	1.26	7.4
265	6	25	1	2	1	CT	B	H	NI	1.55	0.48	8432	1.22	7.1
266	6	26	1	2	1	NT	B	H	NI	1.38	1.52	11788	1.05	6.9
267	6	27	2	2	2	NT	B	H	NI	1.23	1.42	9888	1.15	7.0
268	6	28	2	2	1	CT	B	L	NI	1.35	0.25	5420	1.25	7.0
269	6	29	3	2	3	NT	B	H	NI	1.31	2.18	8896	1.16	6.9
270	6	30	3	2	2	CT	B	L	NI	1.28	0.37	5536	1.19	7.0
271	6	31	1	2	3	CT	B	L	NI	1.68	0.56	5164	1.23	7.1
272	6	32	1	2	1	NT	B	L	NI	1.45	0.59	5012	1.23	7.1
273	6	33	2	2	2	NT	B	L	NI	1.22	0.39	5816	1.13	7.2
274	6	34	2	2	2	CT	B	H	NI	1.23	1.85	7928	1.16	6.9
275	6	35	3	2	3	NT	B	L	NI	1.2	0.91	4644	1.17	7.0
276	6	36	3	2	3	CT	B	H	NI	1.59	1.50	11632	1.19	7.0
277	6	37	1	2	1	CT	NB	H	NI	2.38	0.43	7212	1.21	7.0
278	6	38	1	2	1	NT	NB	L	NI	1.24	0.40	4792	1.22	7.1
279	6	39	2	2	1	NT	NB	H	NI	1.66	1.92	9600	1.26	6.9
280	6	40	2	2	2	CT	NB	H	NI	1.45	1.49	7112	1.22	7.0
281	6	41	3	2	2	NT	NB	L	NI	1.23	0.87	5980	1.28	7.1
282	6	42	3	2	3	CT	NB	H	NI	1.49	1.16	8984	1.24	7.0

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	soybean	wheat	Residue	BD	pH
283	6	43	1	2	1	CT	NB	L	NI	0.67	0.74	5104	1.18	7.1
284	6	44	1	2	2	NT	NB	H	NI	2.06	2.42	8660	1.20	7.1
285	6	45	2	2	3	NT	NB	L	NI	1.61	0.94	5740	1.21	7.1
286	6	46	2	2	2	CT	NB	L	NI	1.45	0.97	5428	1.22	7.3
287	6	47	3	2	3	NT	NB	H	NI	1.24	3.15	9880	1.23	7.1
288	6	48	3	2	3	CT	NB	L	NI	1.71	1.15	5592	1.22	7.3

Electrical conductivity (EC) (dS m^{-1}), extractable P, K, and S (kg ha^{-1})

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	EC	P	K	S
1	1	1	1	1	1	CT	NB	H	I	0.176	73.10	168.97	15.36
2	1	2	1	1	1	NT	NB	L	I	0.115	65.18	163.26	15.84
3	1	3	2	1	1	NT	NB	H	I	0.124	76.75	175.48	15.23
4	1	4	2	1	1	CT	NB	L	I	0.133	60.64	161.65	15.00
5	1	5	3	1	2	NT	NB	L	I	0.128	49.34	145.13	15.84
6	1	6	3	1	2	CT	NB	H	I	0.134	39.92	147.62	13.72
7	1	7	1	1	2	CT	NB	L	I	0.148	64.08	118.95	13.56
8	1	8	1	1	2	NT	NB	H	I	0.129	58.48	116.18	15.23
9	1	9	2	1	3	NT	NB	L	I	0.138	50.56	125.79	16.45
10	1	10	2	1	3	CT	NB	H	I	0.123	51.00	122.00	15.04
11	1	11	3	1	3	NT	NB	H	I	0.109	40.81	126.65	15.23
12	1	12	3	1	3	CT	NB	L	I	0.104	47.95	191.54	15.58
13	1	13	1	1	1	CT	B	L	I	0.128	54.78	221.43	17.00
14	1	14	1	1	1	NT	B	L	I	0.150	53.60	188.87	19.49
15	1	15	2	1	1	NT	B	H	I	0.141	53.60	177.76	17.06
16	1	16	2	1	2	CT	B	L	I	0.163	47.69	167.14	20.08
17	1	17	3	1	2	NT	B	H	I	0.136	48.12	166.12	14.62
18	1	18	3	1	3	CT	B	L	I	0.128	52.73	165.92	14.71
19	1	19	1	1	1	CT	B	H	I	0.156	63.94	176.29	14.90
20	1	20	1	1	3	NT	B	H	I	0.186	54.21	175.94	14.01
21	1	21	2	1	2	NT	B	L	I	0.162	46.29	155.66	14.62
22	1	22	2	1	2	CT	B	H	I	0.168	46.58	165.31	14.85
23	1	23	3	1	3	NT	B	L	I	0.156	43.25	168.16	13.40
24	1	24	3	1	3	CT	B	H	I	0.158	46.72	168.36	13.70
25	1	25	1	2	4	CT	B	H	I	0.257	54.39	154.94	18.34
26	1	26	1	2	4	NT	B	H	I	0.230	50.56	162.31	15.84
27	1	27	2	2	5	NT	B	H	I	0.188	57.26	171.55	17.66
28	1	28	2	2	4	CT	B	L	I	0.202	53.30	176.29	17.11
29	1	29	3	2	6	NT	B	H	I	0.185	52.99	155.84	17.06

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	EC	P	K	S
30	1	30	3	2	5	CT	B	L	I	0.209	54.86	163.48	17.43
31	1	31	1	2	6	CT	B	L	I	0.183	56.31	176.90	17.68
32	1	32	1	2	4	NT	B	L	I	0.169	56.65	188.15	15.23
33	1	33	2	2	5	NT	B	L	I	0.170	53.60	188.25	14.62
34	1	34	2	2	5	CT	B	H	I	0.185	48.05	164.09	13.99
35	1	35	3	2	6	NT	B	L	I	0.161	49.95	173.62	12.79
36	1	36	3	2	6	CT	B	H	I	0.158	41.60	167.14	16.64
37	1	37	1	2	4	CT	NB	H	I	0.168	58.30	173.24	14.58
38	1	38	1	2	4	NT	NB	L	I	0.148	56.04	177.87	14.62
39	1	39	2	2	4	NT	NB	H	I	0.140	60.30	164.19	13.40
40	1	40	2	2	5	CT	NB	H	I	0.131	51.34	155.55	12.08
41	1	41	3	2	5	NT	NB	L	I	0.159	51.78	173.73	12.18
42	1	42	3	2	6	CT	NB	H	I	0.162	48.75	159.82	13.08
43	1	43	1	2	4	CT	NB	L	I	0.170	63.36	171.41	13.28
44	1	44	1	2	5	NT	NB	H	I	0.181	48.73	180.43	12.18
45	1	45	2	2	6	NT	NB	L	I	0.163	51.17	171.30	15.23
46	1	46	2	2	5	CT	NB	L	I	0.161	53.32	168.36	13.49
47	1	47	3	2	6	NT	NB	H	I	0.174	56.65	175.03	12.79
48	1	48	3	2	6	CT	NB	L	I	0.158	46.78	162.87	11.99
49	2	1	1	1	1	CT	NB	H	I	0.139	71.95	126.70	19.83
50	2	2	1	1	1	NT	NB	L	I	0.119	63.02	134.57	27.70
51	2	3	2	1	1	NT	NB	H	I	0.121	50.15	117.90	28.36
52	2	4	2	1	1	CT	NB	L	I	0.127	44.77	133.79	31.51
53	2	5	3	1	2	NT	NB	L	I	0.124	39.78	130.77	30.46
54	2	6	3	1	2	CT	NB	H	I	0.123	35.05	126.57	26.65
55	2	7	1	1	2	CT	NB	L	I	0.103	55.14	108.97	19.69
56	2	8	1	1	2	NT	NB	H	I	0.122	48.97	105.43	21.01
57	2	9	2	1	3	NT	NB	L	I	0.104	48.84	127.09	23.76
58	2	10	2	1	3	CT	NB	H	I	0.107	36.11	101.23	19.83
59	2	11	3	1	3	NT	NB	H	I	0.094	36.50	109.10	16.81
60	2	12	3	1	3	CT	NB	L	I	0.112	40.96	138.64	19.43
61	2	13	1	1	1	CT	B	L	I	0.117	48.32	142.32	16.94
62	2	14	1	1	1	NT	B	L	I	0.106	51.47	137.59	20.88
63	2	15	2	1	1	NT	B	H	I	0.126	44.77	147.31	19.83
64	2	16	2	1	2	CT	B	L	I	0.107	39.52	141.40	23.50
65	2	17	3	1	2	NT	B	H	I	0.110	43.06	131.69	25.08
66	2	18	3	1	3	CT	B	L	I	0.098	42.93	127.35	27.18
67	2	19	1	1	1	CT	B	H	I	0.128	46.74	162.41	23.11
68	2	20	1	1	3	NT	B	H	I	0.109	49.37	139.56	21.79
69	2	21	2	1	2	NT	B	L	I	0.116	48.32	124.60	20.48
70	2	22	2	1	2	CT	B	H	I	0.129	43.59	142.98	29.54

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	EC	P	K	S
71	2	23	3	1	3	NT	B	L	I	0.102	41.75	140.48	26.26
72	2	24	3	1	3	CT	B	H	I	0.115	46.61	134.31	26.52
73	2	25	1	2	4	CT	B	H	I	0.119	45.69	130.24	37.68
74	2	26	1	2	4	NT	B	H	I	0.111	50.02	145.73	36.63
75	2	27	2	2	5	NT	B	H	I	0.116	51.07	143.63	31.51
76	2	28	2	2	4	CT	B	L	I	0.133	45.69	152.95	41.88
77	2	29	3	2	6	NT	B	H	I	0.123	61.05	149.28	40.18
78	2	30	3	2	5	CT	B	L	I	0.123	46.48	153.35	43.46
79	2	31	1	2	6	CT	B	L	I	0.113	46.74	145.60	26.91
80	2	32	1	2	4	NT	B	L	I	0.121	52.52	139.30	33.48
81	2	33	2	2	5	NT	B	L	I	0.115	45.82	144.81	29.15
82	2	34	2	2	5	CT	B	H	I	0.131	45.82	143.63	39.39
83	2	35	3	2	6	NT	B	L	I	0.113	44.25	138.25	37.02
84	2	36	3	2	6	CT	B	H	I	0.117	39.65	138.12	34.14
85	2	37	1	2	4	CT	NB	H	I	0.116	53.70	151.77	28.49
86	2	38	1	2	4	NT	NB	L	I	0.135	58.95	147.44	30.07
87	2	39	2	2	4	NT	NB	H	I	0.130	51.34	142.06	26.26
88	2	40	2	2	5	CT	NB	H	I	0.127	46.08	136.02	26.00
89	2	41	3	2	5	NT	NB	L	I	0.123	49.89	149.02	33.74
90	2	42	3	2	6	CT	NB	H	I	0.141	43.59	129.98	29.80
91	2	43	1	2	4	CT	NB	L	I	0.152	52.91	169.23	40.57
92	2	44	1	2	5	NT	NB	H	I	0.140	51.20	160.96	36.76
93	2	45	2	2	6	NT	NB	L	I	0.142	50.68	166.48	41.88
94	2	46	2	2	5	CT	NB	L	I	0.147	49.23	169.10	36.76
95	2	47	3	2	6	NT	NB	H	I	0.150	49.37	160.18	40.96
96	2	48	3	2	6	CT	NB	L	I	0.146	46.61	154.66	37.94
97	3	1	1	1	1	CT	NB	H	I	0.194	82.17	138.29	45.47
98	3	2	1	1	1	NT	NB	L	I	0.161	59.09	142.47	39.67
99	3	3	2	1	1	NT	NB	H	I	0.164	65.71	148.55	42.36
100	3	4	2	1	1	CT	NB	L	I	0.146	55.99	152.05	39.67
101	3	5	3	1	2	NT	NB	L	I	0.158	54.24	148.28	42.77
102	3	6	3	1	2	CT	NB	H	I	0.145	46.95	177.82	35.35
103	3	7	1	1	2	CT	NB	L	I	0.182	80.82	141.12	33.19
104	3	8	1	1	2	NT	NB	H	I	0.154	55.45	196.17	32.79
105	3	9	2	1	3	NT	NB	L	I	0.143	51.67	111.85	34.00
106	3	10	2	1	3	CT	NB	H	I	0.150	47.90	117.92	33.32
107	3	11	3	1	3	NT	NB	H	I	0.122	42.23	108.74	34.13
108	3	12	3	1	3	CT	NB	L	I	0.147	50.46	152.86	32.25
109	3	13	1	1	1	CT	B	L	I	0.111	64.36	197.12	29.68
110	3	14	1	1	1	NT	B	L	I	0.091	54.91	155.02	28.74
111	3	15	2	1	1	NT	B	H	I	0.115	49.52	168.24	26.98

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	EC	P	K	S
112	3	16	2	1	2	CT	B	L	I	0.115	48.03	170.67	31.98
113	3	17	3	1	2	NT	B	H	I	0.097	42.63	152.73	32.52
114	3	18	3	1	3	CT	B	L	I	0.162	49.11	151.11	35.62
115	3	19	1	1	1	CT	B	H	I	0.108	53.02	174.85	25.23
116	3	20	1	1	3	NT	B	H	I	0.112	45.20	146.93	36.97
117	3	21	2	1	2	NT	B	L	I	0.103	47.76	176.07	32.11
118	3	22	2	1	2	CT	B	H	I	0.105	40.88	140.05	28.47
119	3	23	3	1	3	NT	B	L	I	0.095	38.86	136.67	29.41
120	3	24	3	1	3	CT	B	H	I	0.106	41.55	135.73	27.52
121	3	25	1	2	4	CT	B	H	I	0.078	42.23	137.75	26.58
122	3	26	1	2	4	NT	B	H	I	0.123	48.03	142.20	22.94
123	3	27	2	2	5	NT	B	H	I	0.123	50.86	199.81	26.17
124	3	28	2	2	4	CT	B	L	I	0.098	45.60	157.85	25.36
125	3	29	3	2	6	NT	B	H	I	0.103	47.63	138.56	27.79
126	3	30	3	2	5	CT	B	L	I	0.114	41.69	158.53	23.21
127	3	31	1	2	6	CT	B	L	I	0.098	54.51	186.32	20.51
128	3	32	1	2	4	NT	B	L	I	0.111	43.85	149.76	23.88
129	3	33	2	2	5	NT	B	L	I	0.105	37.37	149.62	27.25
130	3	34	2	2	5	CT	B	H	I	0.119	39.53	150.57	26.31
131	3	35	3	2	6	NT	B	L	I	0.093	43.85	155.97	27.66
132	3	36	3	2	6	CT	B	H	I	0.089	41.42	139.91	31.17
133	3	37	1	2	4	CT	NB	H	I	0.122	58.96	158.12	30.36
134	3	38	1	2	4	NT	NB	L	I	0.105	61.52	167.84	28.20
135	3	39	2	2	4	NT	NB	H	I	0.100	52.35	154.08	32.11
136	3	40	2	2	5	CT	NB	H	I	0.110	52.75	162.31	28.47
137	3	41	3	2	5	NT	NB	L	I	0.111	53.97	174.85	28.87
138	3	42	3	2	6	CT	NB	H	I	0.091	52.48	165.28	35.35
139	3	43	1	2	4	CT	NB	L	I	0.111	54.37	183.22	25.50
140	3	44	1	2	5	NT	NB	H	I	0.165	55.86	179.58	28.20
141	3	45	2	2	6	NT	NB	L	I	0.107	55.45	194.01	30.09
142	3	46	2	2	5	CT	NB	L	I	0.116	49.78	170.00	32.38
143	3	47	3	2	6	NT	NB	H	I	0.132	51.40	176.47	27.39
144	3	48	3	2	6	CT	NB	L	I	0.135	53.56	184.84	31.17
145	4	1	1	1	1	CT	NB	H	I	0.135	60.53	135.61	10.44
146	4	2	1	1	1	NT	NB	L	I	0.139	45.68	137.60	9.08
147	4	3	2	1	1	NT	NB	H	I	0.118	41.04	125.04	9.75
148	4	4	2	1	1	CT	NB	L	I	0.112	38.47	112.46	9.67
149	4	5	3	1	2	NT	NB	L	I	0.099	38.52	111.85	9.77
150	4	6	3	1	2	CT	NB	H	I	0.122	34.54	117.98	9.33
151	4	7	1	1	2	CT	NB	L	I	0.150	50.34	126.13	9.11
152	4	8	1	1	2	NT	NB	H	I	0.098	38.70	81.95	8.33

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	EC	P	K	S
153	4	9	2	1	3	NT	NB	L	I	0.101	37.39	97.83	8.83
154	4	10	2	1	3	CT	NB	H	I	0.128	36.60	115.13	9.27
155	4	11	3	1	3	NT	NB	H	I	0.104	36.93	96.67	7.94
156	4	12	3	1	3	CT	NB	L	I	0.105	38.50	122.04	9.04
157	4	13	1	1	1	CT	B	L	I	0.112	45.14	121.88	8.31
158	4	14	1	1	1	NT	B	L	I	0.185	39.31	151.64	7.95
159	4	15	2	1	1	NT	B	H	I	0.115	43.25	140.51	8.83
160	4	16	2	1	2	CT	B	L	I	0.116	45.51	129.55	8.10
161	4	17	3	1	2	NT	B	H	I	0.106	41.68	139.54	8.15
162	4	18	3	1	3	CT	B	L	I	0.111	44.23	129.47	8.57
163	4	19	1	1	1	CT	B	H	I	0.200	40.42	178.56	8.95
164	4	20	1	1	3	NT	B	H	I	0.146	41.26	151.73	8.63
165	4	21	2	1	2	NT	B	L	I	0.135	39.12	161.24	8.82
166	4	22	2	1	2	CT	B	H	I	0.098	41.04	133.25	8.55
167	4	23	3	1	3	NT	B	L	I	0.098	41.85	133.10	10.57
168	4	24	3	1	3	CT	B	H	I	0.093	41.31	126.43	9.43
169	4	25	1	2	1	CT	B	H	NI	0.117	42.63	135.63	9.25
170	4	26	1	2	1	NT	B	H	NI	0.101	45.76	130.58	10.05
171	4	27	2	2	2	NT	B	H	NI	0.106	44.57	134.00	10.13
172	4	28	2	2	1	CT	B	L	NI	0.222	47.38	171.15	10.23
173	4	29	3	2	3	NT	B	H	NI	0.200	36.61	165.86	8.75
174	4	30	3	2	2	CT	B	L	NI	0.097	42.89	145.27	10.25
175	4	31	1	2	3	CT	B	L	NI	0.094	42.19	122.87	8.26
176	4	32	1	2	1	NT	B	L	NI	0.101	47.76	142.39	9.90
177	4	33	2	2	2	NT	B	L	NI	0.151	41.40	160.91	9.08
178	4	34	2	2	2	CT	B	H	NI	0.127	41.14	141.30	8.96
179	4	35	3	2	3	NT	B	L	NI	0.116	38.42	139.55	8.96
180	4	36	3	2	3	CT	B	H	NI	0.101	37.13	127.49	8.39
181	4	37	1	2	1	CT	NB	H	NI	0.108	50.41	150.40	9.90
182	4	38	1	2	1	NT	NB	L	NI	0.110	55.90	161.14	10.30
183	4	39	2	2	1	NT	NB	H	NI	0.105	46.10	127.20	9.06
184	4	40	2	2	2	CT	NB	H	NI	0.131	45.76	162.01	9.71
185	4	41	3	2	2	NT	NB	L	NI	0.110	51.61	148.57	8.76
186	4	42	3	2	3	CT	NB	H	NI	0.119	42.41	140.02	8.74
187	4	43	1	2	1	CT	NB	L	NI	0.120	52.80	147.63	10.44
188	4	44	1	2	2	NT	NB	H	NI	0.122	51.51	159.16	10.77
189	4	45	2	2	3	NT	NB	L	NI	0.100	45.48	141.84	8.51
190	4	46	2	2	2	CT	NB	L	NI	0.134	43.82	156.58	9.56
191	4	47	3	2	3	NT	NB	H	NI	0.100	38.96	129.56	7.87
192	4	48	3	2	3	CT	NB	L	NI	0.119	47.41	153.70	9.58
193	5	1	1	1	1	CT	NB	H	I	0.145	57.38	137.83	14.56

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	EC	P	K	S
194	5	2	1	1	1	NT	NB	L	I	0.110	47.39	132.22	10.94
195	5	3	2	1	1	NT	NB	H	I	0.124	35.66	115.01	11.71
196	5	4	2	1	1	CT	NB	L	I	0.112	39.56	149.59	13.86
197	5	5	3	1	2	NT	NB	L	I	0.089	39.75	143.25	13.83
198	5	6	3	1	2	CT	NB	H	I	0.141	38.67	184.72	13.79
199	5	7	1	1	2	CT	NB	L	I	0.117	51.65	113.00	13.88
200	5	8	1	1	2	NT	NB	H	I	0.117	36.52	103.15	12.97
201	5	9	2	1	3	NT	NB	L	I	0.115	42.12	149.05	14.49
202	5	10	2	1	3	CT	NB	H	I	0.120	31.89	116.55	13.08
203	5	11	3	1	3	NT	NB	H	I	0.102	36.19	136.51	14.15
204	5	12	3	1	3	CT	NB	L	I	0.096	39.25	145.78	11.25
205	5	13	1	1	1	CT	B	L	I	0.128	48.14	163.90	11.24
206	5	14	1	1	1	NT	B	L	I	0.116	43.86	189.99	10.32
207	5	15	2	1	1	NT	B	H	I	0.128	37.33	160.61	11.55
208	5	16	2	1	2	CT	B	L	I	0.119	41.81	163.59	14.03
209	5	17	3	1	2	NT	B	H	I	0.132	36.09	169.24	11.83
210	5	18	3	1	3	CT	B	L	I	0.108	46.39	182.89	13.62
211	5	19	1	1	1	CT	B	H	I	0.135	39.49	155.86	11.24
212	5	20	1	1	3	NT	B	H	I	0.125	45.21	170.68	11.45
213	5	21	2	1	2	NT	B	L	I	0.117	46.11	165.01	12.05
214	5	22	2	1	2	CT	B	H	I	0.144	40.68	170.15	12.25
215	5	23	3	1	3	NT	B	L	I	0.091	39.75	136.11	11.36
216	5	24	3	1	3	CT	B	H	I	0.141	35.84	149.55	12.54
217	5	25	1	2	1	CT	B	H	NI	0.132	46.91	186.90	9.97
218	5	26	1	2	1	NT	B	H	NI	0.115	39.23	163.96	8.83
219	5	27	2	2	2	NT	B	H	NI	0.114	40.14	206.44	9.37
220	5	28	2	2	1	CT	B	L	NI	0.084	46.51	207.88	9.04
221	5	29	3	2	3	NT	B	H	NI	0.100	39.91	176.27	9.07
222	5	30	3	2	2	CT	B	L	NI	0.103	41.93	183.50	8.63
223	5	31	1	2	3	CT	B	L	NI	0.085	48.86	182.77	7.61
224	5	32	1	2	1	NT	B	L	NI	0.085	48.97	188.28	8.46
225	5	33	2	2	2	NT	B	L	NI	0.085	48.33	207.20	7.88
226	5	34	2	2	2	CT	B	H	NI	0.098	39.14	162.74	7.24
227	5	35	3	2	3	NT	B	L	NI	0.097	36.26	160.30	8.37
228	5	36	3	2	3	CT	B	H	NI	0.116	42.49	181.65	8.31
229	5	37	1	2	1	CT	NB	H	NI	0.124	52.99	194.51	9.73
230	5	38	1	2	1	NT	NB	L	NI	0.103	51.66	168.69	7.56
231	5	39	2	2	1	NT	NB	H	NI	0.092	48.29	165.02	8.46
232	5	40	2	2	2	CT	NB	H	NI	0.116	43.74	179.79	8.61
233	5	41	3	2	2	NT	NB	L	NI	0.111	57.59	234.07	10.40
234	5	42	3	2	3	CT	NB	H	NI	0.126	43.43	197.02	8.83

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	EC	P	K	S
235	5	43	1	2	1	CT	NB	L	NI	0.112	56.20	206.09	9.27
236	5	44	1	2	2	NT	NB	H	NI	0.124	51.08	208.90	8.10
237	5	45	2	2	3	NT	NB	L	NI	0.117	51.77	196.56	9.93
238	5	46	2	2	2	CT	NB	L	NI	0.146	50.33	217.78	9.56
239	5	47	3	2	3	NT	NB	H	NI	0.132	47.94	229.51	8.84
240	5	48	3	2	3	CT	NB	L	NI	0.122	44.92	206.35	8.12
241	6	1	1	1	1	CT	NB	H	I	0.100	43.86	105.75	9.89
242	6	2	1	1	1	NT	NB	L	I	0.080	41.53	122.39	10.61
243	6	3	2	1	1	NT	NB	H	I	0.083	26.20	96.21	9.46
244	6	4	2	1	1	CT	NB	L	I	0.076	32.32	123.41	10.11
245	6	5	3	1	2	NT	NB	L	I	0.081	25.81	104.56	8.38
246	6	6	3	1	2	CT	NB	H	I	0.082	28.80	126.51	9.14
247	6	7	1	1	2	CT	NB	L	I	0.081	41.06	98.94	9.27
248	6	8	1	1	2	NT	NB	H	I	0.078	33.14	77.32	9.11
249	6	9	2	1	3	NT	NB	L	I	0.069	31.28	93.50	7.82
250	6	10	2	1	3	CT	NB	H	I	0.082	26.34	87.65	8.86
251	6	11	3	1	3	NT	NB	H	I	0.067	25.78	91.65	7.49
252	6	12	3	1	3	CT	NB	L	I	0.080	34.92	129.28	9.19
253	6	13	1	1	1	CT	B	L	I	0.082	35.69	136.89	9.09
254	6	14	1	1	1	NT	B	L	I	0.073	32.93	131.80	8.52
255	6	15	2	1	1	NT	B	H	I	0.078	28.60	115.40	8.27
256	6	16	2	1	2	CT	B	L	I	0.072	33.44	122.83	8.66
257	6	17	3	1	2	NT	B	H	I	0.073	30.68	126.88	8.23
258	6	18	3	1	3	CT	B	L	I	0.081	37.54	119.64	8.28
259	6	19	1	1	1	CT	B	H	I	0.075	35.07	114.31	8.45
260	6	20	1	1	3	NT	B	H	I	0.078	28.49	115.33	9.42
261	6	21	2	1	2	NT	B	L	I	0.089	34.19	121.81	8.41
262	6	22	2	1	2	CT	B	H	I	0.077	35.57	136.88	9.49
263	6	23	3	1	3	NT	B	L	I	0.077	31.97	112.58	7.44
264	6	24	3	1	3	CT	B	H	I	0.085	32.64	124.27	8.36
265	6	25	1	2	1	CT	B	H	NI	0.103	37.60	148.65	10.33
266	6	26	1	2	1	NT	B	H	NI	0.065	36.83	169.09	10.03
267	6	27	2	2	2	NT	B	H	NI	0.071	35.35	157.75	9.65
268	6	28	2	2	1	CT	B	L	NI	0.072	37.33	161.74	9.80
269	6	29	3	2	3	NT	B	H	NI	0.069	35.86	161.55	10.21
270	6	30	3	2	2	CT	B	L	NI	0.071	41.14	169.07	9.63
271	6	31	1	2	3	CT	B	L	NI	0.084	46.81	161.69	9.78
272	6	32	1	2	1	NT	B	L	NI	0.070	46.49	160.91	9.23
273	6	33	2	2	2	NT	B	L	NI	0.074	39.76	155.24	8.83
274	6	34	2	2	2	CT	B	H	NI	0.078	33.91	134.26	9.17
275	6	35	3	2	3	NT	B	L	NI	0.063	35.51	142.19	7.21

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	EC	P	K	S
276	6	36	3	2	3	CT	B	H	NI	0.075	34.33	148.31	7.62
277	6	37	1	2	1	CT	NB	H	NI	0.089	45.65	187.32	9.97
278	6	38	1	2	1	NT	NB	L	NI	0.077	52.71	186.93	8.63
279	6	39	2	2	1	NT	NB	H	NI	0.068	39.80	149.63	9.75
280	6	40	2	2	2	CT	NB	H	NI	0.080	41.26	181.55	9.74
281	6	41	3	2	2	NT	NB	L	NI	0.071	42.07	155.00	7.33
282	6	42	3	2	3	CT	NB	H	NI	0.076	39.88	174.40	9.75
283	6	43	1	2	1	CT	NB	L	NI	0.098	51.31	209.28	10.48
284	6	44	1	2	2	NT	NB	H	NI	0.082	38.46	153.17	9.06
285	6	45	2	2	3	NT	NB	L	NI	0.085	45.37	193.76	9.10
286	6	46	2	2	2	CT	NB	L	NI	0.097	42.58	178.49	12.44
287	6	47	3	2	3	NT	NB	H	NI	0.095	34.12	151.86	8.59
288	6	48	3	2	3	CT	NB	L	NI	0.090	45.80	164.84	9.52

Extractable Ca, Mg, Na, and Fe (kg ha^{-1})

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	Ca	Mg	Na	Fe
1	1	1	1	1	1	CT	NB	H	I	1189.20	120.39	30.71	167.08
2	1	2	1	1	1	NT	NB	L	I	1125.68	121.83	32.28	168.73
3	1	3	2	1	1	NT	NB	H	I	1163.44	127.92	31.67	174.21
4	1	4	2	1	1	CT	NB	L	I	1171.62	125.04	28.13	153.17
5	1	5	3	1	2	NT	NB	L	I	1209.74	130.96	34.72	137.05
6	1	6	3	1	2	CT	NB	H	I	1322.38	149.08	33.68	131.61
7	1	7	1	1	2	CT	NB	L	I	1281.68	113.38	27.73	151.58
8	1	8	1	1	2	NT	NB	H	I	1146.39	104.16	29.24	144.36
9	1	9	2	1	3	NT	NB	L	I	1189.03	108.43	35.33	136.45
10	1	10	2	1	3	CT	NB	H	I	1209.57	123.57	33.34	145.80
11	1	11	3	1	3	NT	NB	H	I	1094.00	128.53	26.19	130.35
12	1	12	3	1	3	CT	NB	L	I	1182.05	147.46	35.37	125.88
13	1	13	1	1	1	CT	B	L	I	1522.53	144.82	38.41	164.34
14	1	14	1	1	1	NT	B	L	I	1503.34	149.85	36.55	145.58
15	1	15	2	1	1	NT	B	H	I	1631.26	181.52	38.38	148.63
16	1	16	2	1	2	CT	B	L	I	1642.97	187.64	35.14	145.60
17	1	17	3	1	2	NT	B	H	I	2166.07	191.27	36.55	135.84
18	1	18	3	1	3	CT	B	L	I	1507.05	180.87	36.17	145.31
19	1	19	1	1	1	CT	B	H	I	1473.69	162.02	33.52	159.54
20	1	20	1	1	3	NT	B	H	I	1421.71	157.77	27.41	158.98
21	1	21	2	1	2	NT	B	L	I	1477.75	162.03	36.55	159.59
22	1	22	2	1	2	CT	B	H	I	1659.29	199.14	44.55	154.59
23	1	23	3	1	3	NT	B	L	I	1622.73	183.35	40.20	134.62

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	Ca	Mg	Na	Fe
24	1	24	3	1	3	CT	B	H	1	1498.81	190.00	36.13	143.90
25	1	25	1	2	4	CT	B	H	1	1649.26	214.38	40.47	162.52
26	1	26	1	2	4	NT	B	H	1	1600.80	216.85	38.38	165.68
27	1	27	2	2	5	NT	B	H	1	1503.34	212.59	35.33	162.64
28	1	28	2	2	4	CT	B	L	1	1614.74	239.51	38.16	171.08
29	1	29	3	2	6	NT	B	H	1	1485.06	212.59	39.59	163.25
30	1	30	3	2	5	CT	B	L	1	1657.54	218.16	41.95	171.05
31	1	31	1	2	6	CT	B	L	1	1695.73	234.39	39.28	164.99
32	1	32	1	2	4	NT	B	L	1	1614.20	225.99	34.11	160.20
33	1	33	2	2	5	NT	B	L	1	1574.00	236.95	39.59	158.37
34	1	34	2	2	5	CT	B	H	1	1750.33	245.09	38.32	155.08
35	1	35	3	2	6	NT	B	L	1	1616.64	236.95	33.50	157.16
36	1	36	3	2	6	CT	B	H	1	1583.09	231.16	43.97	142.62
37	1	37	1	2	4	CT	NB	H	1	1789.11	184.01	37.65	167.62
38	1	38	1	2	4	NT	NB	L	1	1860.29	185.79	42.03	149.85
39	1	39	2	2	4	NT	NB	H	1	1788.41	194.92	41.42	160.81
40	1	40	2	2	5	CT	NB	H	1	1776.84	187.83	32.61	149.18
41	1	41	3	2	5	NT	NB	L	1	1884.65	192.49	40.20	149.24
42	1	42	3	2	6	CT	NB	H	1	1876.19	183.70	35.07	151.00
43	1	43	1	2	4	CT	NB	L	1	1957.61	181.04	36.21	168.36
44	1	44	1	2	5	NT	NB	H	1	1979.68	188.22	32.28	154.72
45	1	45	2	2	6	NT	NB	L	1	2094.20	194.92	43.25	143.15
46	1	46	2	2	5	CT	NB	L	1	2218.88	200.43	32.76	154.82
47	1	47	3	2	6	NT	NB	H	1	2055.21	193.09	34.72	154.11
48	1	48	3	2	6	CT	NB	L	1	2009.08	180.52	31.19	140.34
49	2	1	1	1	1	CT	NB	H	1	1301.10	194.05	11.55	196.94
50	2	2	1	1	1	NT	NB	L	1	1251.21	191.55	12.60	174.62
51	2	3	2	1	1	NT	NB	H	1	1213.14	192.21	12.21	158.86
52	2	4	2	1	1	CT	NB	L	1	1251.21	189.19	12.47	152.30
53	2	5	3	1	2	NT	NB	L	1	1339.18	208.10	11.42	137.86
54	2	6	3	1	2	CT	NB	H	1	1324.73	222.01	10.37	143.11
55	2	7	1	1	2	CT	NB	L	1	1318.17	180.79	10.77	177.24
56	2	8	1	1	2	NT	NB	H	1	1273.53	186.17	11.95	149.67
57	2	9	2	1	3	NT	NB	L	1	1261.71	184.46	9.72	147.05
58	2	10	2	1	3	CT	NB	H	1	1121.23	182.76	9.72	133.92
59	2	11	3	1	3	NT	NB	H	1	1194.75	202.19	9.19	127.35
60	2	12	3	1	3	CT	NB	L	1	1381.19	240.79	11.29	133.92
61	2	13	1	1	1	CT	B	L	1	1403.51	214.79	9.06	164.11
62	2	14	1	1	1	NT	B	L	1	1525.61	220.96	10.24	143.11
63	2	15	2	1	1	NT	B	H	1	1666.09	224.11	10.24	152.30
64	2	16	2	1	2	CT	B	L	1	1609.64	239.74	9.85	154.92

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	Ca	Mg	Na	Fe
65	2	17	3	1	2	NT	B	H	I	1561.06	239.87	10.24	150.99
66	2	18	3	1	3	CT	B	L	I	1533.49	248.01	9.06	154.92
67	2	19	1	1	1	CT	B	H	I	1452.09	223.33	11.95	162.80
68	2	20	1	1	3	NT	B	H	I	1457.34	237.64	9.32	191.69
69	2	21	2	1	2	NT	B	L	I	1431.08	210.33	9.58	164.11
70	2	22	2	1	2	CT	B	H	I	1782.94	264.29	10.50	170.68
71	2	23	3	1	3	NT	B	L	I	1575.50	242.36	9.19	148.36
72	2	24	3	1	3	CT	B	H	I	1532.17	275.98	9.98	173.31
73	2	25	1	2	4	CT	B	H	I	1605.70	263.76	14.44	183.81
74	2	26	1	2	4	NT	B	H	I	1673.97	275.32	13.13	193.00
75	2	27	2	2	5	NT	B	H	I	1666.09	282.67	12.47	194.31
76	2	28	2	2	4	CT	B	L	I	1613.57	291.34	14.31	182.50
77	2	29	3	2	6	NT	B	H	I	1629.33	280.83	15.62	189.06
78	2	30	3	2	5	CT	B	L	I	1618.83	281.23	13.92	194.31
79	2	31	1	2	6	CT	B	L	I	1635.89	266.39	10.11	182.50
80	2	32	1	2	4	NT	B	L	I	1572.87	271.25	11.55	179.87
81	2	33	2	2	5	NT	B	L	I	1589.94	291.60	10.90	164.11
82	2	34	2	2	5	CT	B	H	I	1626.70	285.17	12.60	181.18
83	2	35	3	2	6	NT	B	L	I	1689.72	290.55	12.08	166.74
84	2	36	3	2	6	CT	B	H	I	1646.40	288.58	11.42	175.93
85	2	37	1	2	4	CT	NB	H	I	1851.21	260.22	10.77	187.75
86	2	38	1	2	4	NT	NB	L	I	1975.94	252.47	11.03	182.50
87	2	39	2	2	4	NT	NB	H	I	1738.30	251.82	11.42	164.11
88	2	40	2	2	5	CT	NB	H	I	1824.95	262.45	9.32	161.49
89	2	41	3	2	5	NT	NB	L	I	1832.83	248.27	9.98	171.99
90	2	42	3	2	6	CT	NB	H	I	1713.36	243.94	9.98	174.62
91	2	43	1	2	4	CT	NB	L	I	2101.98	253.52	12.08	203.50
92	2	44	1	2	5	NT	NB	H	I	2159.75	250.64	11.03	185.12
93	2	45	2	2	6	NT	NB	L	I	2059.97	261.27	12.87	177.24
94	2	46	2	2	5	CT	NB	L	I	2122.99	274.01	11.03	165.43
95	2	47	3	2	6	NT	NB	H	I	2161.06	277.03	10.90	186.43
96	2	48	3	2	6	CT	NB	L	I	2113.80	255.10	10.90	165.43
97	3	1	1	1	1	CT	NB	H	I	1516.48	236.24	25.77	259.04
98	3	2	1	1	1	NT	NB	L	I	1378.87	246.90	25.09	212.63
99	3	3	2	1	1	NT	NB	H	I	1368.07	236.51	26.17	201.70
100	3	4	2	1	1	CT	NB	L	I	1538.07	263.63	24.96	201.30
101	3	5	3	1	2	NT	NB	L	I	1614.97	273.07	27.39	200.22
102	3	6	3	1	2	CT	NB	H	I	1548.86	262.82	64.90	193.34
103	3	7	1	1	2	CT	NB	L	I	1520.53	234.76	24.42	221.67
104	3	8	1	1	2	NT	NB	H	I	1323.55	196.17	112.12	196.71
105	3	9	2	1	3	NT	NB	L	I	1324.90	197.12	20.78	188.75

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	Ca	Mg	Na	Fe
106	3	10	2	1	3	CT	NB	H	1	1296.57	219.11	21.05	196.04
107	3	11	3	1	3	NT	NB	H	1	1374.82	241.10	20.24	178.23
108	3	12	3	1	3	CT	NB	L	1	1544.82	282.79	21.18	194.28
109	3	13	1	1	1	CT	B	L	1	1726.96	284.27	14.17	207.50
110	3	14	1	1	1	NT	B	L	1	1853.78	306.53	13.76	192.80
111	3	15	2	1	1	NT	B	H	1	1875.37	299.65	12.82	189.56
112	3	16	2	1	2	CT	B	L	1	1886.16	303.16	12.68	197.52
113	3	17	3	1	2	NT	B	H	1	1772.83	302.08	12.82	187.00
114	3	18	3	1	3	CT	B	L	1	1709.42	304.11	19.02	212.36
115	3	19	1	1	1	CT	B	H	1	1671.64	312.74	13.36	227.74
116	3	20	1	1	3	NT	B	H	1	1766.08	282.65	14.98	201.30
117	3	21	2	1	2	NT	B	L	1	1731.00	321.51	32.25	237.32
118	3	22	2	1	2	CT	B	H	1	1806.56	294.12	10.66	219.11
119	3	23	3	1	3	NT	B	L	1	1755.29	285.89	12.41	182.54
120	3	24	3	1	3	CT	B	H	1	1677.04	337.03	10.52	227.88
121	3	25	1	2	4	CT	B	H	1	1890.21	320.97	12.14	215.73
122	3	26	1	2	4	NT	B	H	1	1806.56	316.52	13.09	229.90
123	3	27	2	2	5	NT	B	H	1	1860.52	338.51	14.44	220.19
124	3	28	2	2	4	CT	B	L	1	1944.17	349.71	12.82	216.68
125	3	29	3	2	6	NT	B	H	1	1865.92	346.47	12.68	230.71
126	3	30	3	2	5	CT	B	L	1	1954.97	339.32	11.20	221.54
127	3	31	1	2	6	CT	B	L	1	1942.82	346.88	11.33	225.45
128	3	32	1	2	4	NT	B	L	1	1999.49	343.91	10.52	214.79
129	3	33	2	2	5	NT	B	L	1	1879.41	334.19	13.63	197.79
130	3	34	2	2	5	CT	B	H	1	1942.82	346.34	11.33	201.84
131	3	35	3	2	6	NT	B	L	1	1963.06	355.91	10.93	216.81
132	3	36	3	2	6	CT	B	H	1	1957.67	358.07	10.93	218.97
133	3	37	1	2	4	CT	NB	H	1	2216.71	351.46	11.87	269.03
134	3	38	1	2	4	NT	NB	L	1	2182.98	349.71	12.82	224.91
135	3	39	2	2	4	NT	NB	H	1	2173.54	349.44	13.90	216.27
136	3	40	2	2	5	CT	NB	H	1	2261.23	357.67	13.22	213.04
137	3	41	3	2	5	NT	NB	L	1	2211.31	361.18	15.11	207.23
138	3	42	3	2	6	CT	NB	H	1	2321.95	357.53	15.65	210.34
139	3	43	1	2	4	CT	NB	L	1	2292.26	322.86	15.25	269.43
140	3	44	1	2	5	NT	NB	H	1	2478.45	347.41	14.84	212.90
141	3	45	2	2	6	NT	NB	L	1	2425.83	348.49	14.84	197.66
142	3	46	2	2	5	CT	NB	L	1	2443.37	332.30	12.55	202.65
143	3	47	3	2	6	NT	NB	H	1	2348.93	354.03	11.60	205.35
144	3	48	3	2	6	CT	NB	L	1	2406.94	360.91	13.76	207.10
145	4	1	1	1	1	CT	NB	H	1	1401.86	216.63	11.33	207.10
146	4	2	1	1	1	NT	NB	L	1	1220.25	211.76	11.64	180.36

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	Ca	Mg	Na	Fe
147	4	3	2	1	1	NT	NB	H	I	1219.18	201.07	10.23	165.68
148	4	4	2	1	1	CT	NB	L	I	1308.31	219.02	12.37	164.17
149	4	5	3	1	2	NT	NB	L	I	1423.75	242.04	14.13	173.86
150	4	6	3	1	2	CT	NB	H	I	1395.09	260.42	14.63	153.01
151	4	7	1	1	2	CT	NB	L	I	1337.43	202.86	11.96	192.51
152	4	8	1	1	2	NT	NB	H	I	1125.44	164.14	10.23	156.25
153	4	9	2	1	3	NT	NB	L	I	1254.35	185.99	10.88	165.00
154	4	10	2	1	3	CT	NB	H	I	1305.90	221.92	13.18	161.25
155	4	11	3	1	3	NT	NB	H	I	1285.97	225.52	12.58	146.21
156	4	12	3	1	3	CT	NB	L	I	1543.71	268.72	17.15	166.24
157	4	13	1	1	1	CT	B	L	I	1410.14	244.86	12.29	177.70
158	4	14	1	1	1	NT	B	L	I	1534.17	225.43	16.08	154.05
159	4	15	2	1	1	NT	B	H	I	1649.40	268.15	15.03	167.89
160	4	16	2	1	2	CT	B	L	I	1685.20	269.37	17.04	169.97
161	4	17	3	1	2	NT	B	H	I	1632.23	275.63	17.53	164.55
162	4	18	3	1	3	CT	B	L	I	1562.37	297.18	21.52	173.90
163	4	19	1	1	1	CT	B	H	I	1308.94	245.98	14.90	183.38
164	4	20	1	1	3	NT	B	H	I	1534.58	262.23	16.94	170.08
165	4	21	2	1	2	NT	B	L	I	1489.60	260.04	17.47	180.18
166	4	22	2	1	2	CT	B	H	I	1535.89	270.80	18.23	177.19
167	4	23	3	1	3	NT	B	L	I	1510.67	267.56	18.43	166.04
168	4	24	3	1	3	CT	B	H	I	1384.90	295.26	22.21	183.23
169	4	25	1	2	1	CT	B	H	NI	1487.88	288.11	17.62	192.07
170	4	26	1	2	1	NT	B	H	NI	1618.51	301.37	18.75	185.63
171	4	27	2	2	2	NT	B	H	NI	1615.51	310.19	17.96	181.78
172	4	28	2	2	1	CT	B	L	NI	1654.92	343.23	20.30	185.37
173	4	29	3	2	3	NT	B	H	NI	1705.92	316.76	22.12	179.92
174	4	30	3	2	2	CT	B	L	NI	1750.56	334.14	21.72	195.23
175	4	31	1	2	3	CT	B	L	NI	1448.21	277.20	16.82	170.50
176	4	32	1	2	1	NT	B	L	NI	1799.20	330.03	21.46	186.15
177	4	33	2	2	2	NT	B	L	NI	1589.76	310.44	20.03	163.82
178	4	34	2	2	2	CT	B	H	NI	1612.31	322.46	19.47	177.15
179	4	35	3	2	3	NT	B	L	NI	1644.09	310.90	25.05	175.89
180	4	36	3	2	3	CT	B	H	NI	1596.30	313.94	22.31	165.43
181	4	37	1	2	1	CT	NB	H	NI	1907.22	302.90	17.78	229.34
182	4	38	1	2	1	NT	NB	L	NI	2178.31	345.72	17.86	198.65
183	4	39	2	2	1	NT	NB	H	NI	1896.81	314.65	18.65	171.60
184	4	40	2	2	2	CT	NB	H	NI	1998.27	340.65	21.27	186.68
185	4	41	3	2	2	NT	NB	L	NI	2094.15	325.38	18.49	182.13
186	4	42	3	2	3	CT	NB	H	NI	2142.48	323.55	21.44	173.11
187	4	43	1	2	1	CT	NB	L	NI	2013.29	304.06	18.14	229.67

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	Ca	Mg	Na	Fe
188	4	44	1	2	2	NT	NB	H	NI	2076.04	340.76	17.52	196.93
189	4	45	2	2	3	NT	NB	L	NI	2088.82	311.35	17.53	160.94
190	4	46	2	2	2	CT	NB	L	NI	2118.25	317.55	20.13	171.39
191	4	47	3	2	3	NT	NB	H	NI	2038.03	299.96	18.07	163.22
192	4	48	3	2	3	CT	NB	L	NI	2087.52	352.43	19.12	186.89
193	5	1	1	1	1	CT	NB	H	I	1504.73	321.48	23.37	182.27
194	5	2	1	1	1	NT	NB	L	I	1399.95	285.85	22.94	164.73
195	5	3	2	1	1	NT	NB	H	I	1230.83	257.77	22.41	139.69
196	5	4	2	1	1	CT	NB	L	I	1342.21	296.40	27.49	143.30
197	5	5	3	1	2	NT	NB	L	I	1525.99	330.03	27.24	155.16
198	5	6	3	1	2	CT	NB	H	I	1582.58	375.28	28.05	167.34
199	5	7	1	1	2	CT	NB	L	I	1542.19	279.88	27.46	165.87
200	5	8	1	1	2	NT	NB	H	I	1234.50	264.71	21.63	148.74
201	5	9	2	1	3	NT	NB	L	I	1419.62	287.79	23.95	151.37
202	5	10	2	1	3	CT	NB	H	I	1294.30	280.82	25.20	150.41
203	5	11	3	1	3	NT	NB	H	I	1495.47	335.47	20.00	155.81
204	5	12	3	1	3	CT	NB	L	I	1558.84	341.85	26.05	148.09
205	5	13	1	1	1	CT	B	L	I	1572.22	330.59	20.54	171.18
206	5	14	1	1	1	NT	B	L	I	1629.78	302.80	21.13	151.27
207	5	15	2	1	1	NT	B	H	I	1695.01	343.01	21.73	154.60
208	5	16	2	1	2	CT	B	L	I	1602.06	343.28	26.74	150.17
209	5	17	3	1	2	NT	B	H	I	1790.95	361.77	25.98	154.28
210	5	18	3	1	3	CT	B	L	I	1677.28	401.22	30.77	168.75
211	5	19	1	1	1	CT	B	H	I	1499.52	329.30	19.90	165.21
212	5	20	1	1	3	NT	B	H	I	1566.86	345.73	20.63	157.44
213	5	21	2	1	2	NT	B	L	I	1623.41	348.56	21.80	172.76
214	5	22	2	1	2	CT	B	H	I	1736.95	374.59	28.70	177.87
215	5	23	3	1	3	NT	B	L	I	1604.67	350.61	25.54	157.99
216	5	24	3	1	3	CT	B	H	I	1592.66	374.07	30.94	173.46
217	5	25	1	2	1	CT	B	H	NI	1608.97	331.11	15.37	187.14
218	5	26	1	2	1	NT	B	H	NI	1655.21	321.45	17.49	162.64
219	5	27	2	2	2	NT	B	H	NI	1587.59	326.95	16.04	175.36
220	5	28	2	2	1	CT	B	L	NI	1774.45	394.03	15.47	177.81
221	5	29	3	2	3	NT	B	H	NI	1625.66	336.47	16.63	166.18
222	5	30	3	2	2	CT	B	L	NI	1600.38	342.25	14.21	161.32
223	5	31	1	2	3	CT	B	L	NI	1605.99	333.67	14.48	171.10
224	5	32	1	2	1	NT	B	L	NI	1693.65	329.33	14.19	160.09
225	5	33	2	2	2	NT	B	L	NI	1673.91	351.72	14.17	162.20
226	5	34	2	2	2	CT	B	H	NI	1677.10	348.15	16.99	163.34
227	5	35	3	2	3	NT	B	L	NI	1634.23	326.50	15.72	149.42
228	5	36	3	2	3	CT	B	H	NI	1845.13	387.30	18.38	176.93

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	Ca	Mg	Na	Fe
229	5	37	1	2	1	CT	NB	H	NI	1943.86	345.10	17.65	200.95
230	5	38	1	2	1	NT	NB	L	NI	1781.62	321.17	13.38	150.20
231	5	39	2	2	1	NT	NB	H	NI	1940.27	345.63	17.09	176.42
232	5	40	2	2	2	CT	NB	H	NI	1943.85	346.80	18.89	156.92
233	5	41	3	2	2	NT	NB	L	NI	2022.26	359.26	15.20	166.53
234	5	42	3	2	3	CT	NB	H	NI	2094.60	342.80	16.56	164.68
235	5	43	1	2	1	CT	NB	L	NI	1966.46	343.94	15.01	200.80
236	5	44	1	2	2	NT	NB	H	NI	1948.49	339.25	13.46	149.53
237	5	45	2	2	3	NT	NB	L	NI	1959.69	336.42	12.67	149.15
238	5	46	2	2	2	CT	NB	L	NI	2063.77	349.67	13.83	138.75
239	5	47	3	2	3	NT	NB	H	NI	1973.75	355.61	13.01	127.92
240	5	48	3	2	3	CT	NB	L	NI	2029.16	371.70	14.99	139.27
241	6	1	1	1	1	CT	NB	H	I	1628.88	335.76	19.54	185.99
242	6	2	1	1	1	NT	NB	L	I	1470.91	348.92	22.00	175.52
243	6	3	2	1	1	NT	NB	H	I	1269.54	286.17	17.97	153.72
244	6	4	2	1	1	CT	NB	L	I	1483.93	343.36	22.05	170.99
245	6	5	3	1	2	NT	NB	L	I	1341.89	318.52	18.47	135.07
246	6	6	3	1	2	CT	NB	H	I	1637.23	413.65	23.67	181.46
247	6	7	1	1	2	CT	NB	L	I	1379.80	286.52	16.81	172.97
248	6	8	1	1	2	NT	NB	H	I	1284.71	281.55	19.03	161.44
249	6	9	2	1	3	NT	NB	L	I	1162.93	262.66	17.42	158.82
250	6	10	2	1	3	CT	NB	H	I	1295.46	312.19	18.69	160.61
251	6	11	3	1	3	NT	NB	H	I	1205.98	307.08	15.70	155.89
252	6	12	3	1	3	CT	NB	L	I	1726.73	429.70	25.19	181.63
253	6	13	1	1	1	CT	B	L	I	1661.18	386.25	19.97	204.35
254	6	14	1	1	1	NT	B	L	I	1719.64	380.63	23.29	172.61
255	6	15	2	1	1	NT	B	H	I	1767.00	434.29	23.46	174.93
256	6	16	2	1	2	CT	B	L	I	1790.95	421.72	27.52	200.15
257	6	17	3	1	2	NT	B	H	I	1940.21	484.60	27.49	191.82
258	6	18	3	1	3	CT	B	L	I	1745.69	445.05	27.26	202.95
259	6	19	1	1	1	CT	B	H	I	1641.79	403.10	20.06	213.92
260	6	20	1	1	3	NT	B	H	I	1816.33	435.46	26.75	177.41
261	6	21	2	1	2	NT	B	L	I	1775.99	437.22	23.82	194.74
262	6	22	2	1	2	CT	B	H	I	1893.70	476.85	23.79	214.16
263	6	23	3	1	3	NT	B	L	I	1741.07	403.17	25.45	191.67
264	6	24	3	1	3	CT	B	H	I	1757.88	467.42	20.55	199.17
265	6	25	1	2	1	CT	B	H	NI	1752.41	407.74	19.06	197.64
266	6	26	1	2	1	NT	B	H	NI	1929.44	404.87	21.48	190.07
267	6	27	2	2	2	NT	B	H	NI	1737.55	372.68	15.60	184.26
268	6	28	2	2	1	CT	B	L	NI	1743.37	401.38	20.55	193.24
269	6	29	3	2	3	NT	B	H	NI	1923.69	426.74	29.90	195.35

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	Ca	Mg	Na	Fe
270	6	30	3	2	2	CT	B	L	NI	1973.23	433.80	25.46	195.05
271	6	31	1	2	3	CT	B	L	NI	1800.33	387.29	23.18	196.25
272	6	32	1	2	1	NT	B	L	NI	1897.03	388.50	21.34	187.18
273	6	33	2	2	2	NT	B	L	NI	1777.64	386.75	19.33	175.68
274	6	34	2	2	2	CT	B	H	NI	1715.17	369.10	20.77	176.99
275	6	35	3	2	3	NT	B	L	NI	1823.97	384.28	20.24	171.54
276	6	36	3	2	3	CT	B	H	NI	1863.77	412.21	19.46	177.91
277	6	37	1	2	1	CT	NB	H	NI	2125.84	418.32	17.55	231.26
278	6	38	1	2	1	NT	NB	L	NI	2038.51	405.36	16.05	187.32
279	6	39	2	2	1	NT	NB	H	NI	2048.29	412.70	16.69	186.87
280	6	40	2	2	2	CT	NB	H	NI	2029.40	417.09	15.22	177.04
281	6	41	3	2	2	NT	NB	L	NI	1919.57	343.42	17.05	165.25
282	6	42	3	2	3	CT	NB	H	NI	2245.43	417.53	21.42	179.50
283	6	43	1	2	1	CT	NB	L	NI	2282.27	415.68	22.44	227.17
284	6	44	1	2	2	NT	NB	H	NI	2148.84	380.74	19.57	181.12
285	6	45	2	2	3	NT	NB	L	NI	2059.13	349.38	19.36	161.33
286	6	46	2	2	2	CT	NB	L	NI	2122.39	371.15	17.78	168.76
287	6	47	3	2	3	NT	NB	H	NI	1969.59	332.01	20.58	149.97
288	6	48	3	2	3	CT	NB	L	NI	2033.25	356.64	23.05	174.92

Extractable Mn, Zn, and Cu (kg ka^{-1}), soil organic matter (OM) and total N (TN) concentration (g kg^{-1})

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	Mn	Zn	Cu	OM	TN
1	1	1	1	1	1	CT	NB	H	I	227.89	2.52	2.15	15.9	0.748
2	1	2	1	1	1	NT	NB	L	I	236.95	2.25	2.01	14.6	0.752
3	1	3	2	1	1	NT	NB	H	I	224.77	2.01	2.92	17.3	0.808
4	1	4	2	1	1	CT	NB	L	I	206.31	1.88	2.25	16.3	0.808
5	1	5	3	1	2	NT	NB	L	I	176.04	1.52	1.95	16.7	0.701
6	1	6	3	1	2	CT	NB	H	I	168.42	1.31	2.06	19.1	0.737
7	1	7	1	1	2	CT	NB	L	I	206.43	2.28	2.83	17.2	0.742
8	1	8	1	1	2	NT	NB	H	I	196.14	2.44	2.86	14.9	0.82
9	1	9	2	1	3	NT	NB	L	I	184.57	1.71	2.07	14.8	0.939
10	1	10	2	1	3	CT	NB	H	I	211.18	1.50	1.96	14.4	0.718
11	1	11	3	1	3	NT	NB	H	I	166.90	1.16	2.01	14.4	0.653
12	1	12	3	1	3	CT	NB	L	I	145.06	1.44	2.52	16.5	0.695
13	1	13	1	1	1	CT	B	L	I	179.45	1.76	2.33	16.8	0.76
14	1	14	1	1	1	NT	B	L	I	164.47	1.95	2.68	18.4	0.844
15	1	15	2	1	1	NT	B	H	I	148.02	1.40	2.80	18.7	0.788

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	Mn	Zn	Cu	OM	TN
16	1	16	2	1	2	CT	B	L	I	126.77	1.32	2.26	19.1	0.772
17	1	17	3	1	2	NT	B	H	I	107.82	0.97	1.77	18.7	0.771
18	1	18	3	1	3	CT	B	L	I	108.52	1.23	2.02	15.1	0.742
19	1	19	1	1	1	CT	B	H	I	167.61	1.74	2.92	17.1	0.813
20	1	20	1	1	3	NT	B	H	I	165.68	1.46	1.89	17.2	0.806
21	1	21	2	1	2	NT	B	L	I	153.50	1.22	1.95	16.9	0.782
22	1	22	2	1	2	CT	B	H	I	143.11	1.22	2.03	17.3	0.734
23	1	23	3	1	3	NT	B	L	I	123.65	1.28	2.25	17.1	0.728
24	1	24	3	1	3	CT	B	H	I	128.33	1.18	2.68	18.7	0.765
25	1	25	1	2	4	CT	B	H	I	137.23	1.96	2.15	20.1	0.979
26	1	26	1	2	4	NT	B	H	I	137.05	1.71	2.31	20.6	0.941
27	1	27	2	2	5	NT	B	H	I	155.94	1.89	2.80	18.8	0.984
28	1	28	2	2	4	CT	B	L	I	175.69	2.04	2.43	21.8	0.989
29	1	29	3	2	6	NT	B	H	I	184.57	1.95	2.31	21.6	1.017
30	1	30	3	2	5	CT	B	L	I	186.54	2.26	3.10	19.2	0.921
31	1	31	1	2	6	CT	B	L	I	119.16	1.44	2.95	19.9	0.894
32	1	32	1	2	4	NT	B	L	I	135.84	1.64	2.19	21.2	0.944
33	1	33	2	2	5	NT	B	L	I	132.79	1.71	2.19	22.1	1.005
34	1	34	2	2	5	CT	B	H	I	131.97	1.64	2.55	21.8	0.931
35	1	35	3	2	6	NT	B	L	I	145.58	1.46	2.31	19.9	0.839
36	1	36	3	2	6	CT	B	H	I	133.71	1.19	1.84	17.3	0.865
37	1	37	1	2	4	CT	NB	H	I	146.36	1.46	2.67	19.2	0.924
38	1	38	1	2	4	NT	NB	L	I	137.05	1.52	2.13	19.3	0.865
39	1	39	2	2	4	NT	NB	H	I	139.49	1.52	3.05	18.9	2.006
40	1	40	2	2	5	CT	NB	H	I	132.27	1.33	2.17	18.9	0.803
41	1	41	3	2	5	NT	NB	L	I	134.62	1.40	2.13	20	0.839
42	1	42	3	2	6	CT	NB	H	I	126.03	1.49	1.84	22.2	0.897
43	1	43	1	2	4	CT	NB	L	I	133.36	1.63	2.84	23.7	0.975
44	1	44	1	2	5	NT	NB	H	I	131.57	1.52	2.07	21.3	0.947
45	1	45	2	2	6	NT	NB	L	I	124.26	1.52	2.19	19	0.86
46	1	46	2	2	5	CT	NB	L	I	128.48	1.48	2.89	21.7	0.885
47	1	47	3	2	6	NT	NB	H	I	134.62	1.71	2.31	21.2	0.943
48	1	48	3	2	6	CT	NB	L	I	112.75	1.32	1.92	19.6	0.841
49	2	1	1	1	1	CT	NB	H	I	253.39	2.61	1.77	13.3	1.074
50	2	2	1	1	1	NT	NB	L	I	229.76	2.28	1.72	26.7	1.026
51	2	3	2	1	1	NT	NB	H	I	215.32	2.11	2.05	15.5	1.441
52	2	4	2	1	1	CT	NB	L	I	196.94	1.88	1.65	17.6	1.104
53	2	5	3	1	2	NT	NB	L	I	169.37	1.59	1.71	14.7	1.102
54	2	6	3	1	2	CT	NB	H	I	152.30	1.46	1.47	19.7	1.195
55	2	7	1	1	2	CT	NB	L	I	225.82	2.74	1.64	16.4	0.825
56	2	8	1	1	2	NT	NB	H	I	224.51	2.32	1.73	19.2	0.796

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	Mn	Zn	Cu	OM	TN
57	2	9	2	1	3	NT	NB	L	I	168.05	1.89	1.55	16.7	0.851
58	2	10	2	1	3	CT	NB	H	I	177.24	1.43	1.42	15.9	1.267
59	2	11	3	1	3	NT	NB	H	I	161.49	1.33	1.29	20.8	0.908
60	2	12	3	1	3	CT	NB	L	I	143.11	1.38	1.38	14.6	0.938
61	2	13	1	1	1	CT	B	L	I	174.62	1.89	1.54	18.3	0.94
62	2	14	1	1	1	NT	B	L	I	149.67	1.90	1.64	14.1	1.012
63	2	15	2	1	1	NT	B	H	I	132.60	1.63	1.59	21.7	1.26
64	2	16	2	1	2	CT	B	L	I	131.29	1.17	1.46	22.8	0.995
65	2	17	3	1	2	NT	B	H	I	103.72	1.44	1.63	19.1	1.001
66	2	18	3	1	3	CT	B	L	I	118.16	1.18	1.59	18.3	1.06
67	2	19	1	1	1	CT	B	H	I	177.24	1.85	1.65	18.6	1.152
68	2	20	1	1	3	NT	B	H	I	160.18	1.52	1.58	20.4	1.084
69	2	21	2	1	2	NT	B	L	I	171.99	1.58	1.67	18	1.011
70	2	22	2	1	2	CT	B	H	I	148.36	1.44	1.80	17	1.046
71	2	23	3	1	3	NT	B	L	I	120.79	1.37	1.65	13.7	0.993
72	2	24	3	1	3	CT	B	H	I	143.11	1.76	1.59	18.8	1.007
73	2	25	1	2	4	CT	B	H	I	136.54	2.04	1.79	17.4	1.185
74	2	26	1	2	4	NT	B	H	I	132.60	2.19	2.09	16.8	1.168
75	2	27	2	2	5	NT	B	H	I	145.73	2.25	2.01	20.9	1.234
76	2	28	2	2	4	CT	B	L	I	148.36	2.22	2.05	19.4	1.267
77	2	29	3	2	6	NT	B	H	I	150.99	3.58	2.10	26.9	1.346
78	2	30	3	2	5	CT	B	L	I	149.67	2.07	2.02	16.1	1.203
79	2	31	1	2	6	CT	B	L	I	105.03	1.61	1.56	27.3	1.104
80	2	32	1	2	4	NT	B	L	I	107.66	2.04	1.90	14.7	1.142
81	2	33	2	2	5	NT	B	L	I	112.91	1.90	1.88	20.3	1.462
82	2	34	2	2	5	CT	B	H	I	129.98	1.90	1.86	17.2	1.098
83	2	35	3	2	6	NT	B	L	I	122.10	1.75	1.65	16.9	0.879
84	2	36	3	2	6	CT	B	H	I	129.98	1.52	1.77	19.6	0.865
85	2	37	1	2	4	CT	NB	H	I	144.42	1.90	1.94	20	1.037
86	2	38	1	2	4	NT	NB	L	I	131.29	2.21	1.80	22.6	0.963
87	2	39	2	2	4	NT	NB	H	I	148.36	1.71	1.73	24.9	0.977
88	2	40	2	2	5	CT	NB	H	I	128.67	1.84	1.84	20.3	0.951
89	2	41	3	2	5	NT	NB	L	I	115.54	2.01	1.71	20.4	1.002
90	2	42	3	2	6	CT	NB	H	I	122.10	1.77	1.79	20.6	1.18
91	2	43	1	2	4	CT	NB	L	I	139.17	1.82	2.07	21.8	1.019
92	2	44	1	2	5	NT	NB	H	I	128.67	1.86	2.02	22.3	1.002
93	2	45	2	2	6	NT	NB	L	I	133.92	2.07	2.17	24.1	1.042
94	2	46	2	2	5	CT	NB	L	I	129.98	1.51	2.02	35	1.074
95	2	47	3	2	6	NT	NB	H	I	137.86	1.94	2.00	20.6	1.061
96	2	48	3	2	6	CT	NB	L	I	132.60	1.64	1.93	20.1	0.995
97	3	1	1	1	1	CT	NB	H	I	350.52	2.83	2.29	20.8	1.179

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	Mn	Zn	Cu	OM	TN
98	3	2	1	1	1	NT	NB	L	I	315.98	2.29	2.29	19.4	1.063
99	3	3	2	1	1	NT	NB	H	I	263.50	2.16	2.02	21.1	1.142
100	3	4	2	1	1	CT	NB	L	I	267.27	1.89	2.16	22	1.188
101	3	5	3	1	2	NT	NB	L	I	248.38	1.62	2.16	21.2	1.033
102	3	6	3	1	2	CT	NB	H	I	247.17	1.35	2.16	19.2	0.945
103	3	7	1	1	2	CT	NB	L	I	318.14	2.83	2.16	20.4	1.054
104	3	8	1	1	2	NT	NB	H	I	299.25	2.16	2.02	17.8	0.97
105	3	9	2	1	3	NT	NB	L	I	256.61	1.89	2.02	15.7	0.927
106	3	10	2	1	3	CT	NB	H	I	266.19	1.48	2.02	16.6	0.956
107	3	11	3	1	3	NT	NB	H	I	226.26	1.21	1.89	17.5	0.885
108	3	12	3	1	3	CT	NB	L	I	213.98	1.35	2.02	20.2	1.194
109	3	13	1	1	1	CT	B	L	I	207.10	2.02	2.29	21.6	1.168
110	3	14	1	1	1	NT	B	L	I	194.28	1.89	2.29	22	1.806
111	3	15	2	1	1	NT	B	H	I	168.92	1.62	2.16	22.6	2.016
112	3	16	2	1	2	CT	B	L	I	163.52	1.35	2.29	21.7	1.201
113	3	17	3	1	2	NT	B	H	I	137.35	1.08	2.16	21.1	1.057
114	3	18	3	1	3	CT	B	L	I	194.42	0.94	2.02	18.2	0.982
115	3	19	1	1	1	CT	B	H	I	218.97	1.75	2.29	20.6	1.094
116	3	20	1	1	3	NT	B	H	I	215.33	1.62	2.29	20.6	1.261
117	3	21	2	1	2	NT	B	L	I	188.35	1.35	2.29	21.2	1.03
118	3	22	2	1	2	CT	B	H	I	192.53	1.08	2.29	19.7	0.944
119	3	23	3	1	3	NT	B	L	I	152.73	1.21	2.02	17.9	0.989
120	3	24	3	1	3	CT	B	H	I	195.77	1.08	2.16	22.1	1.065
121	3	25	1	2	4	CT	B	H	I	167.97	1.75	2.43	23.1	1.141
122	3	26	1	2	4	NT	B	H	I	178.36	2.29	2.70	24.7	2.016
123	3	27	2	2	5	NT	B	H	I	190.10	2.29	2.70	23.8	1.339
124	3	28	2	2	4	CT	B	L	I	191.58	1.75	2.56	22.7	1.124
125	3	29	3	2	6	NT	B	H	I	213.44	1.89	2.29	22.7	1.702
126	3	30	3	2	5	CT	B	L	I	194.96	1.48	2.43	21.6	1.089
127	3	31	1	2	6	CT	B	L	I	170.67	1.62	2.43	22.9	1.19
128	3	32	1	2	4	NT	B	L	I	150.97	1.62	2.56	21.2	1.017
129	3	33	2	2	5	NT	B	L	I	154.08	1.48	2.29	21	1.559
130	3	34	2	2	5	CT	B	H	I	177.55	1.35	2.29	21.8	0.989
131	3	35	3	2	6	NT	B	L	I	193.20	1.62	2.29	21.8	1
132	3	36	3	2	6	CT	B	H	I	195.36	1.35	2.29	21.1	1.004
133	3	37	1	2	4	CT	NB	H	I	190.50	1.75	2.56	23.8	1.104
134	3	38	1	2	4	NT	NB	L	I	185.78	1.89	2.29	22.7	1.111
135	3	39	2	2	4	NT	NB	H	I	186.46	1.75	2.16	22.7	1.364
136	3	40	2	2	5	CT	NB	H	I	185.11	1.48	1.89	24.1	1.112
137	3	41	3	2	5	NT	NB	L	I	178.77	1.75	2.43	22.7	1.13
138	3	42	3	2	6	CT	NB	H	I	182.41	1.75	2.56	25.2	1.231

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	Mn	Zn	Cu	OM	TN
139	3	43	1	2	4	CT	NB	L	I	176.20	1.75	2.56	25.2	1.124
140	3	44	1	2	5	NT	NB	H	I	173.64	1.75	2.16	26.5	1.269
141	3	45	2	2	6	NT	NB	L	I	171.48	1.89	2.29	27	1.23
142	3	46	2	2	5	CT	NB	L	I	180.66	1.75	2.43	23	1.023
143	3	47	3	2	6	NT	NB	H	I	182.81	1.89	2.29	26.4	1.219
144	3	48	3	2	6	CT	NB	L	I	197.25	1.89	2.29	26.2	1.209
145	4	1	1	1	1	CT	NB	H	I	274.15	2.38	1.72	19.4	0.91
146	4	2	1	1	1	NT	NB	L	I	242.52	1.86	1.72	16	0.85
147	4	3	2	1	1	NT	NB	H	I	213.57	1.67	1.54	18.9	0.95
148	4	4	2	1	1	CT	NB	L	I	225.68	1.56	1.65	19.4	0.95
149	4	5	3	1	2	NT	NB	L	I	202.61	1.38	1.67	18.9	0.99
150	4	6	3	1	2	CT	NB	H	I	186.01	1.26	1.65	20.3	1
151	4	7	1	1	2	CT	NB	L	I	264.24	2.17	1.76	18.9	1
152	4	8	1	1	2	NT	NB	H	I	196.56	1.56	1.52	15	0.88
153	4	9	2	1	3	NT	NB	L	I	204.56	1.35	1.57	16.5	1.01
154	4	10	2	1	3	CT	NB	H	I	241.22	1.46	1.58	18.3	1.09
155	4	11	3	1	3	NT	NB	H	I	166.35	1.16	1.39	17.2	0.74
156	4	12	3	1	3	CT	NB	L	I	187.75	1.18	1.70	17.7	0.94
157	4	13	1	1	1	CT	B	L	I	188.55	1.16	1.45	20	0.95
158	4	14	1	1	1	NT	B	L	I	149.61	0.97	1.49	17.7	0.81
159	4	15	2	1	1	NT	B	H	I	143.87	0.94	1.51	20.4	0.99
160	4	16	2	1	2	CT	B	L	I	158.51	0.85	1.53	17.7	0.88
161	4	17	3	1	2	NT	B	H	I	128.77	0.72	1.43	18.9	0.81
162	4	18	3	1	3	CT	B	L	I	153.20	0.66	1.52	18.5	0.85
163	4	19	1	1	1	CT	B	H	I	194.61	1.05	1.55	21	0.96
164	4	20	1	1	3	NT	B	H	I	179.26	1.00	1.58	20.1	0.94
165	4	21	2	1	2	NT	B	L	I	170.46	0.85	1.52	19.9	0.78
166	4	22	2	1	2	CT	B	H	I	164.28	0.70	1.60	19.1	0.83
167	4	23	3	1	3	NT	B	L	I	135.96	0.66	1.48	17.3	0.76
168	4	24	3	1	3	CT	B	H	I	173.89	0.74	1.46	18.6	0.85
169	4	25	1	2	1	CT	B	H	NI	153.95	1.03	1.74	20	1
170	4	26	1	2	1	NT	B	H	NI	153.57	1.27	1.84	21.2	0.97
171	4	27	2	2	2	NT	B	H	NI	166.47	1.50	1.87	22.5	1.07
172	4	28	2	2	1	CT	B	L	NI	184.19	1.20	1.64	21.7	1.03
173	4	29	3	2	3	NT	B	H	NI	183.07	1.05	1.56	20.9	0.92
174	4	30	3	2	2	CT	B	L	NI	202.13	1.14	1.80	21.9	0.94
175	4	31	1	2	3	CT	B	L	NI	134.30	0.95	1.54	20.8	1
176	4	32	1	2	1	NT	B	L	NI	153.91	1.24	1.81	22.7	0.94
177	4	33	2	2	2	NT	B	L	NI	137.41	1.10	1.65	19	0.91
178	4	34	2	2	2	CT	B	H	NI	173.14	1.01	1.66	19.7	0.95
179	4	35	3	2	3	NT	B	L	NI	156.08	1.01	2.25	19.8	0.91

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	Mn	Zn	Cu	OM	TN
180	4	36	3	2	3	CT	B	H	NI	165.07	0.81	1.64	21.3	0.95
181	4	37	1	2	1	CT	NB	H	NI	189.54	1.13	2.00	24.2	1.09
182	4	38	1	2	1	NT	NB	L	NI	185.01	1.48	1.97	24.4	1.13
183	4	39	2	2	1	NT	NB	H	NI	157.98	1.21	1.77	23.3	0.99
184	4	40	2	2	2	CT	NB	H	NI	193.12	1.16	1.82	25	1.11
185	4	41	3	2	2	NT	NB	L	NI	157.85	1.21	1.79	21.7	0.92
186	4	42	3	2	3	CT	NB	H	NI	171.66	1.15	1.92	21.9	1
187	4	43	1	2	1	CT	NB	L	NI	171.31	1.35	2.15	24.8	1.15
188	4	44	1	2	2	NT	NB	H	NI	170.52	1.55	2.05	23.6	1.16
189	4	45	2	2	3	NT	NB	L	NI	148.56	1.21	1.93	20.4	0.99
190	4	46	2	2	2	CT	NB	L	NI	169.64	1.12	2.21	23.8	1.11
191	4	47	3	2	3	NT	NB	H	NI	142.35	0.97	1.74	19.8	0.89
192	4	48	3	2	3	CT	NB	L	NI	189.49	1.31	1.94	22.8	1.1
193	5	1	1	1	1	CT	NB	H	I	238.23	3.26	1.82	22.1	1.07
194	5	2	1	1	1	NT	NB	L	I	238.68	2.41	1.73	18.8	0.99
195	5	3	2	1	1	NT	NB	H	I	190.20	2.21	1.48	21	1.12
196	5	4	2	1	1	CT	NB	L	I	200.91	2.49	1.68	18.2	1.02
197	5	5	3	1	2	NT	NB	L	I	179.87	2.25	1.85	19.3	1.12
198	5	6	3	1	2	CT	NB	H	I	190.95	2.05	1.69	22.3	1.12
199	5	7	1	1	2	CT	NB	L	I	249.06	2.86	1.78	19.4	1.07
200	5	8	1	1	2	NT	NB	H	I	203.05	2.40	1.60	20.6	0.86
201	5	9	2	1	3	NT	NB	L	I	202.90	2.46	1.77	22.3	1.18
202	5	10	2	1	3	CT	NB	H	I	190.28	1.97	1.67	19.3	1.01
203	5	11	3	1	3	NT	NB	H	I	169.10	2.00	1.59	23.4	1.15
204	5	12	3	1	3	CT	NB	L	I	138.35	1.87	1.68	21.2	1.04
205	5	13	1	1	1	CT	B	L	I	165.48	2.19	1.76	21.3	1.04
206	5	14	1	1	1	NT	B	L	I	153.07	2.32	1.79	18.1	1.08
207	5	15	2	1	1	NT	B	H	I	129.69	1.99	1.69	21.4	1.1
208	5	16	2	1	2	CT	B	L	I	137.80	1.88	1.61	19.8	1.12
209	5	17	3	1	2	NT	B	H	I	120.63	1.36	1.56	19.1	1.15
210	5	18	3	1	3	CT	B	L	I	137.52	1.70	1.72	20.1	1.17
211	5	19	1	1	1	CT	B	H	I	171.11	1.85	1.68	27.9	1.07
212	5	20	1	1	3	NT	B	H	I	152.81	1.89	1.63	21.4	1.1
213	5	21	2	1	2	NT	B	L	I	147.10	1.85	1.67	19.2	1.15
214	5	22	2	1	2	CT	B	H	I	159.78	1.64	1.61	21.2	1.11
215	5	23	3	1	3	NT	B	L	I	124.99	1.51	1.53	19.4	1.04
216	5	24	3	1	3	CT	B	H	I	141.58	1.46	1.74	20.7	1.13
217	5	25	1	2	1	CT	B	H	NI	136.12	2.21	1.82	24.7	1.31
218	5	26	1	2	1	NT	B	H	NI	120.90	2.18	1.77	23.1	1.41
219	5	27	2	2	2	NT	B	H	NI	140.14	2.74	1.89	25.5	1.09
220	5	28	2	2	1	CT	B	L	NI	145.31	2.24	1.99	24.9	1.16

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	Mn	Zn	Cu	OM	TN
221	5	29	3	2	3	NT	B	H	NI	154.59	2.27	1.85	23	1.13
222	5	30	3	2	2	CT	B	L	NI	141.71	1.88	1.66	24.4	1.13
223	5	31	1	2	3	CT	B	L	NI	119.38	1.84	1.71	22.9	1.04
224	5	32	1	2	1	NT	B	L	NI	115.07	2.07	1.85	24.4	1.11
225	5	33	2	2	2	NT	B	L	NI	125.36	2.44	1.90	24.3	1.13
226	5	34	2	2	2	CT	B	H	NI	143.09	1.94	1.77	24	0.9
227	5	35	3	2	3	NT	B	L	NI	131.60	1.87	1.56	23.6	1.05
228	5	36	3	2	3	CT	B	H	NI	149.82	1.99	1.76	23	1.24
229	5	37	1	2	1	CT	NB	H	NI	158.66	2.16	2.01	25.4	1.28
230	5	38	1	2	1	NT	NB	L	NI	117.90	2.29	1.67	19.1	1.19
231	5	39	2	2	1	NT	NB	H	NI	129.06	2.55	2.00	23.9	1.32
232	5	40	2	2	2	CT	NB	H	NI	141.47	2.43	1.81	24.9	1
233	5	41	3	2	2	NT	NB	L	NI	148.56	2.53	1.91	26.2	1.2
234	5	42	3	2	3	CT	NB	H	NI	148.26	2.31	1.90	26.6	1.17
235	5	43	1	2	1	CT	NB	L	NI	142.76	2.24	2.01	28.9	1.24
236	5	44	1	2	2	NT	NB	H	NI	126.68	2.62	1.82	29.2	1.34
237	5	45	2	2	3	NT	NB	L	NI	125.51	2.39	1.79	30.2	1.45
238	5	46	2	2	2	CT	NB	L	NI	144.80	2.31	1.77	26.8	1.13
239	5	47	3	2	3	NT	NB	H	NI	128.89	2.43	1.68	28.6	1.28
240	5	48	3	2	3	CT	NB	L	NI	149.93	2.04	1.83	25.5	1.09
241	6	1	1	1	1	CT	NB	H	I	231.70	2.27	2.26	25.71	1.1455
242	6	2	1	1	1	NT	NB	L	I	229.64	2.02	2.33	21.09	1.10922
243	6	3	2	1	1	NT	NB	H	I	195.22	1.63	2.06	23.44	1.30738
244	6	4	2	1	1	CT	NB	L	I	227.36	1.78	2.44	21.28	1.13119
245	6	5	3	1	2	NT	NB	L	I	161.95	1.22	1.92	24.07	1.14998
246	6	6	3	1	2	CT	NB	H	I	176.62	1.28	2.19	23.41	1.28103
247	6	7	1	1	2	CT	NB	L	I	231.64	2.07	2.28	18.2	1.06599
248	6	8	1	1	2	NT	NB	H	I	215.49	1.97	2.19	19.75	1.05529
249	6	9	2	1	3	NT	NB	L	I	179.02	1.42	1.91	17.84	0.89086
250	6	10	2	1	3	CT	NB	H	I	208.16	1.31	2.10	19.5	1.06424
251	6	11	3	1	3	NT	NB	H	I	149.54	1.08	2.00	18.77	0.92986
252	6	12	3	1	3	CT	NB	L	I	160.13	1.25	2.33	23.54	1.13015
253	6	13	1	1	1	CT	B	L	I	184.12	1.52	2.61	21.8	1.106
254	6	14	1	1	1	NT	B	L	I	151.69	1.51	2.37	17.98	1.0395
255	6	15	2	1	1	NT	B	H	I	136.13	1.31	2.29	24.06	1.11958
256	6	16	2	1	2	CT	B	L	I	150.29	1.12	2.22	22.23	0.99933
257	6	17	3	1	2	NT	B	H	I	133.24	1.15	2.37	24.03	1.04714
258	6	18	3	1	3	CT	B	L	I	146.31	1.11	2.38	19.1	1.0028
259	6	19	1	1	1	CT	B	H	I	176.06	1.45	2.51	19.5	0.98465
260	6	20	1	1	3	NT	B	H	I	177.79	1.40	2.30	19.49	0.8945
261	6	21	2	1	2	NT	B	L	I	165.83	1.36	2.36	21.28	0.98135

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	Mn	Zn	Cu	OM	TN
262	6	22	2	1	2	CT	B	H	I	172.09	1.27	2.51	22.17	1.0464
263	6	23	3	1	3	NT	B	L	I	137.21	1.13	2.28	20.28	0.86155
264	6	24	3	1	3	CT	B	H	I	153.35	1.09	2.37	23.58	0.96172
265	6	25	1	2	1	CT	B	H	NI	154.04	1.67	2.55	25.03	1.22146
266	6	26	1	2	1	NT	B	H	NI	136.87	1.95	2.63	26.04	1.08973
267	6	27	2	2	2	NT	B	H	NI	147.36	2.10	2.60	22.81	1.12938
268	6	28	2	2	1	CT	B	L	NI	166.58	1.70	2.79	23.9	1.08245
269	6	29	3	2	3	NT	B	H	NI	165.65	2.11	2.97	22.91	1.02094
270	6	30	3	2	2	CT	B	L	NI	174.33	1.73	2.59	23.36	1.04301
271	6	31	1	2	3	CT	B	L	NI	140.85	1.68	2.50	25.49	1.01422
272	6	32	1	2	1	NT	B	L	NI	137.16	1.87	2.73	25.15	1.01192
273	6	33	2	2	2	NT	B	L	NI	128.79	1.76	2.44	25.89	1.06934
274	6	34	2	2	2	CT	B	H	NI	153.19	1.48	2.27	23.88	1.01501
275	6	35	3	2	3	NT	B	L	NI	136.15	1.52	2.43	20.25	0.9072
276	6	36	3	2	3	CT	B	H	NI	153.88	1.54	2.38	22.25	1.10778
277	6	37	1	2	1	CT	NB	H	NI	171.33	1.94	2.86	28.38	1.22297
278	6	38	1	2	1	NT	NB	L	NI	149.18	2.23	2.69	27.76	1.18621
279	6	39	2	2	1	NT	NB	H	NI	145.14	2.02	2.72	30.09	1.21806
280	6	40	2	2	2	CT	NB	H	NI	185.03	2.07	2.56	28.84	1.33629
281	6	41	3	2	2	NT	NB	L	NI	134.88	1.85	2.28	22.76	1.00279
282	6	42	3	2	3	CT	NB	H	NI	186.31	2.26	2.66	26.7	1.18475
283	6	43	1	2	1	CT	NB	L	NI	158.64	2.12	3.10	22.52	1.19511
284	6	44	1	2	2	NT	NB	H	NI	137.52	2.03	2.75	23.88	1.09688
285	6	45	2	2	3	NT	NB	L	NI	133.02	2.08	2.34	23.53	1.10588
286	6	46	2	2	2	CT	NB	L	NI	168.52	2.01	2.66	22.84	1.12306
287	6	47	3	2	3	NT	NB	H	NI	138.13	1.91	2.39	25.9	1.21218
288	6	48	3	2	3	CT	NB	L	NI	174.56	2.15	2.62	24.49	1.09928

Carbon:nitrogen ratio (C:N), soil organic matter (OMc), total N (TNc), and total C (TCc) contents (kg m^{-2})

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	TotC	C:N	OMc	TNc	TCc
1	1	1	1	1	1	CT	NB	H	I	6.59	8.8	1.937	0.091	0.803
2	1	2	1	1	1	NT	NB	L	I	6.49	8.6	1.779	0.092	0.791
3	1	3	2	1	1	NT	NB	H	I	7.6	9.4	2.108	0.098	0.926
4	1	4	2	1	1	CT	NB	L	I	9.7	12.0	1.986	0.098	1.182
5	1	5	3	1	2	NT	NB	L	I	6.55	9.3	2.035	0.085	0.798
6	1	6	3	1	2	CT	NB	H	I	6.55	8.9	2.327	0.090	0.798
7	1	7	1	1	2	CT	NB	L	I	7.32	9.9	2.095	0.090	0.892
8	1	8	1	1	2	NT	NB	H	I	6.52	8.0	1.815	0.100	0.794

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	TotC	C:N	OMc	TNc	TCc
9	1	9	2	1	3	NT	NB	L	I	6.67	7.1	1.803	0.114	0.813
10	1	10	2	1	3	CT	NB	H	I	6.18	8.6	1.754	0.087	0.753
11	1	11	3	1	3	NT	NB	H	I	5.74	8.8	1.754	0.080	0.699
12	1	12	3	1	3	CT	NB	L	I	5.87	8.4	2.010	0.085	0.715
13	1	13	1	1	1	CT	B	L	I	6.48	8.5	2.047	0.093	0.789
14	1	14	1	1	1	NT	B	L	I	8.27	9.8	2.242	0.103	1.008
15	1	15	2	1	1	NT	B	H	I	7.05	8.9	2.278	0.096	0.859
16	1	16	2	1	2	CT	B	L	I	6.92	9.0	2.327	0.094	0.843
17	1	17	3	1	2	NT	B	H	I	7.19	9.3	2.278	0.094	0.876
18	1	18	3	1	3	CT	B	L	I	6.12	8.2	1.840	0.090	0.746
19	1	19	1	1	1	CT	B	H	I	7.71	9.5	2.083	0.099	0.939
20	1	20	1	1	3	NT	B	H	I	7.16	8.9	2.095	0.098	0.872
21	1	21	2	1	2	NT	B	L	I	6.81	8.7	2.059	0.095	0.830
22	1	22	2	1	2	CT	B	H	I	6.27	8.5	2.108	0.089	0.764
23	1	23	3	1	3	NT	B	L	I	6.09	8.4	2.083	0.089	0.742
24	1	24	3	1	3	CT	B	H	I	7.13	9.3	2.278	0.093	0.869
25	1	25	1	2	4	CT	B	H	I	8.5	8.7	2.449	0.119	1.036
26	1	26	1	2	4	NT	B	H	I	8.69	9.2	2.510	0.115	1.059
27	1	27	2	2	5	NT	B	H	I	8.95	9.1	2.290	0.120	1.090
28	1	28	2	2	4	CT	B	L	I	9.26	9.4	2.656	0.120	1.128
29	1	29	3	2	6	NT	B	H	I	9.57	9.4	2.631	0.124	1.166
30	1	30	3	2	5	CT	B	L	I	8.18	8.9	2.339	0.112	0.997
31	1	31	1	2	6	CT	B	L	I	8.07	9.0	2.424	0.109	0.983
32	1	32	1	2	4	NT	B	L	I	8.54	9.0	2.583	0.115	1.040
33	1	33	2	2	5	NT	B	L	I	9.46	9.4	2.692	0.122	1.152
34	1	34	2	2	5	CT	B	H	I	8.5	9.1	2.656	0.113	1.036
35	1	35	3	2	6	NT	B	L	I	6.99	8.3	2.424	0.102	0.852
36	1	36	3	2	6	CT	B	H	I	7.69	8.9	2.108	0.105	0.937
37	1	37	1	2	4	CT	NB	H	I	8.03	8.7	2.339	0.113	0.978
38	1	38	1	2	4	NT	NB	L	I	7.55	8.7	2.351	0.105	0.920
39	1	39	2	2	4	NT	NB	H	I	8.17	4.1	2.303	0.244	0.995
40	1	40	2	2	5	CT	NB	H	I	6.95	8.7	2.303	0.098	0.847
41	1	41	3	2	5	NT	NB	L	I	7.24	8.6	2.437	0.102	0.882
42	1	42	3	2	6	CT	NB	H	I	7.98	8.9	2.705	0.109	0.972
43	1	43	1	2	4	CT	NB	L	I	8.85	9.1	2.887	0.119	1.078
44	1	44	1	2	5	NT	NB	H	I	8.42	8.9	2.595	0.115	1.026
45	1	45	2	2	6	NT	NB	L	I	7.55	8.8	2.315	0.105	0.920
46	1	46	2	2	5	CT	NB	L	I	8.01	9.1	2.644	0.108	0.976
47	1	47	3	2	6	NT	NB	H	I	8.77	9.3	2.583	0.115	1.068
48	1	48	3	2	6	CT	NB	L	I	7.3	8.7	2.388	0.102	0.889
49	2	1	1	1	1	CT	NB	H	I	9.841	9.2	1.746	0.141	1.292

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	TotC	C:N	OMc	TNc	TCc
50	2	2	1	1	1	NT	NB	L	1	8.331	8.1	3.505	0.135	1.094
51	2	3	2	1	1	NT	NB	H	1	7.663	5.3	2.035	0.189	1.006
52	2	4	2	1	1	CT	NB	L	1	8.227	7.5	2.311	0.145	1.080
53	2	5	3	1	2	NT	NB	L	1	7.95	7.2	1.930	0.145	1.044
54	2	6	3	1	2	CT	NB	H	1	8.074	6.8	2.586	0.157	1.060
55	2	7	1	1	2	CT	NB	L	1	7.882	9.6	2.153	0.108	1.035
56	2	8	1	1	2	NT	NB	H	1	7.725	9.7	2.521	0.105	1.014
57	2	9	2	1	3	NT	NB	L	1	7.801	9.2	2.193	0.112	1.024
58	2	10	2	1	3	CT	NB	H	1	6.735	5.3	2.088	0.166	0.884
59	2	11	3	1	3	NT	NB	H	1	6.985	7.7	2.731	0.119	0.917
60	2	12	3	1	3	CT	NB	L	1	8.78	9.4	1.917	0.123	1.153
61	2	13	1	1	1	CT	B	L	1	8.127	8.6	2.403	0.123	1.067
62	2	14	1	1	1	NT	B	L	1	8.603	8.5	1.851	0.133	1.130
63	2	15	2	1	1	NT	B	H	1	7.639	6.1	2.849	0.165	1.003
64	2	16	2	1	2	CT	B	L	1	7.878	7.9	2.993	0.131	1.034
65	2	17	3	1	2	NT	B	H	1	7.639	7.6	2.508	0.131	1.003
66	2	18	3	1	3	CT	B	L	1	7.791	7.4	2.403	0.139	1.023
67	2	19	1	1	1	CT	B	H	1	9.344	8.1	2.442	0.151	1.227
68	2	20	1	1	3	NT	B	H	1	7.87	7.3	2.678	0.142	1.033
69	2	21	2	1	2	NT	B	L	1	7.807	7.7	2.363	0.133	1.025
70	2	22	2	1	2	CT	B	H	1	6.839	6.5	2.232	0.137	0.898
71	2	23	3	1	3	NT	B	L	1	6.807	6.9	1.799	0.130	0.894
72	2	24	3	1	3	CT	B	H	1	7.014	7.0	2.468	0.132	0.921
73	2	25	1	2	4	CT	B	H	1	8.754	7.4	2.284	0.156	1.149
74	2	26	1	2	4	NT	B	H	1	8.757	7.5	2.206	0.153	1.150
75	2	27	2	2	5	NT	B	H	1	8.589	7.0	2.744	0.162	1.128
76	2	28	2	2	4	CT	B	L	1	9.143	7.2	2.547	0.166	1.200
77	2	29	3	2	6	NT	B	H	1	10.13	7.5	3.532	0.177	1.330
78	2	30	3	2	5	CT	B	L	1	9.288	7.7	2.114	0.158	1.219
79	2	31	1	2	6	CT	B	L	1	7.732	7.0	3.584	0.145	1.015
80	2	32	1	2	4	NT	B	L	1	8.473	7.4	1.930	0.150	1.112
81	2	33	2	2	5	NT	B	L	1	9.269	6.3	2.665	0.192	1.217
82	2	34	2	2	5	CT	B	H	1	8.693	7.9	2.258	0.144	1.141
83	2	35	3	2	6	NT	B	L	1	7.814	8.9	2.219	0.115	1.026
84	2	36	3	2	6	CT	B	H	1	7.065	8.2	2.573	0.114	0.928
85	2	37	1	2	4	CT	NB	H	1	8.654	8.3	2.626	0.136	1.136
86	2	38	1	2	4	NT	NB	L	1	7.928	8.2	2.967	0.126	1.041
87	2	39	2	2	4	NT	NB	H	1	8.673	8.9	3.269	0.128	1.139
88	2	40	2	2	5	CT	NB	H	1	8.216	8.6	2.665	0.125	1.079
89	2	41	3	2	5	NT	NB	L	1	8.679	8.7	2.678	0.132	1.139
90	2	42	3	2	6	CT	NB	H	1	7.864	6.7	2.705	0.155	1.032

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	TotC	C:N	OMc	TNc	TCc
91	2	43	1	2	4	CT	NB	L	I	8.69	8.5	2.862	0.134	1.141
92	2	44	1	2	5	NT	NB	H	I	8.957	8.9	2.928	0.132	1.176
93	2	45	2	2	6	NT	NB	L	I	9.361	9.0	3.164	0.137	1.229
94	2	46	2	2	5	CT	NB	L	I	9.424	8.8	4.595	0.141	1.237
95	2	47	3	2	6	NT	NB	H	I	9.231	8.7	2.705	0.139	1.212
96	2	48	3	2	6	CT	NB	L	I	8.623	8.7	2.639	0.131	1.132
97	3	1	1	1	1	CT	NB	H	I	10.45	8.9	2.806	0.159	1.410
98	3	2	1	1	1	NT	NB	L	I	9.179	8.6	2.617	0.143	1.238
99	3	3	2	1	1	NT	NB	H	I	10.22	8.9	2.847	0.154	1.379
100	3	4	2	1	1	CT	NB	L	I	11.16	9.4	2.968	0.160	1.506
101	3	5	3	1	2	NT	NB	L	I	8.892	8.6	2.860	0.139	1.200
102	3	6	3	1	2	CT	NB	H	I	7.411	7.8	2.590	0.127	1.000
103	3	7	1	1	2	CT	NB	L	I	9.118	8.7	2.752	0.142	1.230
104	3	8	1	1	2	NT	NB	H	I	8.233	8.5	2.402	0.131	1.111
105	3	9	2	1	3	NT	NB	L	I	8.238	8.9	2.118	0.125	1.111
106	3	10	2	1	3	CT	NB	H	I	7.369	7.7	2.240	0.129	0.994
107	3	11	3	1	3	NT	NB	H	I	7.146	8.1	2.361	0.119	0.964
108	3	12	3	1	3	CT	NB	L	I	8.436	7.1	2.725	0.161	1.138
109	3	13	1	1	1	CT	B	L	I	10.06	8.6	2.914	0.158	1.357
110	3	14	1	1	1	NT	B	L	I	9.185	5.1	2.968	0.244	1.239
111	3	15	2	1	1	NT	B	H	I	9.863	4.9	3.049	0.272	1.331
112	3	16	2	1	2	CT	B	L	I	9.151	7.6	2.928	0.162	1.235
113	3	17	3	1	2	NT	B	H	I	8.64	8.2	2.847	0.143	1.166
114	3	18	3	1	3	CT	B	L	I	7.742	7.9	2.456	0.132	1.045
115	3	19	1	1	1	CT	B	H	I	9.174	8.4	2.779	0.148	1.238
116	3	20	1	1	3	NT	B	H	I	9.959	7.9	2.779	0.170	1.344
117	3	21	2	1	2	NT	B	L	I	8.543	8.3	2.860	0.139	1.153
118	3	22	2	1	2	CT	B	H	I	7.097	7.5	2.658	0.127	0.958
119	3	23	3	1	3	NT	B	L	I	8.199	8.3	2.415	0.133	1.106
120	3	24	3	1	3	CT	B	H	I	8.964	8.4	2.982	0.144	1.209
121	3	25	1	2	4	CT	B	H	I	9.708	8.5	3.117	0.154	1.310
122	3	26	1	2	4	NT	B	H	I	11.03	5.5	3.332	0.272	1.488
123	3	27	2	2	5	NT	B	H	I	11.96	8.9	3.211	0.181	1.614
124	3	28	2	2	4	CT	B	L	I	9.233	8.2	3.063	0.152	1.246
125	3	29	3	2	6	NT	B	H	I	9.547	5.6	3.063	0.230	1.288
126	3	30	3	2	5	CT	B	L	I	8.838	8.1	2.914	0.147	1.192
127	3	31	1	2	6	CT	B	L	I	9.978	8.4	3.090	0.161	1.346
128	3	32	1	2	4	NT	B	L	I	8.312	8.2	2.860	0.137	1.121
129	3	33	2	2	5	NT	B	L	I	8.277	5.3	2.833	0.210	1.117
130	3	34	2	2	5	CT	B	H	I	8.376	8.5	2.941	0.133	1.130
131	3	35	3	2	6	NT	B	L	I	8.566	8.6	2.941	0.135	1.156
132	3	36	3	2	6	CT	B	H	I	9.014	9.0	2.847	0.135	1.216

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	TotC	C:N	OMc	TNc	TCc
133	3	37	1	2	4	CT	NB	H	I	9.693	8.8	3.211	0.149	1.308
134	3	38	1	2	4	NT	NB	L	I	9.933	8.9	3.063	0.150	1.340
135	3	39	2	2	4	NT	NB	H	I	9.72	7.1	3.063	0.184	1.311
136	3	40	2	2	5	CT	NB	H	I	9.787	8.8	3.252	0.150	1.320
137	3	41	3	2	5	NT	NB	L	I	9.157	8.1	3.063	0.152	1.235
138	3	42	3	2	6	CT	NB	H	I	11.39	9.3	3.400	0.166	1.537
139	3	43	1	2	4	CT	NB	L	I	9.962	8.9	3.400	0.152	1.344
140	3	44	1	2	5	NT	NB	H	I	11.97	9.4	3.575	0.171	1.615
141	3	45	2	2	6	NT	NB	L	I	11.47	9.3	3.643	0.166	1.548
142	3	46	2	2	5	CT	NB	L	I	8.989	8.8	3.103	0.138	1.213
143	3	47	3	2	6	NT	NB	H	I	11.27	9.2	3.562	0.164	1.521
144	3	48	3	2	6	CT	NB	L	I	10.95	9.1	3.535	0.163	1.477
145	4	1	1	1	1	CT	NB	H	I	9.5	10.5	2.460	0.120	1.210
146	4	2	1	1	1	NT	NB	L	I	8.18	9.7	2.040	0.110	1.040
147	4	3	2	1	1	NT	NB	H	I	8.62	9.1	2.360	0.120	1.080
148	4	4	2	1	1	CT	NB	L	I	8.95	9.4	2.440	0.120	1.130
149	4	5	3	1	2	NT	NB	L	I	8.68	8.8	2.590	0.130	1.190
150	4	6	3	1	2	CT	NB	H	I	9.22	9.2	2.590	0.130	1.170
151	4	7	1	1	2	CT	NB	L	I	9.3	9.3	2.360	0.120	1.160
152	4	8	1	1	2	NT	NB	H	I	7.44	8.5	1.820	0.110	0.900
153	4	9	2	1	3	NT	NB	L	I	7.6	7.5	2.100	0.130	0.970
154	4	10	2	1	3	CT	NB	H	I	8.14	7.4	2.420	0.140	1.080
155	4	11	3	1	3	NT	NB	H	I	7.24	9.7	2.180	0.090	0.920
156	4	12	3	1	3	CT	NB	L	I	8.35	8.9	2.310	0.120	1.090
157	4	13	1	1	1	CT	B	L	I	8.94	9.4	2.440	0.120	1.090
158	4	14	1	1	1	NT	B	L	I	7.55	9.3	2.240	0.100	0.960
159	4	15	2	1	1	NT	B	H	I	9.06	9.2	2.740	0.130	1.220
160	4	16	2	1	2	CT	B	L	I	7.86	8.9	2.330	0.120	1.030
161	4	17	3	1	2	NT	B	H	I	7.34	9.0	2.510	0.110	0.980
162	4	18	3	1	3	CT	B	L	I	7.53	8.9	2.440	0.110	0.990
163	4	19	1	1	1	CT	B	H	I	9.3	9.7	2.590	0.120	1.150
164	4	20	1	1	3	NT	B	H	I	8.67	9.2	2.670	0.130	1.150
165	4	21	2	1	2	NT	B	L	I	8.25	10.6	2.550	0.100	1.060
166	4	22	2	1	2	CT	B	H	I	7.77	9.3	2.490	0.110	1.010
167	4	23	3	1	3	NT	B	L	I	6.58	8.6	2.350	0.100	0.900
168	4	24	3	1	3	CT	B	H	I	7.52	8.9	2.410	0.110	0.970
169	4	25	1	2	1	CT	B	H	NI	9.78	9.8	2.460	0.120	1.200
170	4	26	1	2	1	NT	B	H	NI	9	9.3	2.790	0.130	1.180
171	4	27	2	2	2	NT	B	H	NI	11.79	11.0	2.990	0.140	1.570
172	4	28	2	2	1	CT	B	L	NI	9.22	8.9	2.860	0.140	1.210
173	4	29	3	2	3	NT	B	H	NI	8.38	9.1	2.740	0.120	1.100

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	TotC	C:N	OMc	TNc	TCc
174	4	30	3	2	2	CT	B	L	NI	9.18	9.8	2.960	0.130	1.240
175	4	31	1	2	3	CT	B	L	NI	9.97	10.0	2.350	0.110	1.130
176	4	32	1	2	1	NT	B	L	NI	8.76	9.4	3.080	0.130	1.190
177	4	33	2	2	2	NT	B	L	NI	8.59	9.4	2.300	0.110	1.040
178	4	34	2	2	2	CT	B	H	NI	8.78	9.3	2.470	0.120	1.100
179	4	35	3	2	3	NT	B	L	NI	11.1	12.1	2.500	0.120	1.400
180	4	36	3	2	3	CT	B	H	NI	8.28	8.7	2.570	0.110	1.000
181	4	37	1	2	1	CT	NB	H	NI	10.57	9.7	3.170	0.140	1.380
182	4	38	1	2	1	NT	NB	L	NI	11.2	9.9	3.470	0.160	1.590
183	4	39	2	2	1	NT	NB	H	NI	9.28	9.4	3.050	0.130	1.220
184	4	40	2	2	2	CT	NB	H	NI	10.27	9.3	3.350	0.150	1.380
185	4	41	3	2	2	NT	NB	L	NI	8.68	9.4	2.960	0.130	1.180
186	4	42	3	2	3	CT	NB	H	NI	9.16	9.2	2.890	0.130	1.210
187	4	43	1	2	1	CT	NB	L	NI	11.24	9.8	3.210	0.150	1.450
188	4	44	1	2	2	NT	NB	H	NI	11.37	9.8	3.230	0.160	1.560
189	4	45	2	2	3	NT	NB	L	NI	8.83	9.0	2.690	0.130	1.160
190	4	46	2	2	2	CT	NB	L	NI	10.77	9.7	2.990	0.140	1.350
191	4	47	3	2	3	NT	NB	H	NI	8.39	9.4	2.580	0.120	1.090
192	4	48	3	2	3	CT	NB	L	NI	10.14	9.2	2.970	0.140	1.320
193	5	1	1	1	1	CT	NB	H	I	11.2	10.5	2.770	0.130	1.400
194	5	2	1	1	1	NT	NB	L	I	9.43	9.5	2.400	0.130	1.200
195	5	3	2	1	1	NT	NB	H	I	10.45	9.4	2.390	0.130	1.190
196	5	4	2	1	1	CT	NB	L	I	9.54	9.4	2.200	0.120	1.150
197	5	5	3	1	2	NT	NB	L	I	10.12	9.1	2.470	0.140	1.300
198	5	6	3	1	2	CT	NB	H	I	10.49	9.4	2.890	0.140	1.360
199	5	7	1	1	2	CT	NB	L	I	9.64	9.0	2.430	0.130	1.210
200	5	8	1	1	2	NT	NB	H	I	9.2	10.7	2.570	0.110	1.150
201	5	9	2	1	3	NT	NB	L	I	10.8	9.2	2.870	0.150	1.390
202	5	10	2	1	3	CT	NB	H	I	9.3	9.2	2.370	0.120	1.140
203	5	11	3	1	3	NT	NB	H	I	10.95	9.5	3.050	0.150	1.430
204	5	12	3	1	3	CT	NB	L	I	8.8	8.5	2.580	0.130	1.070
205	5	13	1	1	1	CT	B	L	I	10.83	10.4	2.590	0.130	1.320
206	5	14	1	1	1	NT	B	L	I	9.63	8.9	2.330	0.140	1.240
207	5	15	2	1	1	NT	B	H	I	10.43	9.5	2.680	0.140	1.310
208	5	16	2	1	2	CT	B	L	I	10.04	8.9	2.310	0.130	1.170
209	5	17	3	1	2	NT	B	H	I	9.84	8.5	2.440	0.150	1.260
210	5	18	3	1	3	CT	B	L	I	10.27	8.8	2.560	0.150	1.310
211	5	19	1	1	1	CT	B	H	I	9.76	9.1	3.430	0.130	1.200
212	5	20	1	1	3	NT	B	H	I	10.44	9.5	2.670	0.140	1.300
213	5	21	2	1	2	NT	B	L	I	10.03	8.7	2.440	0.150	1.270
214	5	22	2	1	2	CT	B	H	I	9.98	9.0	2.680	0.140	1.260

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	TotC	C:N	OMc	TNc	TCc
215	5	23	3	1	3	NT	B	L	I	9.28	8.9	2.400	0.130	1.150
216	5	24	3	1	3	CT	B	H	I	9.6	8.5	2.580	0.140	1.200
217	5	25	1	2	1	CT	B	H	NI	11.6	8.9	3.030	0.160	1.420
218	5	26	1	2	1	NT	B	H	NI	10.74	7.6	2.770	0.170	1.290
219	5	27	2	2	2	NT	B	H	NI	10.86	10.0	3.210	0.140	1.370
220	5	28	2	2	1	CT	B	L	NI	11.34	9.8	3.010	0.140	1.370
221	5	29	3	2	3	NT	B	H	NI	11.75	10.4	2.870	0.140	1.460
222	5	30	3	2	2	CT	B	L	NI	11.01	9.8	2.850	0.130	1.280
223	5	31	1	2	3	CT	B	L	NI	10.24	9.9	2.640	0.120	1.180
224	5	32	1	2	1	NT	B	L	NI	10.1	9.1	2.980	0.140	1.230
225	5	33	2	2	2	NT	B	L	NI	10.92	9.7	3.000	0.140	1.350
226	5	34	2	2	2	CT	B	H	NI	9.36	10.4	2.910	0.110	1.140
227	5	35	3	2	3	NT	B	L	NI	9.82	9.3	2.730	0.120	1.140
228	5	36	3	2	3	CT	B	H	NI	11.18	9.0	2.860	0.150	1.390
229	5	37	1	2	1	CT	NB	H	NI	11.66	9.1	3.210	0.160	1.470
230	5	38	1	2	1	NT	NB	L	NI	11.39	9.6	2.180	0.140	1.300
231	5	39	2	2	1	NT	NB	H	NI	12.03	9.1	3.030	0.170	1.520
232	5	40	2	2	2	CT	NB	H	NI	11.24	11.2	3.030	0.120	1.370
233	5	41	3	2	2	NT	NB	L	NI	11.99	10.0	3.360	0.150	1.540
234	5	42	3	2	3	CT	NB	H	NI	10.99	9.4	3.310	0.150	1.370
235	5	43	1	2	1	CT	NB	L	NI	11.5	9.3	3.640	0.160	1.450
236	5	44	1	2	2	NT	NB	H	NI	12.36	9.2	3.570	0.160	1.510
237	5	45	2	2	3	NT	NB	L	NI	13.81	9.6	3.550	0.170	1.620
238	5	46	2	2	2	CT	NB	L	NI	10.79	9.6	3.120	0.130	1.260
239	5	47	3	2	3	NT	NB	H	NI	11.98	9.4	3.450	0.150	1.450
240	5	48	3	2	3	CT	NB	L	NI	10.25	9.4	3.020	0.130	1.210
241	6	1	1	1	1	CT	NB	H	I	11.57	10.1	3.090	0.140	1.390
242	6	2	1	1	1	NT	NB	L	I	9.251	8.3	2.620	0.140	1.150
243	6	3	2	1	1	NT	NB	H	I	11.47	8.8	2.740	0.150	1.340
244	6	4	2	1	1	CT	NB	L	I	9.653	8.5	2.670	0.140	1.210
245	6	5	3	1	2	NT	NB	L	I	10.37	9.0	2.640	0.130	1.140
246	6	6	3	1	2	CT	NB	H	I	10.84	8.5	2.900	0.160	1.340
247	6	7	1	1	2	CT	NB	L	I	9.009	8.5	2.230	0.130	1.110
248	6	8	1	1	2	NT	NB	H	I	9.118	8.6	2.390	0.130	1.110
249	6	9	2	1	3	NT	NB	L	I	7.745	8.7	2.100	0.100	0.910
250	6	10	2	1	3	CT	NB	H	I	8.597	8.1	2.350	0.130	1.040
251	6	11	3	1	3	NT	NB	H	I	7.702	8.3	2.210	0.110	0.910
252	6	12	3	1	3	CT	NB	L	I	9.277	8.2	3.010	0.140	1.190
253	6	13	1	1	1	CT	B	L	I	9.797	8.9	2.690	0.140	1.210
254	6	14	1	1	1	NT	B	L	I	8.929	8.6	2.310	0.130	1.150
255	6	15	2	1	1	NT	B	H	I	10.11	9.0	3.040	0.140	1.280

obsv#	year	Plot#	tblock	bblock	rep	Till	Burn	NRate	IR	TotC	C:N	OMc	TNc	TCc
256	6	16	2	1	2	CT	B	L	I	8.979	9.0	2.690	0.120	1.090
257	6	17	3	1	2	NT	B	H	I	9.629	9.2	3.110	0.140	1.250
258	6	18	3	1	3	CT	B	L	I	8.798	8.8	2.340	0.120	1.080
259	6	19	1	1	1	CT	B	H	I	9.697	9.8	2.390	0.120	1.190
260	6	20	1	1	3	NT	B	H	I	8.598	9.6	2.490	0.110	1.100
261	6	21	2	1	2	NT	B	L	I	9.554	9.7	2.720	0.130	1.220
262	6	22	2	1	2	CT	B	H	I	9.88	9.4	2.920	0.140	1.300
263	6	23	3	1	3	NT	B	L	I	8.403	9.8	2.560	0.110	1.060
264	6	24	3	1	3	CT	B	H	I	9.323	9.7	2.800	0.110	1.110
265	6	25	1	2	1	CT	B	H	NI	11.29	9.2	3.000	0.150	1.350
266	6	26	1	2	1	NT	B	H	NI	11.12	10.2	3.250	0.140	1.390
267	6	27	2	2	2	NT	B	H	NI	11	9.7	2.790	0.140	1.340
268	6	28	2	2	1	CT	B	L	NI	10.22	9.4	2.900	0.130	1.240
269	6	29	3	2	3	NT	B	H	NI	9.765	9.6	2.850	0.130	1.210
270	6	30	3	2	2	CT	B	L	NI	9.635	9.2	2.800	0.120	1.150
271	6	31	1	2	3	CT	B	L	NI	9.997	9.9	3.020	0.120	1.180
272	6	32	1	2	1	NT	B	L	NI	9.345	9.2	3.180	0.130	1.180
273	6	33	2	2	2	NT	B	L	NI	10.26	9.6	3.170	0.130	1.260
274	6	34	2	2	2	CT	B	H	NI	10.16	10.0	2.840	0.120	1.210
275	6	35	3	2	3	NT	B	L	NI	8.736	9.6	2.500	0.110	1.080
276	6	36	3	2	3	CT	B	H	NI	10.47	9.5	2.580	0.130	1.220
277	6	37	1	2	1	CT	NB	H	NI	12.13	9.9	3.810	0.160	1.630
278	6	38	1	2	1	NT	NB	L	NI	11.62	9.8	3.610	0.150	1.510
279	6	39	2	2	1	NT	NB	H	NI	12.22	10.0	3.970	0.160	1.610
280	6	40	2	2	2	CT	NB	H	NI	13.72	10.3	3.720	0.170	1.770
281	6	41	3	2	2	NT	NB	L	NI	10.24	10.2	2.780	0.120	1.250
282	6	42	3	2	3	CT	NB	H	NI	12.14	10.2	3.500	0.160	1.590
283	6	43	1	2	1	CT	NB	L	NI	11.55	9.7	2.960	0.160	1.520
284	6	44	1	2	2	NT	NB	H	NI	10.93	10.0	3.090	0.140	1.410
285	6	45	2	2	3	NT	NB	L	NI	11.32	10.2	2.860	0.130	1.380
286	6	46	2	2	2	CT	NB	L	NI	10.9	9.7	2.740	0.130	1.310
287	6	47	3	2	3	NT	NB	H	NI	11.04	9.1	3.070	0.140	1.310
288	6	48	3	2	3	CT	NB	L	NI	10.28	9.4	2.970	0.130	1.250

obsv# = observation number Plot# = plot number
year = time of consistent residue management in years (year 1 = 2002: year 2 = 2003; year 3 = 2004. year 4 = 2005, year 5 = 2006, year 6 = 2007)
tbblock = tillage block bblock = burn block
rep = replications
till = tillage [conventional tillage (CT) and no-tillage (NT)]
burn = burning [burn (B) and no burn (NB)]
NRate = nitrogen rate/residue level [high (H) and low (L)]
IR = irrigation [irrigated (I) and dry-land/non irrigated (NI)

APPENDIX 4: Raw data used in greenhouse experiment

Soil microbial biomass C (SMB C) (mg kg^{-1}), moisture content (MC) (%), soil organic matter (SOM), total C (TN), total C (TC) contents (kg m^{-2}), and C:N ratio.

obs#	sampleID	till	residue	Time	SMB C	MC	SOM	TN	TC	C:N
1	1	NT	no	2 wks	180.16	17.70	1.20	0.054	0.528	9.9
2	2	NT	L	2 wks	197.27	17.64	1.28	0.053	0.501	9.5
3	3	CT	H	2 wks	449.01	15.90	1.31	0.053	0.542	10.3
4	4	CT	no	2 wks	297.30	24.72	1.21	0.053	0.521	9.9
5	5	NT	no	2 wks	201.92	20.21	1.25	0.050	0.489	9.7
6	6	CT	no	2 wks	174.05	9.96	1.08	0.051	0.471	9.3
7	7	CT	no	2 wks	186.94	18.06	1.09	0.051	0.473	9.3
8	8	NT	no	2 wks	187.46	18.99	1.33	0.052	0.503	9.8
9	9	CT	L	2 wks	320.35	18.21	1.33	0.053	0.524	9.9
10	10	CT	L	2 wks	325.53	17.99	1.30	0.053	0.519	9.8
11	11	NT	L	2 wks	170.67	18.99	1.11	0.054	0.504	9.3
12	12	NT	H	2 wks	157.63	19.33	1.24	0.053	0.485	9.2
13	13	CT	H	2 wks	581.89	13.66	1.29	0.054	0.506	9.4
14	14	NT	H	2 wks	273.55	18.84	1.28	0.053	0.514	9.7
15	15	CT	L	2 wks	439.21	15.36	1.24	0.052	0.472	9.0
16	16	NT	H	2 wks	258.45	21.03	1.09	0.054	0.503	9.4
17	17	CT	H	2 wks	577.52	18.26	1.21	0.059	0.546	9.3
18	18	NT	L	2 wks	251.66	20.39	1.18	0.055	0.508	9.3
19	30	NT	H	4 wks	270.69	10.32	1.17	0.060	0.475	8.0
20	31	NT	L	4 wks	289.08	11.77	1.13	0.061	0.464	7.6
21	32	NT	no	4 wks	313.32	12.59	1.17	0.062	0.458	7.3
22	33	CT	no	4 wks	283.21	5.69	1.15	0.062	0.462	7.5
23	34	CT	L	4 wks	355.86	4.65	1.19	0.057	0.527	9.3
24	35	CT	H	4 wks	594.69	14.03	1.22	0.056	0.513	9.1
25	36	CT	H	4 wks	596.33	21.92	1.30	0.060	0.554	9.3
26	37	CT	no	4 wks	274.08	11.60	0.99	0.055	0.468	8.5
27	38	CT	L	4 wks	584.49	10.09	1.07	0.057	0.464	8.2
28	39	NT	no	4 wks	347.83	9.90	1.11	0.057	0.475	8.4
29	40	NT	L	4 wks	302.74	6.96	1.18	0.059	0.481	8.1
30	41	NT	H	4 wks	338.37	12.57	1.26	0.063	0.512	8.1
31	42	NT	H	4 wks	296.04	8.57	1.25	0.066	0.497	7.5
32	43	NT	no	4 wks	262.58	16.26	1.08	0.048	0.490	10.3
33	44	NT	L	4 wks	299.08	16.78	1.15	0.054	0.516	9.6
34	45	CT	L	4 wks	505.78	18.06	1.25	0.055	0.513	9.3
35	46	CT	no	4 wks	381.51	15.87	1.24	0.054	0.505	9.4
36	47	CT	H	4 wks	690.37	15.85	1.24	0.056	0.541	9.7

obs#	sampleID	till	residue	Time	SMB C	MC	SOM	TN	TC	C:N
37	48	NT	H	8 wks	425.93	10.54	1.36	0.060	0.529	8.9
38	49	NT	L	8 wks	640.59	14.62	1.16	0.054	0.517	9.6
39	50	NT	no	8 wks	389.49	10.43	1.24	0.054	0.478	8.9
40	51	CT	no	8 wks	346.23	11.73	1.38	0.058	0.565	9.8
41	52	CT	L	8 wks	282.81	6.32	1.21	0.053	0.490	9.3
42	53	CT	H	8 wks	301.25	10.75	1.19	0.054	0.472	8.7
43	54	CT	H	8 wks	394.33	13.74	1.30	0.055	0.498	9.1
44	55	CT	no	8 wks	521.95	10.59	1.17	0.054	0.510	9.5
45	56	CT	L	8 wks	334.80	10.49	1.08	0.053	0.456	8.7
46	57	NT	no	8 wks	308.69	11.12	1.18	0.054	0.485	9.0
47	58	NT	L	8 wks	256.64	11.25	1.16	0.054	0.484	8.9
48	59	NT	H	8 wks	355.91	11.59	1.18	0.050	0.465	9.3
49	60	NT	H	8 wks	328.78	11.97	1.14	0.051	0.475	9.3
50	61	NT	no	8 wks	239.45	7.78	1.03	0.051	0.458	9.0
51	62	NT	L	8 wks	379.76	10.43	1.16	0.054	0.473	8.7
52	63	CT	L	8 wks	568.87	13.50	1.18	0.057	0.524	9.2
53	64	CT	no	8 wks	385.12	11.13	1.11	0.050	0.471	9.4
54	65	CT	H	8 wks	346.23	3.40	1.24	0.052	0.503	9.6
55	66	CT	H	17 wks	29.14	14.25	1.16	0.048	0.490	10.1
56	67	CT	no	17 wks	61.76	1.56	1.20	0.049	0.453	9.2
57	68	CT	L	17 wks	66.57	20.77	1.23	0.056	0.491	8.8
58	69	NT	H	17 wks	137.27	10.49	1.28	0.050	0.473	9.4
59	70	NT	L	17 wks	31.46	8.42	1.34	0.047	0.436	9.2
60	71	NT	no	17 wks	238.05	15.55	1.32	0.050	0.464	9.3
61	72	CT	H	17 wks	449.15	13.99	1.40	0.055	0.499	9.0
62	73	NT	L	17 wks	0.00	14.07	1.27	0.053	0.489	9.2
63	74	NT	no	17 wks	123.16	13.42	1.30	0.049	0.449	9.2
64	75	NT	H	17 wks	161.01	14.06	1.14	0.050	0.448	8.9
65	76	CT	no	17 wks	90.65	14.23	1.14	0.048	0.451	9.4
66	77	CT	L	17 wks	419.34	14.46	1.23	0.054	0.484	9.0
67	78	CT	no	17 wks	445.57	1.68	1.34	0.053	0.480	9.0
68	79	CT	H	17 wks	649.82	5.08	1.37	0.060	0.539	8.9
69	80	CT	L	17 wks	0.00	3.55	1.37	0.054	0.470	8.7
70	81	NT	no	17 wks	0.00	13.35	1.26	0.053	0.446	8.5
71	82	NT	L	17 wks	181.77	1.89	1.28	0.051	0.481	9.4
72	83	NT	H	17 wks	236.76	6.67	1.29	0.047	0.459	9.8
73	84	NT	L	34 wks	187.23	14.44	1.15	0.058	0.481	8.3
74	85	NT	H	34 wks	178.68	18.61	1.15	0.065	0.496	7.6
75	86	NT	no	34 wks	142.00	18.08	1.16	0.064	0.487	7.6
76	87	CT	no	34 wks	237.30	17.62	0.96	0.062	0.477	7.7

obs#	sampleID	till	residue	Time	MB_C	MC	SOM	TN	TC	C:N
77	88	CT	L	34 wks	222.31	17.28	1.10	0.062	0.511	8.2
78	89	CT	H	34 wks	70.89	20.40	1.23	0.065	0.573	8.8
79	90	NT	no	34 wks	119.65	7.32	0.94	0.060	0.447	7.5
80	91	NT	H	34 wks	-11.30	12.66	1.04	0.063	0.499	7.9
81	92	NT	L	34 wks	37.73	13.38	1.10	0.057	0.484	8.5
82	93	CT	no	34 wks	125.64	17.53	1.03	0.061	0.490	8.0
83	94	CT	H	34 wks	192.45	17.95	1.34	0.067	0.586	8.7
84	95	CT	L	34 wks	225.50	13.65	1.19	0.064	0.529	8.3
85	96	CT	no	34 wks	187.66	4.97	1.09	0.058	0.442	7.6
86	97	CT	H	34 wks	195.61	4.83	1.27	0.074	0.623	8.4
87	98	NT	no	34 wks	204.42	17.27	1.12	0.059	0.509	8.6
88	99	CT	L	34 wks	345.27	9.53	1.24	0.060	0.491	8.1
89	100	NT	H	34 wks	204.49	18.76	1.21	0.059	0.484	8.1
90	101	NT	L	34 wks	224.63	13.84	1.13	0.059	0.466	7.9
91	102	NT	H	56 wks	137.95	19.52	1.21	0.046	0.463	10.0
92	103	NT	no	56 wks	189.88	14.79	1.23	0.046	0.468	10.3
93	104	CT	L	56 wks	282.39	11.22	1.13	0.050	0.507	10.1
94	105	NT	H	56 wks	169.52	21.65	1.10	0.049	0.494	10.1
95	106	NT	no	56 wks	237.14	14.72	1.02	0.045	0.442	9.8
96	107	NT	no	56 wks	171.42	19.50	1.05	0.047	0.441	9.3
97	108	CT	H	56 wks	291.43	26.17	1.37	0.052	0.557	10.7
98	109	CT	no	56 wks	447.17	14.38	1.12	0.045	0.418	9.3
99	110	CT	H	56 wks	303.44	15.09	1.59	0.055	0.625	11.4
100	111	CT	H	56 wks	323.97	8.27	1.25	0.055	0.659	12.0
101	112	NT	L	56 wks	199.22	15.53	1.11	0.042	0.441	10.5
102	113	CT	L	56 wks	355.16	13.63	1.25	0.051	0.535	10.5
103	114	NT	L	56 wks	183.02	21.34	1.08	0.046	0.447	9.8
104	115	NT	L	56 wks	190.81	17.21	1.25	0.044	0.489	11.1
105	116	CT	L	56 wks	281.13	18.96	1.34	0.048	0.527	10.9
106	117	NT	H	56 wks	175.54	18.19	1.20	0.042	0.486	11.6
107	118	CT	no	56 wks	133.62	24.33	1.11	0.040	0.446	11.1
108	119	CT	no	56 wks	301.64	18.63	1.07	0.043	0.442	10.3

obs# - observartion number
sampleID = sample identification number
till = simulated tillage [conventional tillage (CT) and no-tillage (NT)]
residue = residue level [high (H), low (L), and no residue (no)]
time = time of incubation (wk)

APPENDIX 5: Chapter 3 raw data for weed population densities (plants m^{-2}) Soybean yield (Mg ha^{-1}), barnyardgrass (BYG), bermudargrass (bermuda), carpetweed (carpet), and cheat.

obs#	plot	tblock	till	bblock	burn	Res	IR	year	Season	soybean	BYG	bermuda	carpet
1	1	1	CT	1	NB	H	I	2006	early	3.12	0	0	174
2	2	1	NT	1	NB	L	I	2006	early	2.68	8	0	52
3	3	2	NT	1	NB	H	I	2006	early	2.79	0	0	104
4	4	2	CT	1	NB	L	I	2006	early	3.24	0	0	108
5	5	3	NT	1	NB	L	I	2006	early	2.65	0	0	28
6	6	3	CT	1	NB	H	I	2006	early	3.24	0	0	168
7	7	1	CT	1	NB	L	I	2006	early	2.85	0	0	148
8	8	1	NT	1	NB	H	I	2006	early	2.83	0	0	0
9	9	2	NT	1	NB	L	I	2006	early	2.79	0	0	0
10	10	2	CT	1	NB	H	I	2006	early	3.21	0	0	180
11	11	3	NT	1	NB	H	I	2006	early	2.87	0	0	8
12	12	3	CT	1	NB	L	I	2006	early	3.5	0	0	168
13	13	1	CT	1	B	L	I	2006	early	3.75	0	0	100
14	14	1	NT	1	B	L	I	2006	early	3.96	0	0	8
15	15	2	NT	1	B	H	I	2006	early	4.02	0	0	0
16	16	2	CT	1	B	L	I	2006	early	4.38	0	0	76
17	17	3	NT	1	B	H	I	2006	early	3.98	0	0	20
18	18	3	CT	1	B	L	I	2006	early	3.63	0	0	228
19	19	1	CT	1	B	H	I	2006	early	3.31	0	0	44
20	20	1	NT	1	B	H	I	2006	early	3.52	0	0	76
21	21	2	NT	1	B	L	I	2006	early	3.14	0	0	0
22	22	2	CT	1	B	H	I	2006	early	3.93	0	0	76
23	23	3	NT	1	B	L	I	2006	early	3.59	0	0	0
24	24	3	CT	1	B	H	I	2006	early	3.83	0	0	60
25	25	1	CT	2	B	H	NI	2006	early	2	0	0	368
26	26	1	NT	2	B	H	NI	2006	early	0.97	0	0	28
27	27	2	NT	2	B	H	NI	2006	early	0.78	0	0	16
28	28	2	CT	2	B	L	NI	2006	early	0.89	0	0	112
29	29	3	NT	2	B	H	NI	2006	early	1.09	0	0	0
30	30	3	CT	2	B	L	NI	2006	early	1.08	0	0	300
31	31	1	CT	2	B	L	NI	2006	early	1.68	0	0	116
32	32	1	NT	2	B	L	NI	2006	early	0.97	0	0	144
33	33	2	NT	2	B	L	NI	2006	early	1.12	0	0	60
34	34	2	CT	2	B	H	NI	2006	early	1.04	0	0	164
35	35	3	NT	2	B	L	NI	2006	early	0.94	0	0	72

obs#	plot	tblock	till	bblock	burn	res	Irrig	year	Season	soybean	BYG	bermuda	carpet
36	36	3	CT	2	B	H	NI	2006	early	1.31	0	0	316
37	37	1	CT	2	NB	H	NI	2006	early	2.03	0	0	172
38	38	1	NT	2	NB	L	NI	2006	early	0.89	0	0	92
39	39	2	NT	2	NB	H	NI	2006	early	1.25	0	0	64
40	40	2	CT	2	NB	H	NI	2006	early	0.43	0	0	104
41	41	3	NT	2	NB	L	NI	2006	early	0.64	0	0	12
42	42	3	CT	2	NB	H	NI	2006	early	0.88	0	0	124
43	43	1	CT	2	NB	L	NI	2006	early	1.87	0	0	140
44	44	1	NT	2	NB	H	NI	2006	early	1.57	0	0	32
45	45	2	NT	2	NB	L	NI	2006	early	1.1	0	0	16
46	46	2	CT	2	NB	L	NI	2006	early	0.47	0	0	108
47	47	3	NT	2	NB	H	NI	2006	early	1.24	0	0	12
48	48	3	CT	2	NB	L	NI	2006	early	1.45	0	0	108
49	1	1	CT	1	NB	H	I	2006	late	0	0	0	0
50	2	1	NT	1	NB	L	I	2006	late	0	0	0	0
51	3	2	NT	1	NB	H	I	2006	late	0	0	0	0
52	4	2	CT	1	NB	L	I	2006	late	0	0	0	0
53	5	3	NT	1	NB	L	I	2006	late	0	0	0	0
54	6	3	CT	1	NB	H	I	2006	late	0	0	0	0
55	7	1	CT	1	NB	L	I	2006	late	0	0	0	0
56	8	1	NT	1	NB	H	I	2006	late	0	0	0	0
57	9	2	NT	1	NB	L	I	2006	late	0	0	0	0
58	10	2	CT	1	NB	H	I	2006	late	0	0	0	0
59	11	3	NT	1	NB	H	I	2006	late	0	0	0	0
60	12	3	CT	1	NB	L	I	2006	late	0	0	0	0
61	13	1	CT	1	B	L	I	2006	late	0	0	0	0
62	14	1	NT	1	B	L	I	2006	late	0	0	0	0
63	15	2	NT	1	B	H	I	2006	late	0	0	0	0
64	16	2	CT	1	B	L	I	2006	late	0	0	0	0
65	17	3	NT	1	B	H	I	2006	late	0	0	0	0
66	18	3	CT	1	B	L	I	2006	late	0	0	0	0
67	19	1	CT	1	B	H	I	2006	late	0	0	0	0
68	20	1	NT	1	B	H	I	2006	late	0	0	0	0
69	21	2	NT	1	B	L	I	2006	late	0	0	0	0
70	22	2	CT	1	B	H	I	2006	late	0	0	0	0
71	23	3	NT	1	B	L	I	2006	late	0	0	0	0
72	24	3	CT	1	B	H	I	2006	late	0	0	0	0
73	25	1	CT	2	B	H	NI	2006	late	0	0	0	0
74	26	1	NT	2	B	H	NI	2006	late	0	0	0	0

obs#	plot	tblock	till	bblock	burn	res	Irrig	year	Season	soybean	BYG	bermuda	carpet
75	27	2	NT	2	B	H	NI	2006	late	0	0	0	0
76	28	2	CT	2	B	L	NI	2006	late	0	0	0	4
77	29	3	NT	2	B	H	NI	2006	late	0	0	0	0
78	30	3	CT	2	B	L	NI	2006	late	0	0	0	6
79	31	1	CT	2	B	L	NI	2006	late	0	0	0	0
80	32	1	NT	2	B	L	NI	2006	late	0	0	0	10
81	33	2	NT	2	B	L	NI	2006	late	0	0	0	0
82	34	2	CT	2	B	H	NI	2006	late	0	0	0	0
83	35	3	NT	2	B	L	NI	2006	late	0	0	0	0
84	36	3	CT	2	B	H	NI	2006	late	0	0	0	0
85	37	1	CT	2	NB	H	NI	2006	late	0	0	0	0
86	38	1	NT	2	NB	L	NI	2006	late	0	0	0	0
87	39	2	NT	2	NB	H	NI	2006	late	0	0	2	2
88	40	2	CT	2	NB	H	NI	2006	late	0	0	0	0
89	41	3	NT	2	NB	L	NI	2006	late	0	0	0	0
90	42	3	CT	2	NB	H	NI	2006	late	0	0	0	6
91	43	1	CT	2	NB	L	NI	2006	late	0	0	0	0
92	44	1	NT	2	NB	H	NI	2006	late	0	0	0	0
93	45	2	NT	2	NB	L	NI	2006	late	0	0	0	0
94	46	2	CT	2	NB	L	NI	2006	late	0	0	0	0
95	47	3	NT	2	NB	H	NI	2006	late	0	0	0	0
96	48	3	CT	2	NB	L	NI	2006	late	0	0	0	0
97	1	1	CT	1	NB	H	I	2007	early	2.78	0	0	18
98	2	1	NT	1	NB	L	I	2007	early	2.77	0	0	0
99	3	2	NT	1	NB	H	I	2007	early	2.68	0	0	8
100	4	2	CT	1	NB	L	I	2007	early	2.16	0	0	12
101	5	3	NT	1	NB	L	I	2007	early	2.29	0	0	0
102	6	3	CT	1	NB	H	I	2007	early	1.82	0	0	0
103	7	1	CT	1	NB	L	I	2007	early	2.12	0	0	0
104	8	1	NT	1	NB	H	I	2007	early	2.72	0	0	0
105	9	2	NT	1	NB	L	I	2007	early	2.72	0	0	6
106	10	2	CT	1	NB	H	I	2007	early	2.17	0	0	28
107	11	3	NT	1	NB	H	I	2007	early	2.04	0	0	0
108	12	3	CT	1	NB	L	I	2007	early	2.18	0	0	24
109	13	1	CT	1	B	L	I	2007	early	2.34	0	0	16
110	14	1	NT	1	B	L	I	2007	early	2.61	0	0	0
111	15	2	NT	1	B	H	I	2007	early	2.46	0	0	0
112	16	2	CT	1	B	L	I	2007	early	2.55	0	0	2
113	17	3	NT	1	B	H	I	2007	early	2.44	0	0	0
114	18	3	CT	1	B	L	I	2007	early	2.58	0	0	4

obs#	plot	tblock	till	bblock	burn	res	Irrig	year	Season	soybean	BYG	bermuda	carpet
115	19	1	CT	1	B	H	I	2007	early	2.3	0	0	18
116	20	1	NT	1	B	H	I	2007	early	2.32	0	0	0
117	21	2	NT	1	B	L	I	2007	early	2.68	0	0	0
118	22	2	CT	1	B	H	I	2007	early	2.89	0	0	0
119	23	3	NT	1	B	L	I	2007	early	2.68	0	0	2
120	24	3	CT	1	B	H	I	2007	early	3.22	0	0	0
121	25	1	CT	2	B	H	NI	2007	early	1.55	0	0	16
122	26	1	NT	2	B	H	NI	2007	early	1.38	0	0	8
123	27	2	NT	2	B	H	NI	2007	early	1.23	0	0	14
124	28	2	CT	2	B	L	NI	2007	early	1.35	0	0	16
125	29	3	NT	2	B	H	NI	2007	early	1.31	0	0	0
126	30	3	CT	2	B	L	NI	2007	early	1.28	0	0	18
127	31	1	CT	2	B	L	NI	2007	early	1.68	0	0	4
128	32	1	NT	2	B	L	NI	2007	early	1.45	0	0	2
129	33	2	NT	2	B	L	NI	2007	early	1.22	0	0	4
130	34	2	CT	2	B	H	NI	2007	early	1.23	0	0	2
131	35	3	NT	2	B	L	NI	2007	early	1.2	0	0	0
132	36	3	CT	2	B	H	NI	2007	early	1.59	0	0	4
133	37	1	CT	2	NB	H	NI	2007	early	2.38	0	0	4
134	38	1	NT	2	NB	L	NI	2007	early	1.24	0	0	0
135	39	2	NT	2	NB	H	NI	2007	early	1.66	0	0	4
136	40	2	CT	2	NB	H	NI	2007	early	1.45	0	0	0
137	41	3	NT	2	NB	L	NI	2007	early	1.23	0	0	0
138	42	3	CT	2	NB	H	NI	2007	early	1.49	0	0	2
139	43	1	CT	2	NB	L	NI	2007	early	0.67	0	0	36
140	44	1	NT	2	NB	H	NI	2007	early	2.06	0	0	0
141	45	2	NT	2	NB	L	NI	2007	early	1.61	0	0	0
142	46	2	CT	2	NB	L	NI	2007	early	1.45	0	0	8
143	47	3	NT	2	NB	H	NI	2007	early	1.24	0	0	0
144	48	3	CT	2	NB	L	NI	2007	early	1.71	0	0	10
145	1	1	CT	1	NB	H	I	2007	late	0	0	0	0
146	2	1	NT	1	NB	L	I	2007	late	0	0	0	0
147	3	2	NT	1	NB	H	I	2007	late	0	0	0	0
148	4	2	CT	1	NB	L	I	2007	late	0	0	0	0
149	5	3	NT	1	NB	L	I	2007	late	0	0	0	0
150	6	3	CT	1	NB	H	I	2007	late	0	0	0	0
151	7	1	CT	1	NB	L	I	2007	late	0	0	0	0
152	8	1	NT	1	NB	H	I	2007	late	0	0	0	0
153	9	2	NT	1	NB	L	I	2007	late	0	0	0	0
154	10	2	CT	1	NB	H	I	2007	late	0	0	0	0
155	11	3	NT	1	NB	H	I	2007	late	0	0	0	0

obs#	plot	tblock	till	bblock	burn	res	IR	year	Season	soybean	BYG	bermuda	carpet
156	12	3	CT	1	NB	L	I	2007	late	0	0	0	0
157	13	1	CT	1	B	L	I	2007	late	0	0	0	0
158	14	1	NT	1	B	L	I	2007	late	0	0	0	0
159	15	2	NT	1	B	H	I	2007	late	0	0	0	0
160	16	2	CT	1	B	L	I	2007	late	0	0	0	0
161	17	3	NT	1	B	H	I	2007	late	0	0	0	0
162	18	3	CT	1	B	L	I	2007	late	0	0	0	0
163	19	1	CT	1	B	H	I	2007	late	0	0	0	0
164	20	1	NT	1	B	H	I	2007	late	0	0	0	0
165	21	2	NT	1	B	L	I	2007	late	0	0	0	2
166	22	2	CT	1	B	H	I	2007	late	0	0	0	0
167	23	3	NT	1	B	L	I	2007	late	0	0	0	0
168	24	3	CT	1	B	H	I	2007	late	0	0	0	0
169	25	1	CT	2	B	H	NI	2007	late	0	0	0	0
170	26	1	NT	2	B	H	NI	2007	late	0	0	0	0
171	27	2	NT	2	B	H	NI	2007	late	0	0	0	0
172	28	2	CT	2	B	L	NI	2007	late	0	0	0	0
173	29	3	NT	2	B	H	NI	2007	late	0	0	0	2
174	30	3	CT	2	B	L	NI	2007	late	0	0	0	0
175	31	1	CT	2	B	L	NI	2007	late	0	0	0	0
176	32	1	NT	2	B	L	NI	2007	late	0	0	0	0
177	33	2	NT	2	B	L	NI	2007	late	0	0	0	0
178	34	2	CT	2	B	H	NI	2007	late	0	0	0	0
179	35	3	NT	2	B	L	NI	2007	late	0	0	0	0
180	36	3	CT	2	B	H	NI	2007	late	0	0	0	0
181	37	1	CT	2	NB	H	NI	2007	late	0	0	0	0
182	38	1	NT	2	NB	L	NI	2007	late	0	0	0	0
183	39	2	NT	2	NB	H	NI	2007	late	0	0	0	0
184	40	2	CT	2	NB	H	NI	2007	late	0	0	0	0
185	41	3	NT	2	NB	L	NI	2007	late	0	0	0	0
186	42	3	CT	2	NB	H	NI	2007	late	0	0	0	0
187	43	1	CT	2	NB	L	NI	2007	late	0	0	0	0
188	44	1	NT	2	NB	H	NI	2007	late	0	0	0	0
189	45	2	NT	2	NB	L	NI	2007	late	0	0	0	0
190	46	2	CT	2	NB	L	NI	2007	late	0	0	0	0
191	47	3	NT	2	NB	H	NI	2007	late	0	0	0	0
192	48	3	CT	2	NB	L	NI	2007	late	0	0	0	0

Cheat, common purslane (Cpurslane), cutleaf ground cherry (CLGC), and eclipta

obs#	plot	tblock	till	bblock	burn	res	IR	year	Season	cheat	Cpurslane	CLGC	eclipta
1	1	1	CT	1	NB	H	I	2006	early	0	0	0	0
2	2	1	NT	1	NB	L	I	2006	early	0	0	0	0
3	3	2	NT	1	NB	H	I	2006	early	0	0	0	0
4	4	2	CT	1	NB	L	I	2006	early	0	0	0	0
5	5	3	NT	1	NB	L	I	2006	early	0	0	0	0
6	6	3	CT	1	NB	H	I	2006	early	0	0	0	0
7	7	1	CT	1	NB	L	I	2006	early	0	0	0	0
8	8	1	NT	1	NB	H	I	2006	early	0	0	0	0
9	9	2	NT	1	NB	L	I	2006	early	0	0	0	0
10	10	2	CT	1	NB	H	I	2006	early	0	0	0	0
11	11	3	NT	1	NB	H	I	2006	early	0	0	0	8
12	12	3	CT	1	NB	L	I	2006	early	0	0	0	0
13	13	1	CT	1	B	L	I	2006	early	0	0	0	0
14	14	1	NT	1	B	L	I	2006	early	0	0	0	0
15	15	2	NT	1	B	H	I	2006	early	0	0	0	0
16	16	2	CT	1	B	L	I	2006	early	0	0	0	0
17	17	3	NT	1	B	H	I	2006	early	0	0	4	0
18	18	3	CT	1	B	L	I	2006	early	0	0	0	0
19	19	1	CT	1	B	H	I	2006	early	0	0	0	0
20	20	1	NT	1	B	H	I	2006	early	0	0	0	0
21	21	2	NT	1	B	L	I	2006	early	0	0	20	0
22	22	2	CT	1	B	H	I	2006	early	0	0	8	0
23	23	3	NT	1	B	L	I	2006	early	0	0	0	0
24	24	3	CT	1	B	H	I	2006	early	0	4	0	8
25	25	1	CT	2	B	H	NI	2006	early	0	0	0	0
26	26	1	NT	2	B	H	NI	2006	early	0	0	0	0
27	27	2	NT	2	B	H	NI	2006	early	0	0	0	0
28	28	2	CT	2	B	L	NI	2006	early	0	0	0	4
29	29	3	NT	2	B	H	NI	2006	early	0	28	0	0
30	30	3	CT	2	B	L	NI	2006	early	0	0	0	0
31	31	1	CT	2	B	L	NI	2006	early	0	0	0	16
32	32	1	NT	2	B	L	NI	2006	early	0	0	0	0
33	33	2	NT	2	B	L	NI	2006	early	0	0	0	0
34	34	2	CT	2	B	H	NI	2006	early	0	0	0	0
35	35	3	NT	2	B	L	NI	2006	early	0	0	0	0

obs#	plot	tblock	till	bblock	burn	res	IR	year	Season	cheat	Cpurslane	CLGC	eclipta
36	36	3	CT	2	B	H	NI	2006	early	0	0	8	0
37	37	1	CT	2	NB	H	NI	2006	early	0	0	0	8
38	38	1	NT	2	NB	L	NI	2006	early	0	4	0	0
39	39	2	NT	2	NB	H	NI	2006	early	0	0	0	0
40	40	2	CT	2	NB	H	NI	2006	early	0	0	0	0
41	41	3	NT	2	NB	L	NI	2006	early	0	0	0	0
42	42	3	CT	2	NB	H	NI	2006	early	0	0	0	0
43	43	1	CT	2	NB	L	NI	2006	early	0	0	0	36
44	44	1	NT	2	NB	H	NI	2006	early	0	0	0	0
45	45	2	NT	2	NB	L	NI	2006	early	0	0	0	0
46	46	2	CT	2	NB	L	NI	2006	early	0	0	0	4
47	47	3	NT	2	NB	H	NI	2006	early	0	0	0	0
48	48	3	CT	2	NB	L	NI	2006	early	0	0	0	28
49	1	1	CT	1	NB	H	I	2006	late	0	0	0	0
50	2	1	NT	1	NB	L	I	2006	late	0	0	0	0
51	3	2	NT	1	NB	H	I	2006	late	0	0	0	0
52	4	2	CT	1	NB	L	I	2006	late	0	0	0	0
53	5	3	NT	1	NB	L	I	2006	late	0	0	0	0
54	6	3	CT	1	NB	H	I	2006	late	0	0	0	0
55	7	1	CT	1	NB	L	I	2006	late	0	0	0	0
56	8	1	NT	1	NB	H	I	2006	late	0	0	0	0
57	9	2	NT	1	NB	L	I	2006	late	0	0	0	0
58	10	2	CT	1	NB	H	I	2006	late	0	0	0	0
59	11	3	NT	1	NB	H	I	2006	late	0	0	0	0
60	12	3	CT	1	NB	L	I	2006	late	0	0	0	0
61	13	1	CT	1	B	L	I	2006	late	0	0	0	0
62	14	1	NT	1	B	L	I	2006	late	0	0	0	0
63	15	2	NT	1	B	H	I	2006	late	0	0	0	0
64	16	2	CT	1	B	L	I	2006	late	0	0	0	0
65	17	3	NT	1	B	H	I	2006	late	0	0	0	0
66	18	3	CT	1	B	L	I	2006	late	0	0	0	0
67	19	1	CT	1	B	H	I	2006	late	0	0	0	0
68	20	1	NT	1	B	H	I	2006	late	0	0	0	0
69	21	2	NT	1	B	L	I	2006	late	0	0	0	0
70	22	2	CT	1	B	H	I	2006	late	0	0	0	0
71	23	3	NT	1	B	L	I	2006	late	0	0	0	0
72	24	3	CT	1	B	H	I	2006	late	0	0	0	0
73	25	1	CT	2	B	H	NI	2006	late	0	0	0	0
74	26	1	NT	2	B	H	NI	2006	late	0	0	0	0
75	27	2	NT	2	B	H	NI	2006	late	0	0	0	0
76	28	2	CT	2	B	L	NI	2006	late	0	2	0	0

obs#	plot	tblock	till	bblock	burn	res	IR	year	Season	cheat	Cpurslane	CLGC	eclipta
77	29	3	NT	2	B	H	NI	2006	late	0	0	0	0
78	30	3	CT	2	B	L	NI	2006	late	0	0	0	0
79	31	1	CT	2	B	L	NI	2006	late	0	0	0	0
80	32	1	NT	2	B	L	NI	2006	late	0	0	0	0
81	33	2	NT	2	B	L	NI	2006	late	0	0	0	0
82	34	2	CT	2	B	H	NI	2006	late	0	0	0	0
83	35	3	NT	2	B	L	NI	2006	late	0	0	0	0
84	36	3	CT	2	B	H	NI	2006	late	0	0	0	0
85	37	1	CT	2	NB	H	NI	2006	late	0	0	0	0
86	38	1	NT	2	NB	L	NI	2006	late	0	0	0	0
87	39	2	NT	2	NB	H	NI	2006	late	0	2	0	0
88	40	2	CT	2	NB	H	NI	2006	late	0	0	0	0
89	41	3	NT	2	NB	L	NI	2006	late	0	0	0	0
90	42	3	CT	2	NB	H	NI	2006	late	0	0	0	0
91	43	1	CT	2	NB	L	NI	2006	late	0	0	0	0
92	44	1	NT	2	NB	H	NI	2006	late	0	0	0	0
93	45	2	NT	2	NB	L	NI	2006	late	0	0	0	0
94	46	2	CT	2	NB	L	NI	2006	late	0	0	0	0
95	47	3	NT	2	NB	H	NI	2006	late	0	0	0	0
96	48	3	CT	2	NB	L	NI	2006	late	0	0	0	0
97	1	1	CT	1	NB	H	I	2007	early	0	0	0	0
98	2	1	NT	1	NB	L	I	2007	early	14	0	0	0
99	3	2	NT	1	NB	H	I	2007	early	74	0	0	0
100	4	2	CT	1	NB	L	I	2007	early	94	0	2	0
101	5	3	NT	1	NB	L	I	2007	early	82	0	0	0
102	6	3	CT	1	NB	H	I	2007	early	86	0	0	0
103	7	1	CT	1	NB	L	I	2007	early	30	0	0	0
104	8	1	NT	1	NB	H	I	2007	early	38	0	2	0
105	9	2	NT	1	NB	L	I	2007	early	56	0	0	0
106	10	2	CT	1	NB	H	I	2007	early	148	0	2	2
107	11	3	NT	1	NB	H	I	2007	early	40	0	0	0
108	12	3	CT	1	NB	L	I	2007	early	48	0	2	0
109	13	1	CT	1	B	L	I	2007	early	72	0	6	2
110	14	1	NT	1	B	L	I	2007	early	56	0	0	0
111	15	2	NT	1	B	H	I	2007	early	58	0	0	0
112	16	2	CT	1	B	L	I	2007	early	38	0	0	0
113	17	3	NT	1	B	H	I	2007	early	146	0	0	0
114	18	3	CT	1	B	L	I	2007	early	24	0	0	6
115	19	1	CT	1	B	H	I	2007	early	56	0	4	4
116	20	1	NT	1	B	H	I	2007	early	92	0	10	0
117	21	2	NT	1	B	L	I	2007	early	34	0	6	2

obs#	plot	tblock	till	bblock	burn	res	Irrig	year	Season	Cheat	Cpurslane	CLGC	Eclipta
118	22	2	CT	1	B	H	I	2007	early	32	0	0	2
119	23	3	NT	1	B	L	I	2007	early	40	0	0	0
120	24	3	CT	1	B	H	I	2007	early	62	0	0	6
121	25	1	CT	2	B	H	NI	2007	early	14	0	0	0
122	26	1	NT	2	B	H	NI	2007	early	24	0	0	0
123	27	2	NT	2	B	H	NI	2007	early	186	0	0	0
124	28	2	CT	2	B	L	NI	2007	early	84	0	0	0
125	29	3	NT	2	B	H	NI	2007	early	190	0	0	2
126	30	3	CT	2	B	L	NI	2007	early	72	0	0	4
127	31	1	CT	2	B	L	NI	2007	early	70	0	0	2
128	32	1	NT	2	B	L	NI	2007	early	38	0	0	0
129	33	2	NT	2	B	L	NI	2007	early	16	0	0	0
130	34	2	CT	2	B	H	NI	2007	early	52	0	0	0
131	35	3	NT	2	B	L	NI	2007	early	36	0	0	0
132	36	3	CT	2	B	H	NI	2007	early	188	0	0	2
133	37	1	CT	2	NB	H	NI	2007	early	4	0	0	10
134	38	1	NT	2	NB	L	NI	2007	early	8	0	0	0
135	39	2	NT	2	NB	H	NI	2007	early	44	0	0	0
136	40	2	CT	2	NB	H	NI	2007	early	60	0	0	0
137	41	3	NT	2	NB	L	NI	2007	early	6	0	0	0
138	42	3	CT	2	NB	H	NI	2007	early	86	0	0	0
139	43	1	CT	2	NB	L	NI	2007	early	0	0	0	0
140	44	1	NT	2	NB	H	NI	2007	early	14	0	0	0
141	45	2	NT	2	NB	L	NI	2007	early	16	0	0	0
142	46	2	CT	2	NB	L	NI	2007	early	48	8	0	0
143	47	3	NT	2	NB	H	NI	2007	early	52	0	0	0
144	48	3	CT	2	NB	L	NI	2007	early	196	0	0	4
145	1	1	CT	1	NB	H	I	2007	late	0	0	0	0
146	2	1	NT	1	NB	L	I	2007	late	0	0	0	0
147	3	2	NT	1	NB	H	I	2007	late	0	0	0	0
148	4	2	CT	1	NB	L	I	2007	late	0	0	0	0
149	5	3	NT	1	NB	L	I	2007	late	0	0	0	0
150	6	3	CT	1	NB	H	I	2007	late	0	0	0	0
151	7	1	CT	1	NB	L	I	2007	late	0	0	0	0
152	8	1	NT	1	NB	H	I	2007	late	0	0	0	0
153	9	2	NT	1	NB	L	I	2007	late	0	0	0	0
154	10	2	CT	1	NB	H	I	2007	late	0	0	0	0
155	11	3	NT	1	NB	H	I	2007	late	0	0	0	0
156	12	3	CT	1	NB	L	I	2007	late	0	0	0	0
157	13	1	CT	1	B	L	I	2007	late	0	0	0	0
158	14	1	NT	1	B	L	I	2007	late	0	0	0	0

obs#	plot	tblock	till	bblock	burn	res	Irrig	year	Season	cheat	Cpurslane	CLGC	eclipta
159	15	2	NT	1	B	H	I	2007	late	0	2	0	0
160	16	2	CT	1	B	L	I	2007	late	0	0	0	0
161	17	3	NT	1	B	H	I	2007	late	0	0	0	0
162	18	3	CT	1	B	L	I	2007	late	0	0	0	0
163	19	1	CT	1	B	H	I	2007	late	0	0	0	0
164	20	1	NT	1	B	H	I	2007	late	0	0	0	0
165	21	2	NT	1	B	L	I	2007	late	0	10	0	0
166	22	2	CT	1	B	H	I	2007	late	0	4	0	0
167	23	3	NT	1	B	L	I	2007	late	0	0	0	0
168	24	3	CT	1	B	H	I	2007	late	0	0	0	0
169	25	1	CT	2	B	H	NI	2007	late	0	0	0	0
170	26	1	NT	2	B	H	NI	2007	late	0	0	0	0
171	27	2	NT	2	B	H	NI	2007	late	0	0	0	0
172	28	2	CT	2	B	L	NI	2007	late	0	0	0	0
173	29	3	NT	2	B	H	NI	2007	late	0	0	0	0
174	30	3	CT	2	B	L	NI	2007	late	0	0	0	0
175	31	1	CT	2	B	L	NI	2007	late	0	0	0	0
176	32	1	NT	2	B	L	NI	2007	late	0	0	0	0
177	33	2	NT	2	B	L	NI	2007	late	0	0	0	0
178	34	2	CT	2	B	H	NI	2007	late	0	0	0	0
179	35	3	NT	2	B	L	NI	2007	late	0	4	0	0
180	36	3	CT	2	B	H	NI	2007	late	0	0	0	0
181	37	1	CT	2	NB	H	NI	2007	late	0	0	0	0
182	38	1	NT	2	NB	L	NI	2007	late	0	0	0	0
183	39	2	NT	2	NB	H	NI	2007	late	0	0	0	0
184	40	2	CT	2	NB	H	NI	2007	late	0	0	0	0
185	41	3	NT	2	NB	L	NI	2007	late	0	0	0	0
186	42	3	CT	2	NB	H	NI	2007	late	0	0	0	0
187	43	1	CT	2	NB	L	NI	2007	late	0	0	0	0
188	44	1	NT	2	NB	H	NI	2007	late	0	0	0	0
189	45	2	NT	2	NB	L	NI	2007	late	0	0	0	0
190	46	2	CT	2	NB	L	NI	2007	late	0	0	0	0
191	47	3	NT	2	NB	H	NI	2007	late	0	0	0	0
192	48	3	CT	2	NB	L	NI	2007	late	0	0	0	0

Entireleaf morningglory (EMG), fall panicum (FP), goosegrass (GG), henbit, and horseweed (horsew) population densities

obs#	plot	tblock	till	bblock	burn	res	IR	year	Season	EMG	FP	GG	henbit	horsew
1	1	1	CT	1	NB	H	I	2006	early	4	16	28	0	0
2	2	1	NT	1	NB	L	I	2006	early	4	8	16	0	0
3	3	2	NT	1	NB	H	I	2006	early	0	8	4	0	0
4	4	2	CT	1	NB	L	I	2006	early	0	8	56	0	0
5	5	3	NT	1	NB	L	I	2006	early	4	0	0	0	0
6	6	3	CT	1	NB	H	I	2006	early	8	0	12	0	0
7	7	1	CT	1	NB	L	I	2006	early	12	0	20	0	0
8	8	1	NT	1	NB	H	I	2006	early	0	4	8	0	0
9	9	2	NT	1	NB	L	I	2006	early	0	0	12	0	0
10	10	2	CT	1	NB	H	I	2006	early	0	32	84	0	0
11	11	3	NT	1	NB	H	I	2006	early	0	0	12	0	0
12	12	3	CT	1	NB	L	I	2006	early	4	8	0	0	0
13	13	1	CT	1	B	L	I	2006	early	0	4	24	0	0
14	14	1	NT	1	B	L	I	2006	early	4	4	24	0	0
15	15	2	NT	1	B	H	I	2006	early	4	4	8	0	0
16	16	2	CT	1	B	L	I	2006	early	0	0	4	0	0
17	17	3	NT	1	B	H	I	2006	early	0	4	8	0	0
18	18	3	CT	1	B	L	I	2006	early	0	0	28	0	0
19	19	1	CT	1	B	H	I	2006	early	0	16	28	0	0
20	20	1	NT	1	B	H	I	2006	early	0	0	4	0	0
21	21	2	NT	1	B	L	I	2006	early	0	0	16	0	0
22	22	2	CT	1	B	H	I	2006	early	0	4	8	0	0
23	23	3	NT	1	B	L	I	2006	early	0	12	8	0	0
24	24	3	CT	1	B	H	I	2006	early	0	16	24	0	0
25	25	1	CT	2	B	H	NI	2006	early	0	4	12	0	0
26	26	1	NT	2	B	H	NI	2006	early	0	0	8	0	0
27	27	2	NT	2	B	H	NI	2006	early	0	0	8	0	0
28	28	2	CT	2	B	L	NI	2006	early	0	4	8	0	0
29	29	3	NT	2	B	H	NI	2006	early	0	0	12	0	0
30	30	3	CT	2	B	L	NI	2006	early	0	0	20	0	0
31	31	1	CT	2	B	L	NI	2006	early	0	16	4	0	0
32	32	1	NT	2	B	L	NI	2006	early	0	8	28	0	0
33	33	2	NT	2	B	L	NI	2006	early	0	8	0	0	0
34	34	2	CT	2	B	H	NI	2006	early	0	12	4	0	0
35	35	3	NT	2	B	L	NI	2006	early	0	52	0	0	0
36	36	3	CT	2	B	H	NI	2006	early	0	20	8	0	0

obs#	plot	tblock	till	bblock	burn	res	Irrig	year	Season	EMG	FP	GG	Hernbit	Horsew
37	37	1	CT	2	NB	H	NI	2006	early	4	0	8	0	0
38	38	1	NT	2	NB	L	NI	2006	early	4	0	20	0	0
39	39	2	NT	2	NB	H	NI	2006	early	0	0	40	0	0
40	40	2	CT	2	NB	H	NI	2006	early	0	0	16	0	0
41	41	3	NT	2	NB	L	NI	2006	early	0	0	4	0	0
42	42	3	CT	2	NB	H	NI	2006	early	0	0	16	0	0
43	43	1	CT	2	NB	L	NI	2006	early	0	4	44	0	0
44	44	1	NT	2	NB	H	NI	2006	early	0	0	0	0	0
45	45	2	NT	2	NB	L	NI	2006	early	0	0	8	0	0
46	46	2	CT	2	NB	L	NI	2006	early	0	0	4	0	0
47	47	3	NT	2	NB	H	NI	2006	early	0	0	0	0	0
48	48	3	CT	2	NB	L	NI	2006	early	0	0	24	0	0
49	1	1	CT	1	NB	H	I	2006	late	2	0	0	0	0
50	2	1	NT	1	NB	L	I	2006	late	2	0	0	0	4
51	3	2	NT	1	NB	H	I	2006	late	0	0	0	0	0
52	4	2	CT	1	NB	L	I	2006	late	0	0	0	0	0
53	5	3	NT	1	NB	L	I	2006	late	0	0	0	0	0
54	6	3	CT	1	NB	H	I	2006	late	2	0	0	0	0
55	7	1	CT	1	NB	L	I	2006	late	0	0	0	0	0
56	8	1	NT	1	NB	H	I	2006	late	0	0	0	0	0
57	9	2	NT	1	NB	L	I	2006	late	0	0	0	0	0
58	10	2	CT	1	NB	H	I	2006	late	0	0	0	0	0
59	11	3	NT	1	NB	H	I	2006	late	0	0	0	0	0
60	12	3	CT	1	NB	L	I	2006	late	2	0	0	0	0
61	13	1	CT	1	B	L	I	2006	late	4	0	0	0	0
62	14	1	NT	1	B	L	I	2006	late	4	0	0	0	0
63	15	2	NT	1	B	H	I	2006	late	4	0	0	0	0
64	16	2	CT	1	B	L	I	2006	late	0	0	0	0	0
65	17	3	NT	1	B	H	I	2006	late	0	0	0	0	0
66	18	3	CT	1	B	L	I	2006	late	0	0	0	0	0
67	19	1	CT	1	B	H	I	2006	late	0	0	0	0	0
68	20	1	NT	1	B	H	I	2006	late	0	0	0	0	0
69	21	2	NT	1	B	L	I	2006	late	0	0	0	0	0
70	22	2	CT	1	B	H	I	2006	late	0	0	0	0	0
71	23	3	NT	1	B	L	I	2006	late	0	0	0	0	0
72	24	3	CT	1	B	H	I	2006	late	0	0	0	0	0
73	25	1	CT	2	B	H	NI	2006	late	0	32	0	0	0
74	26	1	NT	2	B	H	NI	2006	late	0	42	0	0	0
75	27	2	NT	2	B	H	NI	2006	late	0	50	0	0	0
76	28	2	CT	2	B	L	NI	2006	late	2	88	0	0	0
77	29	3	NT	2	B	H	NI	2006	late	0	90	0	0	0

obs#	plot	tblock	till	bblock	burn	res	Irrig	year	Season	EMG	FP	GG	hernbit	horsew
78	30	3	CT	2	B	L	NI	2006	late	0	48	0	0	0
79	31	1	CT	2	B	L	NI	2006	late	0	38	0	0	0
80	32	1	NT	2	B	L	NI	2006	late	0	76	0	0	0
81	33	2	NT	2	B	L	NI	2006	late	0	94	2	0	0
82	34	2	CT	2	B	H	NI	2006	late	0	76	0	0	0
83	35	3	NT	2	B	L	NI	2006	late	4	108	0	0	0
84	36	3	CT	2	B	H	NI	2006	late	0	44	0	0	0
85	37	1	CT	2	NB	H	NI	2006	late	0	4	0	0	0
86	38	1	NT	2	NB	L	NI	2006	late	8	38	2	0	0
87	39	2	NT	2	NB	H	NI	2006	late	0	40	0	0	0
88	40	2	CT	2	NB	H	NI	2006	late	8	108	0	0	0
89	41	3	NT	2	NB	L	NI	2006	late	0	60	0	0	0
90	42	3	CT	2	NB	H	NI	2006	late	4	78	0	0	0
91	43	1	CT	2	NB	L	NI	2006	late	0	2	0	0	0
92	44	1	NT	2	NB	H	NI	2006	late	0	8	0	0	0
93	45	2	NT	2	NB	L	NI	2006	late	4	34	0	0	0
94	46	2	CT	2	NB	L	NI	2006	late	18	44	0	0	0
95	47	3	NT	2	NB	H	NI	2006	late	4	10	0	0	0
96	48	3	CT	2	NB	L	NI	2006	late	6	74	0	0	0
97	1	1	CT	1	NB	H	I	2007	early	10	0	12	0	0
98	2	1	NT	1	NB	L	I	2007	early	8	16	8	0	0
99	3	2	NT	1	NB	H	I	2007	early	4	2	0	0	0
100	4	2	CT	1	NB	L	I	2007	early	0	0	8	0	0
101	5	3	NT	1	NB	L	I	2007	early	0	0	2	0	0
102	6	3	CT	1	NB	H	I	2007	early	6	0	0	0	0
103	7	1	CT	1	NB	L	I	2007	early	6	0	4	0	0
104	8	1	NT	1	NB	H	I	2007	early	4	0	0	0	0
105	9	2	NT	1	NB	L	I	2007	early	2	0	0	0	2
106	10	2	CT	1	NB	H	I	2007	early	4	4	6	0	0
107	11	3	NT	1	NB	H	I	2007	early	2	0	2	0	0
108	12	3	CT	1	NB	L	I	2007	early	4	0	0	0	0
109	13	1	CT	1	B	L	I	2007	early	4	2	12	0	0
110	14	1	NT	1	B	L	I	2007	early	2	2	0	0	0
111	15	2	NT	1	B	H	I	2007	early	4	0	24	0	0
112	16	2	CT	1	B	L	I	2007	early	0	0	0	0	0
113	17	3	NT	1	B	H	I	2007	early	2	0	0	0	0
114	18	3	CT	1	B	L	I	2007	early	0	0	0	0	0
115	19	1	CT	1	B	H	I	2007	early	2	0	2	0	0

obs#	plot	tblock	till	bblock	burn	res	Irrig	year	Season	EMG	FP	GG	hernblt	horsew
116	20	1	NT	1	B	H	I	2007	early	0	0	4	0	0
117	21	2	NT	1	B	L	I	2007	early	0	0	0	0	0
118	22	2	CT	1	B	H	I	2007	early	0	0	0	0	0
119	23	3	NT	1	B	L	I	2007	early	0	6	0	0	0
120	24	3	CT	1	B	H	I	2007	early	0	0	0	0	0
121	25	1	CT	2	B	H	NI	2007	early	0	0	0	0	0
122	26	1	NT	2	B	H	NI	2007	early	0	0	0	0	0
123	27	2	NT	2	B	H	NI	2007	early	0	0	0	0	0
124	28	2	CT	2	B	L	NI	2007	early	0	2	0	0	0
125	29	3	NT	2	B	H	NI	2007	early	0	0	0	0	0
126	30	3	CT	2	B	L	NI	2007	early	0	0	0	0	0
127	31	1	CT	2	B	L	NI	2007	early	0	0	2	0	0
128	32	1	NT	2	B	L	NI	2007	early	0	0	0	0	0
129	33	2	NT	2	B	L	NI	2007	early	0	0	0	0	0
130	34	2	CT	2	B	H	NI	2007	early	0	0	0	0	0
131	35	3	NT	2	B	L	NI	2007	early	0	4	0	0	0
132	36	3	CT	2	B	H	NI	2007	early	0	0	0	0	0
133	37	1	CT	2	NB	H	NI	2007	early	0	0	0	0	0
134	38	1	NT	2	NB	L	NI	2007	early	6	0	2	0	0
135	39	2	NT	2	NB	H	NI	2007	early	0	0	6	0	0
136	40	2	CT	2	NB	H	NI	2007	early	0	0	0	0	0
137	41	3	NT	2	NB	L	NI	2007	early	0	0	0	0	0
138	42	3	CT	2	NB	H	NI	2007	early	0	0	0	0	0
139	43	1	CT	2	NB	L	NI	2007	early	0	0	0	0	0
140	44	1	NT	2	NB	H	NI	2007	early	0	0	0	0	0
141	45	2	NT	2	NB	L	NI	2007	early	0	0	0	0	0
142	46	2	CT	2	NB	L	NI	2007	early	0	0	0	0	0
143	47	3	NT	2	NB	H	NI	2007	early	0	0	0	0	0
144	48	3	CT	2	NB	L	NI	2007	early	0	0	0	0	2
145	1	1	CT	1	NB	H	I	2007	late	0	0	0	10	0
146	2	1	NT	1	NB	L	I	2007	late	0	0	0	10	0
147	3	2	NT	1	NB	H	I	2007	late	0	0	2	14	0
148	4	2	CT	1	NB	L	I	2007	late	0	0	0	2	0
149	5	3	NT	1	NB	L	I	2007	late	0	0	0	0	0
150	6	3	CT	1	NB	H	I	2007	late	0	0	0	14	0
151	7	1	CT	1	NB	L	I	2007	late	0	0	0	16	0
152	8	1	NT	1	NB	H	I	2007	late	0	0	0	10	0
153	9	2	NT	1	NB	L	I	2007	late	0	0	0	34	0

obs#	plot	tblock	till	bblock	burn	res	irrig	year	Season	EMG	FP	GG	hernblt	horsew
154	10	2	CT	1	NB	H	I	2007	late	0	0	0	10	0
155	11	3	NT	1	NB	H	I	2007	late	0	0	0	8	0
156	12	3	CT	1	NB	L	I	2007	late	0	0	0	0	0
157	13	1	CT	1	B	L	I	2007	late	0	0	0	6	2
158	14	1	NT	1	B	L	I	2007	late	0	0	0	10	0
159	15	2	NT	1	B	H	I	2007	late	0	0	0	0	0
160	16	2	CT	1	B	L	I	2007	late	2	0	0	10	0
161	17	3	NT	1	B	H	I	2007	late	0	0	0	60	0
162	18	3	CT	1	B	L	I	2007	late	0	0	0	10	0
163	19	1	CT	1	B	H	I	2007	late	0	0	0	8	0
164	20	1	NT	1	B	H	I	2007	late	0	0	0	4	0
165	21	2	NT	1	B	L	I	2007	late	0	0	2	20	4
166	22	2	CT	1	B	H	I	2007	late	0	0	0	12	0
167	23	3	NT	1	B	L	I	2007	late	0	0	0	20	0
168	24	3	CT	1	B	H	I	2007	late	0	0	0	66	0
169	25	1	CT	2	B	H	NI	2007	late	0	0	0	24	0
170	26	1	NT	2	B	H	NI	2007	late	0	0	0	40	0
171	27	2	NT	2	B	H	NI	2007	late	0	0	0	24	0
172	28	2	CT	2	B	L	NI	2007	late	0	0	0	30	0
173	29	3	NT	2	B	H	NI	2007	late	0	0	0	20	0
174	30	3	CT	2	B	L	NI	2007	late	0	0	0	30	0
175	31	1	CT	2	B	L	NI	2007	late	0	0	0	2	0
176	32	1	NT	2	B	L	NI	2007	late	0	0	0	30	4
177	33	2	NT	2	B	L	NI	2007	late	0	0	0	60	0
178	34	2	CT	2	B	H	NI	2007	late	0	0	0	90	2
179	35	3	NT	2	B	L	NI	2007	late	0	0	0	124	0
180	36	3	CT	2	B	H	NI	2007	late	0	0	0	62	0
181	37	1	CT	2	NB	H	NI	2007	late	0	0	0	28	2
182	38	1	NT	2	NB	L	NI	2007	late	0	0	0	42	0
183	39	2	NT	2	NB	H	NI	2007	late	0	0	0	20	0
184	40	2	CT	2	NB	H	NI	2007	late	0	0	0	12	0
185	41	3	NT	2	NB	L	NI	2007	late	0	0	0	26	2
186	42	3	CT	2	NB	H	NI	2007	late	0	0	0	12	0
187	43	1	CT	2	NB	L	NI	2007	late	0	0	0	34	0
188	44	1	NT	2	NB	H	NI	2007	late	2	0	0	172	0
189	45	2	NT	2	NB	L	NI	2007	late	0	0	0	232	2
190	46	2	CT	2	NB	L	NI	2007	late	0	0	0	32	0
191	47	3	NT	2	NB	H	NI	2007	late	0	0	0	68	0
192	48	3	CT	2	NB	L	NI	2007	late	0	0	0	38	0

Large crabgrass (LCG), Palmer amaranth (PalmerA), pitted morningglory (PMG), prickly sida (PS), and cutleaf evening-primrose (CLPR) densities in plants m^{-2}

obs#	plot	tblock	till	bblock	burn	res	IR	year	Season	LCG	PalmerA	PMG	PS	CLPR
1	1	1	CT	1	NB	H	I	2006	early	2	2	8	4	0
2	2	1	NT	1	NB	L	I	2006	early	8	0	4	4	0
3	3	2	NT	1	NB	H	I	2006	early	8	0	0	8	0
4	4	2	CT	1	NB	L	I	2006	early	0	0	0	0	0
5	5	3	NT	1	NB	L	I	2006	early	16	0	4	0	4
6	6	3	CT	1	NB	H	I	2006	early	8	0	0	0	0
7	7	1	CT	1	NB	L	I	2006	early	8	0	12	12	0
8	8	1	NT	1	NB	H	I	2006	early	32	0	0	0	0
9	9	2	NT	1	NB	L	I	2006	early	12	0	4	0	0
10	10	2	CT	1	NB	H	I	2006	early	0	0	0	0	0
11	11	3	NT	1	NB	H	I	2006	early	12	0	0	0	0
12	12	3	CT	1	NB	L	I	2006	early	8	4	0	4	0
13	13	1	CT	1	B	L	I	2006	early	4	0	20	20	0
14	14	1	NT	1	B	L	I	2006	early	4	20	0	12	0
15	15	2	NT	1	B	H	I	2006	early	8	12	32	12	0
16	16	2	CT	1	B	L	I	2006	early	4	0	0	20	0
17	17	3	NT	1	B	H	I	2006	early	4	0	0	16	0
18	18	3	CT	1	B	L	I	2006	early	0	4	0	4	0
19	19	1	CT	1	B	H	I	2006	early	0	0	0	4	0
20	20	1	NT	1	B	H	I	2006	early	8	0	0	44	0
21	21	2	NT	1	B	L	I	2006	early	0	0	0	20	0
22	22	2	CT	1	B	H	I	2006	early	4	0	0	8	0
23	23	3	NT	1	B	L	I	2006	early	0	0	4	24	0
24	24	3	CT	1	B	H	I	2006	early	0	4	0	20	0
25	25	1	CT	2	B	H	NI	2006	early	4	0	12	0	0
26	26	1	NT	2	B	H	NI	2006	early	0	12	12	0	0
27	27	2	NT	2	B	H	NI	2006	early	4	0	0	4	0
28	28	2	CT	2	B	L	NI	2006	early	0	12	40	0	0
29	29	3	NT	2	B	H	NI	2006	early	8	4	0	20	0
30	30	3	CT	2	B	L	NI	2006	early	0	0	0	8	0
31	31	1	CT	2	B	L	NI	2006	early	0	4	28	8	0
32	32	1	NT	2	B	L	NI	2006	early	0	0	0	0	0
33	33	2	NT	2	B	L	NI	2006	early	8	0	0	8	0
34	34	2	CT	2	B	H	NI	2006	early	0	16	40	28	0
35	35	3	NT	2	B	L	NI	2006	early	0	0	0	0	0

obs#	plot	tblock	till	bblock	burn	res	IR	year	Season	LCG	PalmerA	PMG	PS	CLPR
36	36	3	CT	2	B	H	NI	2006	early	4	20	0	16	0
37	37	1	CT	2	NB	H	NI	2006	early	8	0	4	24	0
38	38	1	NT	2	NB	L	NI	2006	early	0	4	4	4	0
39	39	2	NT	2	NB	H	NI	2006	early	0	12	24	20	0
40	40	2	CT	2	NB	H	NI	2006	early	0	8	56	4	0
41	41	3	NT	2	NB	L	NI	2006	early	4	4	4	8	4
42	42	3	CT	2	NB	H	NI	2006	early	0	8	0	0	0
43	43	1	CT	2	NB	L	NI	2006	early	0	0	0	0	0
44	44	1	NT	2	NB	H	NI	2006	early	4	4	4	0	0
45	45	2	NT	2	NB	L	NI	2006	early	0	8	0	0	4
46	46	2	CT	2	NB	L	NI	2006	early	0	8	20	0	0
47	47	3	NT	2	NB	H	NI	2006	early	0	12	8	0	0
48	48	3	CT	2	NB	L	NI	2006	early	0	0	8	0	0
49	1	1	CT	1	NB	H	I	2006	late	0	0	10	8	0
50	2	1	NT	1	NB	L	I	2006	late	0	0	0	2	0
51	3	2	NT	1	NB	H	I	2006	late	0	0	0	4	0
52	4	2	CT	1	NB	L	I	2006	late	0	0	4	2	0
53	5	3	NT	1	NB	L	I	2006	late	0	0	0	2	0
54	6	3	CT	1	NB	H	I	2006	late	0	0	4	0	0
55	7	1	CT	1	NB	L	I	2006	late	0	0	16	4	0
56	8	1	NT	1	NB	H	I	2006	late	0	0	0	0	0
57	9	2	NT	1	NB	L	I	2006	late	0	2	4	6	0
58	10	2	CT	1	NB	H	I	2006	late	0	0	6	0	0
59	11	3	NT	1	NB	H	I	2006	late	0	0	0	4	0
60	12	3	CT	1	NB	L	I	2006	late	0	6	0	4	0
61	13	1	CT	1	B	L	I	2006	late	0	0	0	6	0
62	14	1	NT	1	B	L	I	2006	late	0	0	0	38	0
63	15	2	NT	1	B	H	I	2006	late	0	0	2	22	0
64	16	2	CT	1	B	L	I	2006	late	0	0	2	4	0
65	17	3	NT	1	B	H	I	2006	late	0	0	2	22	0
66	18	3	CT	1	B	L	I	2006	late	0	0	8	4	0
67	19	1	CT	1	B	H	I	2006	late	0	0	0	0	0
68	20	1	NT	1	B	H	I	2006	late	0	0	2	6	0
69	21	2	NT	1	B	L	I	2006	late	0	0	0	14	0
70	22	2	CT	1	B	H	I	2006	late	0	0	2	0	0
71	23	3	NT	1	B	L	I	2006	late	0	0	0	48	0
72	24	3	CT	1	B	H	I	2006	late	0	0	0	8	0
73	25	1	CT	2	B	H	NI	2006	late	0	0	22	2	0
74	26	1	NT	2	B	H	NI	2006	late	0	0	22	6	0

obs#	plot	tblock	till	bblock	burn	res	IR	year	Season	LCG	PalmerA	PMG	PS	CLPR
75	27	2	NT	2	B	H	NI	2006	late	0	0	10	10	0
76	28	2	CT	2	B	L	NI	2006	late	0	0	2	2	0
77	29	3	NT	2	B	H	NI	2006	late	0	0	0	12	0
78	30	3	CT	2	B	L	NI	2006	late	0	2	2	2	0
79	31	1	CT	2	B	L	NI	2006	late	0	0	14	4	0
80	32	1	NT	2	B	L	NI	2006	late	0	2	0	38	0
81	33	2	NT	2	B	L	NI	2006	late	0	0	0	4	0
82	34	2	CT	2	B	H	NI	2006	late	0	0	8	12	0
83	35	3	NT	2	B	L	NI	2006	late	0	0	0	26	0
84	36	3	CT	2	B	H	NI	2006	late	0	0	0	4	0
85	37	1	CT	2	NB	H	NI	2006	late	0	0	26	0	0
86	38	1	NT	2	NB	L	NI	2006	late	0	0	32	10	0
87	39	2	NT	2	NB	H	NI	2006	late	0	0	2	6	0
88	40	2	CT	2	NB	H	NI	2006	late	0	2	48	12	0
89	41	3	NT	2	NB	L	NI	2006	late	0	0	8	6	0
90	42	3	CT	2	NB	H	NI	2006	late	0	0	8	2	0
91	43	1	CT	2	NB	L	NI	2006	late	0	0	0	0	0
92	44	1	NT	2	NB	H	NI	2006	late	0	0	0	0	0
93	45	2	NT	2	NB	L	NI	2006	late	0	0	0	0	0
94	46	2	CT	2	NB	L	NI	2006	late	0	0	56	0	0
95	47	3	NT	2	NB	H	NI	2006	late	0	0	0	0	0
96	48	3	CT	2	NB	L	NI	2006	late	0	0	0	0	0
97	1	1	CT	1	NB	H	I	2007	early	0	24	2	14	0
98	2	1	NT	1	NB	L	I	2007	early	0	0	0	0	0
99	3	2	NT	1	NB	H	I	2007	early	0	4	0	4	0
100	4	2	CT	1	NB	L	I	2007	early	0	32	0	0	0
101	5	3	NT	1	NB	L	I	2007	early	0	0	0	14	0
102	6	3	CT	1	NB	H	I	2007	early	0	0	2	4	0
103	7	1	CT	1	NB	L	I	2007	early	2	0	6	8	0
104	8	1	NT	1	NB	H	I	2007	early	0	0	2	4	0
105	9	2	NT	1	NB	L	I	2007	early	4	0	0	2	0
106	10	2	CT	1	NB	H	I	2007	early	0	0	0	4	0
107	11	3	NT	1	NB	H	I	2007	early	0	2	0	0	0
108	12	3	CT	1	NB	L	I	2007	early	0	0	0	6	0
109	13	1	CT	1	B	L	I	2007	early	0	0	2	16	0
110	14	1	NT	1	B	L	I	2007	early	0	2	0	8	0
111	15	2	NT	1	B	H	I	2007	early	0	0	0	4	0
112	16	2	CT	1	B	L	I	2007	early	0	0	2	6	0
113	17	3	NT	1	B	H	I	2007	early	2	0	0	8	0

obs#	plot	tblock	till	bblock	burn	res	IR	year	Season	LCG	PalmerA	PMG	PS	CLPR
114	18	3	CT	1	B	L	I	2007	early	0	0	0	6	0
115	19	1	CT	1	B	H	I	2007	early	2	0	0	8	0
116	20	1	NT	1	B	H	I	2007	early	0	0	2	4	0
117	21	2	NT	1	B	L	I	2007	early	2	0	0	12	0
118	22	2	CT	1	B	H	I	2007	early	0	0	0	0	0
119	23	3	NT	1	B	L	I	2007	early	0	0	0	18	0
120	24	3	CT	1	B	H	I	2007	early	0	0	0	10	0
121	25	1	CT	2	B	H	NI	2007	early	0	4	4	8	0
122	26	1	NT	2	B	H	NI	2007	early	0	16	10	0	0
123	27	2	NT	2	B	H	NI	2007	early	0	2	0	0	0
124	28	2	CT	2	B	L	NI	2007	early	0	10	2	2	0
125	29	3	NT	2	B	H	NI	2007	early	0	24	0	0	0
126	30	3	CT	2	B	L	NI	2007	early	0	4	0	6	0
127	31	1	CT	2	B	L	NI	2007	early	0	6	0	2	0
128	32	1	NT	2	B	L	NI	2007	early	0	2	0	14	2
129	33	2	NT	2	B	L	NI	2007	early	0	0	4	54	0
130	34	2	CT	2	B	H	NI	2007	early	0	6	2	10	0
131	35	3	NT	2	B	L	NI	2007	early	0	8	0	0	2
132	36	3	CT	2	B	H	NI	2007	early	0	12	0	10	0
133	37	1	CT	2	NB	H	NI	2007	early	0	18	0	12	0
134	38	1	NT	2	NB	L	NI	2007	early	0	18	10	8	8
135	39	2	NT	2	NB	H	NI	2007	early	0	8	26	10	0
136	40	2	CT	2	NB	H	NI	2007	early	0	6	2	16	0
137	41	3	NT	2	NB	L	NI	2007	early	0	2	34	30	4
138	42	3	CT	2	NB	H	NI	2007	early	0	2	0	0	0
139	43	1	CT	2	NB	L	NI	2007	early	0	0	2	0	0
140	44	1	NT	2	NB	H	NI	2007	early	0	0	2	0	0
141	45	2	NT	2	NB	L	NI	2007	early	0	4	4	0	0
142	46	2	CT	2	NB	L	NI	2007	early	0	32	4	18	0
143	47	3	NT	2	NB	H	NI	2007	early	0	0	0	2	0
144	48	3	CT	2	NB	L	NI	2007	early	0	8	0	2	0
145	1	1	CT	1	NB	H	I	2007	late	0	0	0	0	0
146	2	1	NT	1	NB	L	I	2007	late	0	0	0	6	0
147	3	2	NT	1	NB	H	I	2007	late	0	0	0	0	0
148	4	2	CT	1	NB	L	I	2007	late	0	0	0	0	0
149	5	3	NT	1	NB	L	I	2007	late	0	0	2	2	0
150	6	3	CT	1	NB	H	I	2007	late	0	0	4	0	0
151	7	1	CT	1	NB	L	I	2007	late	0	0	0	0	0
152	8	1	NT	1	NB	H	I	2007	late	0	0	8	0	0

obs#	plot	tblock	till	bblock	burn	res	IR	year	Season	LCG	PalmerA	PMG	PS	CLPR
153	9	2	NT	1	NB	L	I	2007	late	0	0	4	0	0
154	10	2	CT	1	NB	H	I	2007	late	0	0	2	0	0
155	11	3	NT	1	NB	H	I	2007	late	0	0	2	0	0
156	12	3	CT	1	NB	L	I	2007	late	0	0	0	2	0
157	13	1	CT	1	B	L	I	2007	late	0	0	0	4	0
158	14	1	NT	1	B	L	I	2007	late	0	0	2	6	0
159	15	2	NT	1	B	H	I	2007	late	0	0	6	0	0
160	16	2	CT	1	B	L	I	2007	late	0	0	0	0	0
161	17	3	NT	1	B	H	I	2007	late	0	0	0	4	0
162	18	3	CT	1	B	L	I	2007	late	0	0	0	0	0
163	19	1	CT	1	B	H	I	2007	late	0	0	0	0	0
164	20	1	NT	1	B	H	I	2007	late	0	0	0	0	0
165	21	2	NT	1	B	L	I	2007	late	0	0	0	4	0
166	22	2	CT	1	B	H	I	2007	late	0	0	2	6	0
167	23	3	NT	1	B	L	I	2007	late	0	0	2	4	0
168	24	3	CT	1	B	H	I	2007	late	0	0	0	0	0
169	25	1	CT	2	B	H	NI	2007	late	0	0	8	4	0
170	26	1	NT	2	B	H	NI	2007	late	0	0	12	2	0
171	27	2	NT	2	B	H	NI	2007	late	0	0	2	0	0
172	28	2	CT	2	B	L	NI	2007	late	0	0	0	2	0
173	29	3	NT	2	B	H	NI	2007	late	0	0	0	6	0
174	30	3	CT	2	B	L	NI	2007	late	0	0	2	10	0
175	31	1	CT	2	B	L	NI	2007	late	0	0	8	0	0
176	32	1	NT	2	B	L	NI	2007	late	0	0	0	4	0
177	33	2	NT	2	B	L	NI	2007	late	0	0	2	0	0
178	34	2	CT	2	B	H	NI	2007	late	0	0	2	6	0
179	35	3	NT	2	B	L	NI	2007	late	0	0	10	12	0
180	36	3	CT	2	B	H	NI	2007	late	0	0	0	4	0
181	37	1	CT	2	NB	H	NI	2007	late	0	0	2	0	0
182	38	1	NT	2	NB	L	NI	2007	late	0	0	32	0	0
183	39	2	NT	2	NB	H	NI	2007	late	0	0	14	2	0
184	40	2	CT	2	NB	H	NI	2007	late	0	0	14	4	0
185	41	3	NT	2	NB	L	NI	2007	late	0	0	18	2	0
186	42	3	CT	2	NB	H	NI	2007	late	0	0	0	0	0
187	43	1	CT	2	NB	L	NI	2007	late	0	0	2	0	0
188	44	1	NT	2	NB	H	NI	2007	late	0	0	6	0	0
189	45	2	NT	2	NB	L	NI	2007	late	0	0	2	0	0
190	46	2	CT	2	NB	L	NI	2007	late	0	0	18	2	0
191	47	3	NT	2	NB	H	NI	2007	late	0	0	10	0	0
192	48	3	CT	2	NB	L	NI	2007	late	0	0	2	0	0

Red sprangletop (RST), rice flatsedge (RFS), smooth pigweed (SPW), spotted spurge (spurge), red clover (Rclover) population densities (plants m^{-2})

obs#	plot	tblock	till	bblock	burn	res	IR	year	Season	RST	RFS	SPW	spurge	Rclover
1	1	1	CT	1	NB	H	I	2006	early	52	164	230	0	0
2	2	1	NT	1	NB	L	I	2006	early	4	12	48	0	0
3	3	2	NT	1	NB	H	I	2006	early	16	128	224	0	0
4	4	2	CT	1	NB	L	I	2006	early	56	52	368	0	0
5	5	3	NT	1	NB	L	I	2006	early	0	0	104	0	0
6	6	3	CT	1	NB	H	I	2006	early	12	84	228	0	0
7	7	1	CT	1	NB	L	I	2006	early	28	128	408	0	0
8	8	1	NT	1	NB	H	I	2006	early	40	0	208	0	0
9	9	2	NT	1	NB	L	I	2006	early	24	8	88	0	0
10	10	2	CT	1	NB	H	I	2006	early	28	56	304	4	0
11	11	3	NT	1	NB	H	I	2006	early	20	100	68	0	0
12	12	3	CT	1	NB	L	I	2006	early	12	72	272	0	0
13	13	1	CT	1	B	L	I	2006	early	20	124	312	0	0
14	14	1	NT	1	B	L	I	2006	early	48	36	128	0	0
15	15	2	NT	1	B	H	I	2006	early	44	260	108	0	0
16	16	2	CT	1	B	L	I	2006	early	12	100	156	0	0
17	17	3	NT	1	B	H	I	2006	early	28	300	348	0	0
18	18	3	CT	1	B	L	I	2006	early	4	196	208	0	0
19	19	1	CT	1	B	H	I	2006	early	28	160	156	0	0
20	20	1	NT	1	B	H	I	2006	early	40	100	96	0	0
21	21	2	NT	1	B	L	I	2006	early	256	0	128	0	0
22	22	2	CT	1	B	H	I	2006	early	72	100	56	0	0
23	23	3	NT	1	B	L	I	2006	early	168	140	276	0	0
24	24	3	CT	1	B	H	I	2006	early	56	196	156	0	0
25	25	1	CT	2	B	H	NI	2006	early	32	132	56	0	0
26	26	1	NT	2	B	H	NI	2006	early	88	24	108	0	0
27	27	2	NT	2	B	H	NI	2006	early	100	44	64	0	0
28	28	2	CT	2	B	L	NI	2006	early	48	52	60	0	0
29	29	3	NT	2	B	H	NI	2006	early	20	44	332	16	0
30	30	3	CT	2	B	L	NI	2006	early	36	44	60	28	0
31	31	1	CT	2	B	L	NI	2006	early	24	96	80	16	0
32	32	1	NT	2	B	L	NI	2006	early	128	40	68	0	0
33	33	2	NT	2	B	L	NI	2006	early	72	56	80	0	0
34	34	2	CT	2	B	H	NI	2006	early	0	72	72	0	0
35	35	3	NT	2	B	L	NI	2006	early	160	0	88	4	0
36	36	3	CT	2	B	H	NI	2006	early	72	60	48	0	0
37	37	1	CT	2	NB	H	NI	2006	early	48	140	80	4	0

obs#	plot	tblock	till	bblock	burn	res	IR	year	Season	RST	RFS	SPW	spurge	Rclover
38	38	1	NT	2	NB	L	NI	2006	early	36	64	124	0	0
39	39	2	NT	2	NB	H	NI	2006	early	68	4	168	0	0
40	40	2	CT	2	NB	H	NI	2006	early	32	20	76	4	0
41	41	3	NT	2	NB	L	NI	2006	early	56	20	24	80	0
42	42	3	CT	2	NB	H	NI	2006	early	36	24	48	0	0
43	43	1	CT	2	NB	L	NI	2006	early	24	76	16	16	0
44	44	1	NT	2	NB	H	NI	2006	early	4	0	68	16	0
45	45	2	NT	2	NB	L	NI	2006	early	12	0	28	12	0
46	46	2	CT	2	NB	L	NI	2006	early	16	60	92	0	0
47	47	3	NT	2	NB	H	NI	2006	early	0	28	84	4	0
48	48	3	CT	2	NB	L	NI	2006	early	124	84	12	20	0
49	1	1	CT	1	NB	H	I	2006	late	0	0	0	0	0
50	2	1	NT	1	NB	L	I	2006	late	0	0	0	0	0
51	3	2	NT	1	NB	H	I	2006	late	0	0	0	0	0
52	4	2	CT	1	NB	L	I	2006	late	0	0	0	0	0
53	5	3	NT	1	NB	L	I	2006	late	0	0	0	0	0
54	6	3	CT	1	NB	H	I	2006	late	0	0	14	0	0
55	7	1	CT	1	NB	L	I	2006	late	0	0	0	0	0
56	8	1	NT	1	NB	H	I	2006	late	0	0	0	0	0
57	9	2	NT	1	NB	L	I	2006	late	0	0	0	0	0
58	10	2	CT	1	NB	H	I	2006	late	0	0	0	0	0
59	11	3	NT	1	NB	H	I	2006	late	0	0	0	0	0
60	12	3	CT	1	NB	L	I	2006	late	0	0	4	0	0
61	13	1	CT	1	B	L	I	2006	late	0	0	0	0	0
62	14	1	NT	1	B	L	I	2006	late	0	0	0	0	0
63	15	2	NT	1	B	H	I	2006	late	0	0	2	0	0
64	16	2	CT	1	B	L	I	2006	late	0	0	0	0	0
65	17	3	NT	1	B	H	I	2006	late	0	0	4	0	0
66	18	3	CT	1	B	L	I	2006	late	0	0	0	0	0
67	19	1	CT	1	B	H	I	2006	late	0	0	0	0	0
68	20	1	NT	1	B	H	I	2006	late	0	0	0	0	0
69	21	2	NT	1	B	L	I	2006	late	0	0	0	0	0
70	22	2	CT	1	B	H	I	2006	late	0	0	0	0	0
71	23	3	NT	1	B	L	I	2006	late	0	0	0	0	0
72	24	3	CT	1	B	H	I	2006	late	0	0	0	0	0
73	25	1	CT	2	B	H	NI	2006	late	0	0	0	0	0
74	26	1	NT	2	B	H	NI	2006	late	0	0	20	0	0
75	27	2	NT	2	B	H	NI	2006	late	0	0	0	0	0
76	28	2	CT	2	B	L	NI	2006	late	6	0	0	0	0
77	29	3	NT	2	B	H	NI	2006	late	0	0	4	0	0

obs#	plot	tblock	till	bblock	burn	res	IR	year	Season	RST	RFS	SPW	spurge	Rclover
78	30	3	CT	2	B	L	NI	2006	late	0	0	2	0	0
79	31	1	CT	2	B	L	NI	2006	late	0	0	0	4	0
80	32	1	NT	2	B	L	NI	2006	late	0	0	0	4	0
81	33	2	NT	2	B	L	NI	2006	late	0	0	14	8	0
82	34	2	CT	2	B	H	NI	2006	late	0	2	0	0	0
83	35	3	NT	2	B	L	NI	2006	late	0	0	0	0	0
84	36	3	CT	2	B	H	NI	2006	late	0	0	0	0	0
85	37	1	CT	2	NB	H	NI	2006	late	0	0	0	0	0
86	38	1	NT	2	NB	L	NI	2006	late	0	0	2	0	0
87	39	2	NT	2	NB	H	NI	2006	late	0	0	0	0	0
88	40	2	CT	2	NB	H	NI	2006	late	0	0	2	0	0
89	41	3	NT	2	NB	L	NI	2006	late	0	0	0	0	0
90	42	3	CT	2	NB	H	NI	2006	late	0	0	0	2	0
91	43	1	CT	2	NB	L	NI	2006	late	0	0	0	0	0
92	44	1	NT	2	NB	H	NI	2006	late	0	0	0	0	0
93	45	2	NT	2	NB	L	NI	2006	late	0	0	0	0	0
94	46	2	CT	2	NB	L	NI	2006	late	0	0	0	0	0
95	47	3	NT	2	NB	H	NI	2006	late	0	0	0	0	0
96	48	3	CT	2	NB	L	NI	2006	late	0	0	0	0	0
97	1	1	CT	1	NB	H	I	2007	early	0	0	0	0	0
98	2	1	NT	1	NB	L	I	2007	early	0	0	2	0	0
99	3	2	NT	1	NB	H	I	2007	early	0	0	0	0	0
100	4	2	CT	1	NB	L	I	2007	early	2	0	38	0	0
101	5	3	NT	1	NB	L	I	2007	early	0	0	14	0	0
102	6	3	CT	1	NB	H	I	2007	early	0	0	10	0	0
103	7	1	CT	1	NB	L	I	2007	early	0	4	24	0	0
104	8	1	NT	1	NB	H	I	2007	early	10	0	44	0	0
105	9	2	NT	1	NB	L	I	2007	early	0	0	14	0	0
106	10	2	CT	1	NB	H	I	2007	early	0	0	58	0	0
107	11	3	NT	1	NB	H	I	2007	early	4	0	24	0	0
108	12	3	CT	1	NB	L	I	2007	early	0	10	22	0	0
109	13	1	CT	1	B	L	I	2007	early	26	6	102	0	0
110	14	1	NT	1	B	L	I	2007	early	28	0	46	0	0
111	15	2	NT	1	B	H	I	2007	early	8	0	6	0	0
112	16	2	CT	1	B	L	I	2007	early	0	0	32	0	0
113	17	3	NT	1	B	H	I	2007	early	0	0	10	0	0
114	18	3	CT	1	B	L	I	2007	early	0	2	50	0	0
115	19	1	CT	1	B	H	I	2007	early	4	0	22	0	0
116	20	1	NT	1	B	H	I	2007	early	4	0	12	0	0
117	21	2	NT	1	B	L	I	2007	early	0	0	20	0	0
118	22	2	CT	1	B	H	I	2007	early	0	0	8	0	0

obs#	plot	tblock	till	bblock	burn	res	IR	year	Season	RST	RFS	SPW	spurge	Rclover
119	23	3	NT	1	B	L	I	2007	early	0	0	20	0	0
120	24	3	CT	1	B	H	I	2007	early	0	0	10	0	0
121	25	1	CT	2	B	H	NI	2007	early	60	0	0	0	0
122	26	1	NT	2	B	H	NI	2007	early	68	0	0	0	0
123	27	2	NT	2	B	H	NI	2007	early	6	0	0	0	0
124	28	2	CT	2	B	L	NI	2007	early	52	8	0	0	0
125	29	3	NT	2	B	H	NI	2007	early	20	8	0	0	0
126	30	3	CT	2	B	L	NI	2007	early	34	0	0	0	0
127	31	1	CT	2	B	L	NI	2007	early	84	2	0	0	0
128	32	1	NT	2	B	L	NI	2007	early	40	0	0	0	0
129	33	2	NT	2	B	L	NI	2007	early	102	0	0	0	0
130	34	2	CT	2	B	H	NI	2007	early	58	22	0	0	0
131	35	3	NT	2	B	L	NI	2007	early	90	0	4	0	0
132	36	3	CT	2	B	H	NI	2007	early	62	4	0	0	0
133	37	1	CT	2	NB	H	NI	2007	early	56	6	0	0	0
134	38	1	NT	2	NB	L	NI	2007	early	106	0	0	0	0
135	39	2	NT	2	NB	H	NI	2007	early	84	2	10	0	0
136	40	2	CT	2	NB	H	NI	2007	early	34	0	32	0	0
137	41	3	NT	2	NB	L	NI	2007	early	14	0	2	0	0
138	42	3	CT	2	NB	H	NI	2007	early	104	0	0	0	0
139	43	1	CT	2	NB	L	NI	2007	early	2	0	8	0	0
140	44	1	NT	2	NB	H	NI	2007	early	2	0	2	0	0
141	45	2	NT	2	NB	L	NI	2007	early	4	0	2	0	0
142	46	2	CT	2	NB	L	NI	2007	early	4	0	4	0	0
143	47	3	NT	2	NB	H	NI	2007	early	6	0	2	0	0
144	48	3	CT	2	NB	L	NI	2007	early	88	0	4	0	0
145	1	1	CT	1	NB	H	I	2007	late	0	0	0	0	0
146	2	1	NT	1	NB	L	I	2007	late	0	0	0	0	0
147	3	2	NT	1	NB	H	I	2007	late	0	0	0	0	0
148	4	2	CT	1	NB	L	I	2007	late	2	0	0	0	0
149	5	3	NT	1	NB	L	I	2007	late	0	0	0	0	0
150	6	3	CT	1	NB	H	I	2007	late	2	0	0	0	0
151	7	1	CT	1	NB	L	I	2007	late	0	0	0	0	0
152	8	1	NT	1	NB	H	I	2007	late	0	0	0	0	0
153	9	2	NT	1	NB	L	I	2007	late	2	0	0	0	0
154	10	2	CT	1	NB	H	I	2007	late	0	0	0	0	0
155	11	3	NT	1	NB	H	I	2007	late	2	0	0	0	0
156	12	3	CT	1	NB	L	I	2007	late	2	0	0	0	0
157	13	1	CT	1	B	L	I	2007	late	0	0	0	0	0
158	14	1	NT	1	B	L	I	2007	late	0	0	0	0	0
159	15	2	NT	1	B	H	I	2007	late	0	0	0	0	0

obs#	plot	tblock	till	bblock	burn	res	IR	year	Season	RST	RFS	SPW	spurge	Rclover
160	16	2	CT	1	B	L	I	2007	late	0	0	0	0	0
161	17	3	NT	1	B	H	I	2007	late	0	0	0	0	0
162	18	3	CT	1	B	L	I	2007	late	0	0	0	0	0
163	19	1	CT	1	B	H	I	2007	late	0	0	0	0	0
164	20	1	NT	1	B	H	I	2007	late	0	0	0	0	0
165	21	2	NT	1	B	L	I	2007	late	12	0	0	0	0
166	22	2	CT	1	B	H	I	2007	late	0	0	0	0	0
167	23	3	NT	1	B	L	I	2007	late	6	0	0	0	0
168	24	3	CT	1	B	H	I	2007	late	0	0	0	0	0
169	25	1	CT	2	B	H	NI	2007	late	2	0	0	0	0
170	26	1	NT	2	B	H	NI	2007	late	0	0	0	0	0
171	27	2	NT	2	B	H	NI	2007	late	12	0	0	0	0
172	28	2	CT	2	B	L	NI	2007	late	4	0	0	0	0
173	29	3	NT	2	B	H	NI	2007	late	0	0	0	0	0
174	30	3	CT	2	B	L	NI	2007	late	4	0	0	0	0
175	31	1	CT	2	B	L	NI	2007	late	0	0	0	0	0
176	32	1	NT	2	B	L	NI	2007	late	16	0	0	0	0
177	33	2	NT	2	B	L	NI	2007	late	16	0	0	0	0
178	34	2	CT	2	B	H	NI	2007	late	10	0	0	0	0
179	35	3	NT	2	B	L	NI	2007	late	26	0	0	0	0
180	36	3	CT	2	B	H	NI	2007	late	14	0	0	0	0
181	37	1	CT	2	NB	H	NI	2007	late	2	0	0	0	0
182	38	1	NT	2	NB	L	NI	2007	late	6	0	0	0	0
183	39	2	NT	2	NB	H	NI	2007	late	0	0	0	0	0
184	40	2	CT	2	NB	H	NI	2007	late	0	0	0	0	0
185	41	3	NT	2	NB	L	NI	2007	late	2	0	0	0	0
186	42	3	CT	2	NB	H	NI	2007	late	0	0	0	0	0
187	43	1	CT	2	NB	L	NI	2007	late	0	0	0	0	0
188	44	1	NT	2	NB	H	NI	2007	late	0	0	0	0	0
189	45	2	NT	2	NB	L	NI	2007	late	2	0	0	0	4
190	46	2	CT	2	NB	L	NI	2007	late	2	0	0	0	0
191	47	3	NT	2	NB	H	NI	2007	late	12	0	0	0	0
192	48	3	CT	2	NB	L	NI	2007	late	8	0	0	0	0

Spotted spurge (spurge), trumpetcreeper (trumpet), and northern jointvetch (vetch) densities in plants m^{-2}

obs#	plot	tblock	till	bblock	burn	res	IR	year	season	spurge	spurge	trumpet	vetch
1	1	1	CT	1	NB	H	I	2006	early	0	0	0	0
2	2	1	NT	1	NB	L	I	2006	early	0	0	0	0
3	3	2	NT	1	NB	H	I	2006	early	0	0	0	0
4	4	2	CT	1	NB	L	I	2006	early	0	0	0	0
5	5	3	NT	1	NB	L	I	2006	early	0	0	0	0
6	6	3	CT	1	NB	H	I	2006	early	0	0	0	0
7	7	1	CT	1	NB	L	I	2006	early	0	0	0	0
8	8	1	NT	1	NB	H	I	2006	early	0	0	0	0
9	9	2	NT	1	NB	L	I	2006	early	0	0	0	0
10	10	2	CT	1	NB	H	I	2006	early	0	0	0	0
11	11	3	NT	1	NB	H	I	2006	early	0	0	0	0
12	12	3	CT	1	NB	L	I	2006	early	0	0	4	0
13	13	1	CT	1	B	L	I	2006	early	0	0	0	0
14	14	1	NT	1	B	L	I	2006	early	0	0	0	0
15	15	2	NT	1	B	H	I	2006	early	0	0	2	0
16	16	2	CT	1	B	L	I	2006	early	0	0	0	0
17	17	3	NT	1	B	H	I	2006	early	0	0	0	0
18	18	3	CT	1	B	L	I	2006	early	0	0	0	0
19	19	1	CT	1	B	H	I	2006	early	0	0	0	0
20	20	1	NT	1	B	H	I	2006	early	0	0	0	0
21	21	2	NT	1	B	L	I	2006	early	0	0	0	0
22	22	2	CT	1	B	H	I	2006	early	0	0	0	0
23	23	3	NT	1	B	L	I	2006	early	0	0	0	0
24	24	3	CT	1	B	H	I	2006	early	0	0	0	0
25	25	1	CT	2	B	H	NI	2006	early	0	24	0	0
26	26	1	NT	2	B	H	NI	2006	early	0	24	0	0
27	27	2	NT	2	B	H	NI	2006	early	0	52	0	0
28	28	2	CT	2	B	L	NI	2006	early	0	0	0	0
29	29	3	NT	2	B	H	NI	2006	early	0	0	0	0
30	30	3	CT	2	B	L	NI	2006	early	0	0	0	0
31	31	1	CT	2	B	L	NI	2006	early	0	12	0	0
32	32	1	NT	2	B	L	NI	2006	early	0	44	4	0
33	33	2	NT	2	B	L	NI	2006	early	0	100	0	0
34	34	2	CT	2	B	H	NI	2006	early	0	0	0	0
35	35	3	NT	2	B	L	NI	2006	early	0	0	0	0
36	36	3	CT	2	B	H	NI	2006	early	0	356	0	0
37	37	1	CT	2	NB	H	NI	2006	early	0	0	0	0

obs#	plot	tblock	till	bblock	burn	res	IR	year	season	spurge	spurge	trumpet	vetch
38	38	1	NT	2	NB	L	NI	2006	early	0	0	0	0
39	39	2	NT	2	NB	H	NI	2006	early	0	4	0	0
40	40	2	CT	2	NB	H	NI	2006	early	0	0	0	0
41	41	3	NT	2	NB	L	NI	2006	early	0	0	4	0
42	42	3	CT	2	NB	H	NI	2006	early	0	0	0	0
43	43	1	CT	2	NB	L	NI	2006	early	0	0	0	0
44	44	1	NT	2	NB	H	NI	2006	early	0	0	0	0
45	45	2	NT	2	NB	L	NI	2006	early	0	0	0	0
46	46	2	CT	2	NB	L	NI	2006	early	0	0	0	0
47	47	3	NT	2	NB	H	NI	2006	early	0	0	0	0
48	48	3	CT	2	NB	L	NI	2006	early	0	0	0	0
49	1	1	CT	1	NB	H	I	2006	late	0	0	0	0
50	2	1	NT	1	NB	L	I	2006	late	0	0	0	0
51	3	2	NT	1	NB	H	I	2006	late	0	0	0	0
52	4	2	CT	1	NB	L	I	2006	late	0	0	0	0
53	5	3	NT	1	NB	L	I	2006	late	0	0	0	0
54	6	3	CT	1	NB	H	I	2006	late	0	0	0	0
55	7	1	CT	1	NB	L	I	2006	late	0	0	0	0
56	8	1	NT	1	NB	H	I	2006	late	0	0	0	0
57	9	2	NT	1	NB	L	I	2006	late	0	0	0	0
58	10	2	CT	1	NB	H	I	2006	late	0	0	2	0
59	11	3	NT	1	NB	H	I	2006	late	0	0	4	0
60	12	3	CT	1	NB	L	I	2006	late	0	0	0	0
61	13	1	CT	1	B	L	I	2006	late	0	0	0	0
62	14	1	NT	1	B	L	I	2006	late	0	0	0	0
63	15	2	NT	1	B	H	I	2006	late	0	0	0	0
64	16	2	CT	1	B	L	I	2006	late	0	0	0	0
65	17	3	NT	1	B	H	I	2006	late	0	0	0	0
66	18	3	CT	1	B	L	I	2006	late	0	0	2	0
67	19	1	CT	1	B	H	I	2006	late	0	0	4	0
68	20	1	NT	1	B	H	I	2006	late	0	0	2	0
69	21	2	NT	1	B	L	I	2006	late	0	0	0	0
70	22	2	CT	1	B	H	I	2006	late	0	0	0	0
71	23	3	NT	1	B	L	I	2006	late	0	0	0	0
72	24	3	CT	1	B	H	I	2006	late	0	0	4	0
73	25	1	CT	2	B	H	NI	2006	late	0	0	0	0
74	26	1	NT	2	B	H	NI	2006	late	2	0	0	0
75	27	2	NT	2	B	H	NI	2006	late	0	0	0	0
76	28	2	CT	2	B	L	NI	2006	late	0	0	0	0
77	29	3	NT	2	B	H	NI	2006	late	0	0	0	0

obs#	plot	tblock	till	bblock	burn	res	IR	year	season	spurge	spurge	trumpet	vetch
78	30	3	CT	2	B	L	NI	2006	late	0	0	0	0
79	31	1	CT	2	B	L	NI	2006	late	10	0	0	0
80	32	1	NT	2	B	L	NI	2006	late	2	0	0	0
81	33	2	NT	2	B	L	NI	2006	late	0	0	0	0
82	34	2	CT	2	B	H	NI	2006	late	0	0	0	0
83	35	3	NT	2	B	L	NI	2006	late	0	0	0	0
84	36	3	CT	2	B	H	NI	2006	late	0	0	0	0
85	37	1	CT	2	NB	H	NI	2006	late	0	0	0	0
86	38	1	NT	2	NB	L	NI	2006	late	0	0	0	0
87	39	2	NT	2	NB	H	NI	2006	late	0	0	2	0
88	40	2	CT	2	NB	H	NI	2006	late	0	0	0	0
89	41	3	NT	2	NB	L	NI	2006	late	0	2	0	0
90	42	3	CT	2	NB	H	NI	2006	late	0	0	0	0
91	43	1	CT	2	NB	L	NI	2006	late	0	0	0	0
92	44	1	NT	2	NB	H	NI	2006	late	0	0	0	0
93	45	2	NT	2	NB	L	NI	2006	late	0	0	0	0
94	46	2	CT	2	NB	L	NI	2006	late	0	0	0	0
95	47	3	NT	2	NB	H	NI	2006	late	0	0	0	0
96	48	3	CT	2	NB	L	NI	2006	late	0	0	0	0
97	1	1	CT	1	NB	H	I	2007	early	0	0	0	0
98	2	1	NT	1	NB	L	I	2007	early	0	0	0	0
99	3	2	NT	1	NB	H	I	2007	early	0	0	0	0
100	4	2	CT	1	NB	L	I	2007	early	0	0	0	0
101	5	3	NT	1	NB	L	I	2007	early	0	0	0	0
102	6	3	CT	1	NB	H	I	2007	early	0	0	0	0
103	7	1	CT	1	NB	L	I	2007	early	0	0	0	0
104	8	1	NT	1	NB	H	I	2007	early	0	0	0	0
105	9	2	NT	1	NB	L	I	2007	early	0	0	0	0
106	10	2	CT	1	NB	H	I	2007	early	0	0	0	0
107	11	3	NT	1	NB	H	I	2007	early	0	0	0	0
108	12	3	CT	1	NB	L	I	2007	early	0	0	0	0
109	13	1	CT	1	B	L	I	2007	early	0	0	0	0
110	14	1	NT	1	B	L	I	2007	early	0	0	0	0
111	15	2	NT	1	B	H	I	2007	early	0	0	0	0
112	16	2	CT	1	B	L	I	2007	early	0	0	0	0
113	17	3	NT	1	B	H	I	2007	early	0	0	0	0
114	18	3	CT	1	B	L	I	2007	early	0	0	0	0
115	19	1	CT	1	B	H	I	2007	early	0	0	0	0
116	20	1	NT	1	B	H	I	2007	early	0	0	0	0
117	21	2	NT	1	B	L	I	2007	early	0	0	0	0
118	22	2	CT	1	B	H	I	2007	early	0	0	0	0

obs#	plot	tblock	till	bblock	burn	res	IR	year	season	spurge	spurge	trumpet	vetch
119	23	3	NT	1	B	L	I	2007	early	0	0	0	0
120	24	3	CT	1	B	H	I	2007	early	0	0	0	0
121	25	1	CT	2	B	H	NI	2007	early	0	8	0	0
122	26	1	NT	2	B	H	NI	2007	early	0	4	0	0
123	27	2	NT	2	B	H	NI	2007	early	0	0	0	0
124	28	2	CT	2	B	L	NI	2007	early	0	2	0	0
125	29	3	NT	2	B	H	NI	2007	early	0	0	0	0
126	30	3	CT	2	B	L	NI	2007	early	0	0	0	0
127	31	1	CT	2	B	L	NI	2007	early	0	8	0	0
128	32	1	NT	2	B	L	NI	2007	early	0	2	0	0
129	33	2	NT	2	B	L	NI	2007	early	0	2	0	0
130	34	2	CT	2	B	H	NI	2007	early	0	0	0	0
131	35	3	NT	2	B	L	NI	2007	early	0	0	0	0
132	36	3	CT	2	B	H	NI	2007	early	0	0	0	0
133	37	1	CT	2	NB	H	NI	2007	early	0	2	0	0
134	38	1	NT	2	NB	L	NI	2007	early	0	2	0	0
135	39	2	NT	2	NB	H	NI	2007	early	0	2	0	0
136	40	2	CT	2	NB	H	NI	2007	early	0	6	0	0
137	41	3	NT	2	NB	L	NI	2007	early	0	2	0	0
138	42	3	CT	2	NB	H	NI	2007	early	0	4	0	0
139	43	1	CT	2	NB	L	NI	2007	early	0	0	0	0
140	44	1	NT	2	NB	H	NI	2007	early	0	0	0	0
141	45	2	NT	2	NB	L	NI	2007	early	0	0	0	0
142	46	2	CT	2	NB	L	NI	2007	early	0	0	0	0
143	47	3	NT	2	NB	H	NI	2007	early	0	6	0	0
144	48	3	CT	2	NB	L	NI	2007	early	0	0	0	0
145	1	1	CT	1	NB	H	I	2007	late	0	0	0	0
146	2	1	NT	1	NB	L	I	2007	late	0	0	0	0
147	3	2	NT	1	NB	H	I	2007	late	0	0	0	0
148	4	2	CT	1	NB	L	I	2007	late	0	0	0	0
149	5	3	NT	1	NB	L	I	2007	late	0	0	0	0
150	6	3	CT	1	NB	H	I	2007	late	0	0	0	2
151	7	1	CT	1	NB	L	I	2007	late	0	0	0	0
152	8	1	NT	1	NB	H	I	2007	late	0	0	0	0
153	9	2	NT	1	NB	L	I	2007	late	0	0	0	0
154	10	2	CT	1	NB	H	I	2007	late	0	0	0	2
155	11	3	NT	1	NB	H	I	2007	late	0	0	0	0
156	12	3	CT	1	NB	L	I	2007	late	0	0	0	4
157	13	1	CT	1	B	L	I	2007	late	0	0	0	0
158	14	1	NT	1	B	L	I	2007	late	0	0	0	0
159	15	2	NT	1	B	H	I	2007	late	0	0	0	0

obs#	plot	tblock	till	bblock	burn	res	IR	year	season	spurge	spurge	trumpet	vetch
160	16	2	CT	1	B	L	I	2007	late	0	0	0	0
161	17	3	NT	1	B	H	I	2007	late	0	0	0	0
162	18	3	CT	1	B	L	I	2007	late	0	0	0	0
163	19	1	CT	1	B	H	I	2007	late	0	0	2	0
164	20	1	NT	1	B	H	I	2007	late	0	0	0	0
165	21	2	NT	1	B	L	I	2007	late	0	0	0	0
166	22	2	CT	1	B	H	I	2007	late	0	0	0	2
167	23	3	NT	1	B	L	I	2007	late	0	0	2	0
168	24	3	CT	1	B	H	I	2007	late	0	0	2	0
169	25	1	CT	2	B	H	NI	2007	late	0	0	0	0
170	26	1	NT	2	B	H	NI	2007	late	0	0	0	0
171	27	2	NT	2	B	H	NI	2007	late	0	0	0	0
172	28	2	CT	2	B	L	NI	2007	late	0	0	0	0
173	29	3	NT	2	B	H	NI	2007	late	0	0	0	2
174	30	3	CT	2	B	L	NI	2007	late	0	2	0	0
175	31	1	CT	2	B	L	NI	2007	late	0	0	0	0
176	32	1	NT	2	B	L	NI	2007	late	0	0	4	2
177	33	2	NT	2	B	L	NI	2007	late	0	0	0	0
178	34	2	CT	2	B	H	NI	2007	late	0	0	0	0
179	35	3	NT	2	B	L	NI	2007	late	0	0	0	4
180	36	3	CT	2	B	H	NI	2007	late	0	2	0	0
181	37	1	CT	2	NB	H	NI	2007	late	0	0	0	0
182	38	1	NT	2	NB	L	NI	2007	late	0	0	0	0
183	39	2	NT	2	NB	H	NI	2007	late	0	0	0	0
184	40	2	CT	2	NB	H	NI	2007	late	0	0	0	0
185	41	3	NT	2	NB	L	NI	2007	late	0	0	0	0
186	42	3	CT	2	NB	H	NI	2007	late	0	0	0	0
187	43	1	CT	2	NB	L	NI	2007	late	0	0	0	2
188	44	1	NT	2	NB	H	NI	2007	late	0	0	0	0
189	45	2	NT	2	NB	L	NI	2007	late	0	0	0	0
190	46	2	CT	2	NB	L	NI	2007	late	0	0	0	2
191	47	3	NT	2	NB	H	NI	2007	late	0	4	0	0
192	48	3	CT	2	NB	L	NI	2007	late	0	0	0	4

Virginia pepperweed (VPW), white clover (wclover), wild onion (Wonion), yellow woodsorrel (YWS), and yellow nutsedge (YNS), densities in plants m^{-2}

obs#	plot	tblock	till	bblock	burn	res	IR	year	season	VPW	Wclover	Wonion	YWS	YNS
1	1	1	CT	1	NB	H	I	2006	early	0	0	0	0	0
2	2	1	NT	1	NB	L	I	2006	early	0	0	0	0	0
3	3	2	NT	1	NB	H	I	2006	early	0	0	0	0	0
4	4	2	CT	1	NB	L	I	2006	early	0	0	0	0	0
5	5	3	NT	1	NB	L	I	2006	early	0	0	0	4	0
6	6	3	CT	1	NB	H	I	2006	early	0	0	0	0	0
7	7	1	CT	1	NB	L	I	2006	early	0	0	0	0	0
8	8	1	NT	1	NB	H	I	2006	early	0	0	0	0	0
9	9	2	NT	1	NB	L	I	2006	early	0	0	0	4	0
10	10	2	CT	1	NB	H	I	2006	early	0	0	0	0	0
11	11	3	NT	1	NB	H	I	2006	early	0	0	0	8	0
12	12	3	CT	1	NB	L	I	2006	early	0	0	0	0	0
13	13	1	CT	1	B	L	I	2006	early	0	0	0	0	0
14	14	1	NT	1	B	L	I	2006	early	0	0	0	0	0
15	15	2	NT	1	B	H	I	2006	early	0	0	0	0	0
16	16	2	CT	1	B	L	I	2006	early	0	0	0	0	0
17	17	3	NT	1	B	H	I	2006	early	0	0	0	0	0
18	18	3	CT	1	B	L	I	2006	early	0	0	0	0	0
19	19	1	CT	1	B	H	I	2006	early	0	0	0	0	0
20	20	1	NT	1	B	H	I	2006	early	0	0	0	0	0
21	21	2	NT	1	B	L	I	2006	early	0	0	0	0	0
22	22	2	CT	1	B	H	I	2006	early	0	0	0	0	0
23	23	3	NT	1	B	L	I	2006	early	0	0	0	0	0
24	24	3	CT	1	B	H	I	2006	early	0	0	0	0	0
25	25	1	CT	2	B	H	NI	2006	early	0	0	0	0	0
26	26	1	NT	2	B	H	NI	2006	early	0	0	0	0	0
27	27	2	NT	2	B	H	NI	2006	early	0	0	0	0	0
28	28	2	CT	2	B	L	NI	2006	early	0	0	0	0	0
29	29	3	NT	2	B	H	NI	2006	early	0	0	0	0	0
30	30	3	CT	2	B	L	NI	2006	early	0	0	0	0	0
31	31	1	CT	2	B	L	NI	2006	early	0	0	0	0	0
32	32	1	NT	2	B	L	NI	2006	early	0	0	0	0	0
33	33	2	NT	2	B	L	NI	2006	early	0	0	0	0	0
34	34	2	CT	2	B	H	NI	2006	early	0	0	0	0	0
35	35	3	NT	2	B	L	NI	2006	early	0	0	0	0	0
36	36	3	CT	2	B	H	NI	2006	early	0	0	0	0	0
37	37	1	CT	2	NB	H	NI	2006	early	0	0	0	0	0

obs#	plot	tblock	till	bblock	burn	res	IR	year	season	VPW	Welover	Wonion	YWS	YNS
38	38	1	NT	2	NB	L	NI	2006	early	0	0	0	4	0
39	39	2	NT	2	NB	H	NI	2006	early	4	0	0	0	0
40	40	2	CT	2	NB	H	NI	2006	early	0	0	0	0	24
41	41	3	NT	2	NB	L	NI	2006	early	4	0	0	0	0
42	42	3	CT	2	NB	H	NI	2006	early	0	0	0	0	0
43	43	1	CT	2	NB	L	NI	2006	early	0	0	0	0	0
44	44	1	NT	2	NB	H	NI	2006	early	0	0	0	0	0
45	45	2	NT	2	NB	L	NI	2006	early	4	0	0	0	0
46	46	2	CT	2	NB	L	NI	2006	early	0	0	0	0	52
47	47	3	NT	2	NB	H	NI	2006	early	0	0	0	0	0
48	48	3	CT	2	NB	L	NI	2006	early	0	0	0	0	0
49	1	1	CT	1	NB	H	I	2006	late	0	0	0	0	0
50	2	1	NT	1	NB	L	I	2006	late	0	0	0	0	0
51	3	2	NT	1	NB	H	I	2006	late	0	0	0	0	0
52	4	2	CT	1	NB	L	I	2006	late	0	0	0	0	0
53	5	3	NT	1	NB	L	I	2006	late	0	0	0	0	0
54	6	3	CT	1	NB	H	I	2006	late	0	0	0	0	0
55	7	1	CT	1	NB	L	I	2006	late	0	0	0	0	0
56	8	1	NT	1	NB	H	I	2006	late	0	0	0	0	0
57	9	2	NT	1	NB	L	I	2006	late	0	0	0	0	0
58	10	2	CT	1	NB	H	I	2006	late	0	0	0	0	0
59	11	3	NT	1	NB	H	I	2006	late	0	0	0	0	0
60	12	3	CT	1	NB	L	I	2006	late	0	0	0	0	0
61	13	1	CT	1	B	L	I	2006	late	0	0	0	0	0
62	14	1	NT	1	B	L	I	2006	late	0	0	0	0	0
63	15	2	NT	1	B	H	I	2006	late	0	0	0	0	0
64	16	2	CT	1	B	L	I	2006	late	0	0	0	0	0
65	17	3	NT	1	B	H	I	2006	late	0	0	0	0	0
66	18	3	CT	1	B	L	I	2006	late	0	0	0	0	0
67	19	1	CT	1	B	H	I	2006	late	0	0	0	0	0
68	20	1	NT	1	B	H	I	2006	late	0	0	0	0	0
69	21	2	NT	1	B	L	I	2006	late	0	0	0	0	0
70	22	2	CT	1	B	H	I	2006	late	0	0	0	0	0
71	23	3	NT	1	B	L	I	2006	late	0	0	0	0	0
72	24	3	CT	1	B	H	I	2006	late	0	0	0	0	0
73	25	1	CT	2	B	H	NI	2006	late	0	0	0	0	0
74	26	1	NT	2	B	H	NI	2006	late	0	0	0	0	0
75	27	2	NT	2	B	H	NI	2006	late	0	0	0	0	0
76	28	2	CT	2	B	L	NI	2006	late	0	0	0	0	36
77	29	3	NT	2	B	H	NI	2006	late	0	0	0	0	0
78	30	3	CT	2	B	L	NI	2006	late	0	0	0	0	2

obs#	plot	tblock	till	bblock	burn	res	IR	year	season	VPW	Wclover	Wonion	YWS	YNS
79	31	1	CT	2	B	L	NI	2006	late	0	0	0	0	0
80	32	1	NT	2	B	L	NI	2006	late	0	0	0	0	0
81	33	2	NT	2	B	L	NI	2006	late	0	0	0	0	0
82	34	2	CT	2	B	H	NI	2006	late	0	0	0	0	48
83	35	3	NT	2	B	L	NI	2006	late	0	0	0	0	0
84	36	3	CT	2	B	H	NI	2006	late	0	0	0	0	0
85	37	1	CT	2	NB	H	NI	2006	late	0	0	0	0	0
86	38	1	NT	2	NB	L	NI	2006	late	0	0	0	0	0
87	39	2	NT	2	NB	H	NI	2006	late	0	0	0	0	0
88	40	2	CT	2	NB	H	NI	2006	late	0	0	0	0	0
89	41	3	NT	2	NB	L	NI	2006	late	0	0	0	0	2
90	42	3	CT	2	NB	H	NI	2006	late	0	0	0	0	0
91	43	1	CT	2	NB	L	NI	2006	late	0	0	0	0	0
92	44	1	NT	2	NB	H	NI	2006	late	0	0	0	0	0
93	45	2	NT	2	NB	L	NI	2006	late	0	0	0	0	0
94	46	2	CT	2	NB	L	NI	2006	late	0	0	0	0	0
95	47	3	NT	2	NB	H	NI	2006	late	0	0	0	0	0
96	48	3	CT	2	NB	L	NI	2006	late	0	0	0	0	0
97	1	1	CT	1	NB	H	I	2007	early	0	0	0	6	0
98	2	1	NT	1	NB	L	I	2007	early	0	0	0	66	0
99	3	2	NT	1	NB	H	I	2007	early	0	0	0	46	0
100	4	2	CT	1	NB	L	I	2007	early	0	0	0	0	0
101	5	3	NT	1	NB	L	I	2007	early	0	0	0	90	0
102	6	3	CT	1	NB	H	I	2007	early	0	0	0	0	0
103	7	1	CT	1	NB	L	I	2007	early	0	0	0	8	0
104	8	1	NT	1	NB	H	I	2007	early	0	0	0	6	0
105	9	2	NT	1	NB	L	I	2007	early	0	0	0	118	0
106	10	2	CT	1	NB	H	I	2007	early	0	0	0	2	0
107	11	3	NT	1	NB	H	I	2007	early	0	0	0	46	0
108	12	3	CT	1	NB	L	I	2007	early	0	0	0	0	0
109	13	1	CT	1	B	L	I	2007	early	0	0	0	0	0
110	14	1	NT	1	B	L	I	2007	early	0	0	0	8	0
111	15	2	NT	1	B	H	I	2007	early	0	0	0	4	0
112	16	2	CT	1	B	L	I	2007	early	0	0	0	0	0
113	17	3	NT	1	B	H	I	2007	early	0	0	0	10	0
114	18	3	CT	1	B	L	I	2007	early	0	0	0	0	2
115	19	1	CT	1	B	H	I	2007	early	0	0	0	0	0
116	20	1	NT	1	B	H	I	2007	early	0	0	0	6	0
117	21	2	NT	1	B	L	I	2007	early	0	0	0	28	0
118	22	2	CT	1	B	H	I	2007	early	0	0	0	0	0
119	23	3	NT	1	B	L	I	2007	early	0	0	0	2	0

obs#	plot	tblock	till	bblock	burn	res	IR	year	season	VPW	Wclover	Wonion	YWS	YNS
79	31	1	CT	2	B	L	NI	2006	late	0	0	0	0	0
80	32	1	NT	2	B	L	NI	2006	late	0	0	0	0	0
81	33	2	NT	2	B	L	NI	2006	late	0	0	0	0	0
82	34	2	CT	2	B	H	NI	2006	late	0	0	0	0	48
83	35	3	NT	2	B	L	NI	2006	late	0	0	0	0	0
84	36	3	CT	2	B	H	NI	2006	late	0	0	0	0	0
85	37	1	CT	2	NB	H	NI	2006	late	0	0	0	0	0
86	38	1	NT	2	NB	L	NI	2006	late	0	0	0	0	0
87	39	2	NT	2	NB	H	NI	2006	late	0	0	0	0	0
88	40	2	CT	2	NB	H	NI	2006	late	0	0	0	0	0
89	41	3	NT	2	NB	L	NI	2006	late	0	0	0	0	2
90	42	3	CT	2	NB	H	NI	2006	late	0	0	0	0	0
91	43	1	CT	2	NB	L	NI	2006	late	0	0	0	0	0
92	44	1	NT	2	NB	H	NI	2006	late	0	0	0	0	0
93	45	2	NT	2	NB	L	NI	2006	late	0	0	0	0	0
94	46	2	CT	2	NB	L	NI	2006	late	0	0	0	0	0
95	47	3	NT	2	NB	H	NI	2006	late	0	0	0	0	0
96	48	3	CT	2	NB	L	NI	2006	late	0	0	0	0	0
97	1	1	CT	1	NB	H	I	2007	early	0	0	0	6	0
98	2	1	NT	1	NB	L	I	2007	early	0	0	0	66	0
99	3	2	NT	1	NB	H	I	2007	early	0	0	0	46	0
100	4	2	CT	1	NB	L	I	2007	early	0	0	0	0	0
101	5	3	NT	1	NB	L	I	2007	early	0	0	0	90	0
102	6	3	CT	1	NB	H	I	2007	early	0	0	0	0	0
103	7	1	CT	1	NB	L	I	2007	early	0	0	0	8	0
104	8	1	NT	1	NB	H	I	2007	early	0	0	0	6	0
105	9	2	NT	1	NB	L	I	2007	early	0	0	0	118	0
106	10	2	CT	1	NB	H	I	2007	early	0	0	0	2	0
107	11	3	NT	1	NB	H	I	2007	early	0	0	0	46	0
108	12	3	CT	1	NB	L	I	2007	early	0	0	0	0	0
109	13	1	CT	1	B	L	I	2007	early	0	0	0	0	0
110	14	1	NT	1	B	L	I	2007	early	0	0	0	8	0
111	15	2	NT	1	B	H	I	2007	early	0	0	0	4	0
112	16	2	CT	1	B	L	I	2007	early	0	0	0	0	0
113	17	3	NT	1	B	H	I	2007	early	0	0	0	10	0
114	18	3	CT	1	B	L	I	2007	early	0	0	0	0	2
115	19	1	CT	1	B	H	I	2007	early	0	0	0	0	0
116	20	1	NT	1	B	H	I	2007	early	0	0	0	6	0
117	21	2	NT	1	B	L	I	2007	early	0	0	0	28	0
118	22	2	CT	1	B	H	I	2007	early	0	0	0	0	0
119	23	3	NT	1	B	L	I	2007	early	0	0	0	2	0

obs#	plot	tblock	till	bblock	burn	res	IR	year	season	VPW	Wclover	Wonion	YWS	YNS
120	24	3	CT	1	B	H	I	2007	early	0	0	0	12	0
121	25	1	CT	2	B	H	NI	2007	early	0	0	0	2	0
122	26	1	NT	2	B	H	NI	2007	early	0	0	0	14	0
123	27	2	NT	2	B	H	NI	2007	early	0	0	0	8	0
124	28	2	CT	2	B	L	NI	2007	early	0	0	0	2	0
125	29	3	NT	2	B	H	NI	2007	early	0	0	0	16	0
126	30	3	CT	2	B	L	NI	2007	early	0	0	0	2	0
127	31	1	CT	2	B	L	NI	2007	early	0	0	0	2	0
128	32	1	NT	2	B	L	NI	2007	early	6	150	0	20	0
129	33	2	NT	2	B	L	NI	2007	early	0	0	0	38	0
130	34	2	CT	2	B	H	NI	2007	early	0	0	0	2	0
131	35	3	NT	2	B	L	NI	2007	early	6	40	0	38	0
132	36	3	CT	2	B	H	NI	2007	early	0	0	0	8	0
133	37	1	CT	2	NB	H	NI	2007	early	0	0	0	0	0
134	38	1	NT	2	NB	L	NI	2007	early	0	0	0	0	0
135	39	2	NT	2	NB	H	NI	2007	early	2	0	0	0	0
136	40	2	CT	2	NB	H	NI	2007	early	0	0	0	0	0
137	41	3	NT	2	NB	L	NI	2007	early	4	0	0	16	0
138	42	3	CT	2	NB	H	NI	2007	early	0	0	0	0	0
139	43	1	CT	2	NB	L	NI	2007	early	0	0	0	0	0
140	44	1	NT	2	NB	H	NI	2007	early	0	0	0	2	0
141	45	2	NT	2	NB	L	NI	2007	early	0	0	0	6	0
142	46	2	CT	2	NB	L	NI	2007	early	0	0	0	0	0
143	47	3	NT	2	NB	H	NI	2007	early	6	0	0	0	0
144	48	3	CT	2	NB	L	NI	2007	early	0	0	0	0	0
145	1	1	CT	1	NB	H	I	2007	late	0	0	0	0	0
146	2	1	NT	1	NB	L	I	2007	late	0	0	0	0	0
147	3	2	NT	1	NB	H	I	2007	late	0	0	0	0	0
148	4	2	CT	1	NB	L	I	2007	late	0	0	0	0	0
149	5	3	NT	1	NB	L	I	2007	late	0	0	0	0	0
150	6	3	CT	1	NB	H	I	2007	late	0	0	0	0	0
151	7	1	CT	1	NB	L	I	2007	late	0	0	0	0	0
152	8	1	NT	1	NB	H	I	2007	late	0	0	0	0	0
153	9	2	NT	1	NB	L	I	2007	late	0	0	0	0	0
154	10	2	CT	1	NB	H	I	2007	late	0	0	0	0	0
155	11	3	NT	1	NB	H	I	2007	late	0	0	0	0	0
156	12	3	CT	1	NB	L	I	2007	late	0	0	0	0	0
157	13	1	CT	1	B	L	I	2007	late	0	0	0	0	0
158	14	1	NT	1	B	L	I	2007	late	0	0	0	0	0
159	15	2	NT	1	B	H	I	2007	late	0	0	0	0	0
160	16	2	CT	1	B	L	I	2007	late	0	0	0	0	0

obs#	plot	tblock	till	bblock	burn	res	IR	year	season	VPW	Wclover	Wonion	YWS	YNS
161	17	3	NT	1	B	H	I	2007	late	0	0	0	0	0
162	18	3	CT	1	B	L	I	2007	late	0	0	0	0	0
163	19	1	CT	1	B	H	I	2007	late	0	0	0	0	0
164	20	1	NT	1	B	H	I	2007	late	0	0	0	0	0
165	21	2	NT	1	B	L	I	2007	late	0	0	0	0	0
166	22	2	CT	1	B	H	I	2007	late	0	0	0	4	0
167	23	3	NT	1	B	L	I	2007	late	0	0	10	0	0
168	24	3	CT	1	B	H	I	2007	late	0	0	0	0	0
169	25	1	CT	2	B	H	NI	2007	late	0	0	0	0	0
170	26	1	NT	2	B	H	NI	2007	late	0	0	2	0	0
171	27	2	NT	2	B	H	NI	2007	late	0	0	0	0	0
172	28	2	CT	2	B	L	NI	2007	late	0	0	0	4	0
173	29	3	NT	2	B	H	NI	2007	late	0	0	0	0	0
174	30	3	CT	2	B	L	NI	2007	late	0	0	0	0	0
175	31	1	CT	2	B	L	NI	2007	late	0	0	0	0	0
176	32	1	NT	2	B	L	NI	2007	late	0	0	24	0	0
177	33	2	NT	2	B	L	NI	2007	late	0	0	0	0	0
178	34	2	CT	2	B	H	NI	2007	late	0	0	20	0	0
179	35	3	NT	2	B	L	NI	2007	late	0	0	16	0	0
180	36	3	CT	2	B	H	NI	2007	late	0	0	0	0	0
181	37	1	CT	2	NB	H	NI	2007	late	0	0	0	0	0
182	38	1	NT	2	NB	L	NI	2007	late	0	0	0	0	0
183	39	2	NT	2	NB	H	NI	2007	late	0	0	0	0	0
184	40	2	CT	2	NB	H	NI	2007	late	0	0	0	0	0
185	41	3	NT	2	NB	L	NI	2007	late	0	0	0	0	0
186	42	3	CT	2	NB	H	NI	2007	late	0	0	0	0	0
187	43	1	CT	2	NB	L	NI	2007	late	0	0	0	0	0
188	44	1	NT	2	NB	H	NI	2007	late	0	0	0	0	0
189	45	2	NT	2	NB	L	NI	2007	late	0	0	0	0	0
190	46	2	CT	2	NB	L	NI	2007	late	0	0	0	0	0
191	47	3	NT	2	NB	H	NI	2007	late	0	0	0	0	0
192	48	3	CT	2	NB	L	NI	2007	late	0	0	2	0	0

obs# = observation number

Plot# = plot number

tbblock = tillage block

bblock = burn block

till = tillage [conventional tillage (CT) and no-tillage (NT)]

burn = burning [burn (B) and no burn (NB)]

NRate = nitrogen rate/residue level [high (H) and low (L)]

IR = irrigation [irrigated (I) and dry-land/non irrigated (NI)

year = time of weed assessment (2006, after 5, and 2007, after 6 years of consistent residue management)

season = soybean growing season [pre- (early) and postherbicide (late) application]

APPENDIX 6: Raw data used in chapter 4.

A. 2003

Soil penetration resistance (PR) at 0- to 30-cm depth at the interval of 5 cm

						……Penetration Resistance (kPa)……							
plot#	tblock	bblock	tillage	burn	fert	0 cm	5 cm	10 cm	15 cm	20 cm	25 cm	30 cm	35 cm
1	1	1	CT	NB	H	544	597	3072	4178	4301	3037	2142	2668
2	1	1	NT	NB	L	263	597	2546	3142	2493	2756	2563	2721
3	2	1	NT	NB	H	316	913	1931	2440	2633	4178	3230	2212
4	2	1	CT	NB	L	527	878	2229	2721	2984	3247	2686	1773
5	3	1	NT	NB	L	491	895	1966	2616	3335	2738	1913	1387
6	3	1	CT	NB	H	509	597	2457	3072	2967	2563	2106	1667
7	1	1	CT	NB	L	597	1053	2177	2791	3002	2826	2247	2300
8	1	1	NT	NB	H	491	474	1843	2124	2721	2826	2370	2159
9	2	1	NT	NB	L	526	807	1404	2370	2299	2546	2387	2071
10	2	1	CT	NB	H	439	1018	1545	2616	3739	2809	1843	1843
11	3	1	NT	NB	H	386	930	1896	2528	3897	2932	2089	1703
12	3	1	CT	NB	L	509	562	1703	2036	3248	2282	1966	1790
13	1	1	CT	B	L	491	526	1720	2036	1833	2334	2177	1475
14	1	1	NT	B	L	404	614	1527	2212	1948	2001	2528	2019
15	2	1	NT	B	H	650	790	1808	2615	2651	2458	2264	1983
16	2	1	CT	B	L	632	1176	1896	2440	2528	2264	2106	1966
17	3	1	NT	B	H	667	1088	1896	2212	2264	2124	2004	1949
18	3	1	CT	B	L	772	1070	1334	1790	1615	1756	1896	1825
19	1	1	CT	B	H	632	878	1825	2879	2107	1896	2844	2001
20	1	1	NT	B	H	632	1316	2405	2598	2300	2212	2387	1615
21	2	1	NT	B	L	685	1000	2633	3248	3212	2844	2177	1755
22	2	1	CT	B	H	650	948	2405	2335	2054	2194	2001	1949
23	3	1	NT	B	L	579	913	2247	2738	3125	2143	1984	2036
24	3	1	CT	B	H	649	1035	2563	2721	2440	1755	1773	1983
25	1	2	CT	B	H	579	1387	2071	2651	2124	2440	2510	2212
26	1	2	NT	B	H	614	1159	2107	2089	1422	1176	1475	1808
27	2	2	NT	B	H	579	1141	1790	2387	2212	2124	1896	1843
28	2	2	CT	B	L	632	632	1509	2422	2826	2177	1983	2300
29	3	2	NT	B	H	702	614	2001	2054	2141	2036	2054	2387
30	3	2	CT	B	L	790	1071	1843	1474	1667	2756	3634	4915
31	1	2	CT	B	L	1018	1088	1103	2282	2107	1861	1808	1387
32	1	2	NT	B	L	649	719	2018	2616	2089	1650	1632	1878
33	2	2	NT	B	L	544	667	1334	2230	1931	2001	2019	2089
34	2	2	CT	B	H	562	807	755	1949	1615	2194	2334	2124

plot#	tblock	bblock	tillage	burn	fert	……………………Penetration Resistance (kPa)…………………… 0 cm	5 cm	10 cm	15 cm	20 cm	25 cm	30 cm	35 cm
35	3	2	NT	B	L	544	807	2352	2703	2580	2370	3107	3370
36	3	2	CT	B	H	702	913	1299	1562	1369	1527	1931	2207
37	1	2	CT	NB	H	808	825	1439	2282	2054	2107	3037	3722
38	1	2	NT	NB	L	474	492	1369	2440	2510	2721	2808	3687
39	2	2	NT	NB	H	632	983	2159	1984	2001	3528	3458	4442
40	2	2	CT	NB	H	965	1703	2405	2458	1826	2686	4441	4827
41	3	2	NT	NB	L	403	737	842	2142	1615	1773	3072	4090
42	3	2	CT	NB	H	807	1475	2194	1914	1720	2300	2668	2493
43	1	2	CT	NB	L	684	787	1527	2019	1562	2352	4108	4950
44	1	2	NT	NB	H	614	1158	2317	2633	1843	2545	3651	4687
45	2	2	NT	NB	L	491	737	1843	2141	2019	2809	4231	4178
46	2	2	CT	NB	L	684	1070	1246	2475	2405	3002	3704	3915
47	3	2	NT	NB	H	632	913	1492	2335	2265	3809	4986	5372
48	3	2	CT	NB	L	474	790	1281	1896	2370	3142	2826	3476

Soil PR at 40 cm (kPa), moisture content (cm^3 cm^{-3}), sand, silt, and clay (g g^{-1}), soil bulk density (BD) (g cm^{-3}) at 10-cm depth, average PR at 10 to 15-cm depth (kPa), and soybean yield (Mg ha^{-1})

plot#	tblock	bblock	tillage	burn	fert	PR 40cm	vol MC	sand	silt	clay	OM	BD	PR 10-15cm	soybean
1	1	1	CT	NB	H	2159	0.32	0.17	0.79	0.04	13.3	1.22	3625	3.80
2	1	1	NT	NB	L	2475	0.26	0.20	0.77	0.04	26.7	1.30	2844	4.25
3	2	1	NT	NB	H	1931	0.32	0.20	0.75	0.06	15.5	1.27	2185	3.87
4	2	1	CT	NB	L	1632	0.32	0.13	0.75	0.13	17.6	1.23	2475	2.60
5	3	1	NT	NB	L	1598	0.31	0.21	0.72	0.07	14.7	1.21	2291	3.35
6	3	1	CT	NB	H	1422	0.29	0.19	0.72	0.09	19.7	1.26	2765	2.98
7	1	1	CT	NB	L	2282	0.32	0.18	0.78	0.04	16.4	1.23	2484	3.29
8	1	1	NT	NB	H	1755	0.29	0.19	0.75	0.06	19.2	1.30	1983	3.86
9	2	1	NT	NB	L	1966	0.32	0.19	0.76	0.05	16.7	1.34	1887	3.81
10	2	1	CT	NB	H	1598	0.32	0.20	0.73	0.07	15.9	1.25	2080	2.97
11	3	1	NT	NB	H	1562	0.29	0.17	0.75	0.08	20.8	1.32	2212	3.31
12	3	1	CT	NB	L	1791	0.30	0.18	0.72	0.10	14.6	1.34	1869	3.65
13	1	1	CT	B	L	1597	0.31	0.15	0.75	0.11	18.3	1.25	1878	3.77
14	1	1	NT	B	L	1598	0.29	0.15	0.73	0.12	14.1	1.34	1869	4.45
15	2	1	NT	B	H	1808	0.30	0.15	0.72	0.13	21.7	1.33	2211	4.41
16	2	1	CT	B	L	1791	0.42	0.14	0.73	0.13	22.8	1.22	2168	3.57

plot#	tblock	bblock	tillage	burn	fert	PR 40cm	vol MC	sand	silt	clay	OM	BD	PR 10-15cm	soybean
17	3	1	NT	B	H	1966	0.31	0.14	0.72	0.14	19.1	1.31	2054	4.94
18	3	1	CT	B	L	1808	0.32	0.15	0.72	0.14	18.3	1.29	1562	3.24
19	1	1	CT	B	H	1737	0.33	0.15	0.76	0.10	18.6	1.30	2352	3.31
20	1	1	NT	B	H	1229	0.31	0.20	0.71	0.09	20.4	1.32	2501	3.51
21	2	1	NT	B	L	1439	0.29	0.19	0.71	0.10	18.0	1.38	2940	3.94
22	2	1	CT	B	H	1755	0.32	0.19	0.70	0.11	17.0	1.33	2370	3.01
23	3	1	NT	B	L	2089	0.30	0.18	0.70	0.12	13.7	1.30	2492	3.87
24	3	1	CT	B	H	2106	0.31	0.19	0.70	0.12	18.8	1.27	2642	3.28
25	1	2	CT	B	H	2440	0.32	0.16	0.71	0.13	17.4	1.32	2361	3.86
26	1	2	NT	B	H	2142	0.31	0.20	0.68	0.13	16.8	1.39	2098	3.60
27	2	2	NT	B	H	2282	0.29	0.19	0.70	0.12	20.9	1.24	2089	3.97
28	2	2	CT	B	L	2159	0.28	0.19	0.71	0.11	19.4	1.21	1966	3.54
29	3	2	NT	B	H	3739	0.26	0.18	0.70	0.12	26.9	1.34	2028	3.95
30	3	2	CT	B	L	4002	0.30	0.15	0.73	0.12	16.1	1.31	1658	3.14
31	1	2	CT	B	L	2177	0.29	0.15	0.72	0.13	27.3	1.25	1693	3.41
32	1	2	NT	B	L	1825	0.28	0.15	0.71	0.14	14.7	1.30	2317	3.77
33	2	2	NT	B	L	2071	0.30	0.16	0.71	0.13	20.3	1.36	1782	3.97
34	2	2	CT	B	H	2580	0.30	0.14	0.72	0.14	17.2	1.30	1352	3.83
35	3	2	NT	B	L	4003	0.29	0.15	0.71	0.14	16.9	1.36	2528	4.08
36	3	2	CT	B	H	2229	0.33	0.15	0.71	0.14	19.6	1.30	1430	3.56
37	1	2	CT	NB	H	3072	0.32	0.14	0.69	0.17	20.0	1.19	1860	3.74
38	1	2	NT	NB	L	5249	0.27	0.16	0.79	0.06	22.6	1.29	1904	2.96
39	2	2	NT	NB	H	5319	0.31	0.16	0.71	0.14	24.9	1.28	2071	3.97
40	2	2	CT	NB	H	4318	0.34	0.15	0.73	0.13	20.3	1.26	2431	2.78
41	3	2	NT	NB	L	4055	0.28	0.13	0.73	0.14	20.4	1.32	1492	4.30
42	3	2	CT	NB	H	2545	0.32	0.12	0.74	0.14	20.6	1.31	2054	3.97
43	1	2	CT	NB	L	4371	0.31	0.14	0.73	0.14	21.8	1.30	1773	3.39
44	1	2	NT	NB	H	4459	0.31	0.14	0.72	0.14	22.3	1.29	2475	3.65
45	2	2	NT	NB	L	4248	0.32	0.11	0.75	0.14	24.1	1.29	1992	3.88
46	2	2	CT	NB	L	4055	0.31	0.14	0.73	0.14	35.0	1.22	1861	2.61
47	3	2	NT	NB	H	5635	0.30	0.16	0.71	0.13	20.6	1.33	1913	4.01
48	3	2	CT	NB	L	3932	0.31	0.13	0.74	0.14	20.1	1.30	1588	3.65

B. 2006

Soil PR at 0- to 30-cm depth at the interval of 5 cm

						……………………Penetration Resistance (kPa)……………………						
plot#	**tblock**	**bblock**	**tillage**	**burn**	**fert**	**0 cm**	**5 cm**	**10 cm**	**15 cm**	**20 cm**	**25 cm**	**30 cm**
1	1	1	CT	NB	H	316	1036	2475	2949	3616	3055	1861
2	1	1	NT	NB	L	421	1422	1843	2879	3107	2580	2212
3	2	1	NT	NB	H	316	1141	1896	2984	2896	2581	2282
4	2	1	CT	NB	L	280	808	1685	2931	3072	2773	2398
5	3	1	NT	NB	L	421	1422	2528	2984	2756	2247	1527
6	3	1	CT	NB	H	439	913	2019	3020	2879	2054	1439
7	1	1	CT	NB	L	386	1475	2387	3634	4284	4353	2914
8	1	1	NT	NB	H	474	1582	2498	2914	3107	3441	3072
9	2	1	NT	NB	L	281	1141	2247	2229	2721	2984	3388
10	2	1	CT	NB	H	614	1580	2686	3107	2633	2230	1720
11	3	1	NT	NB	H	404	1106	1913	2124	2651	2089	1404
12	3	1	CT	NB	L	316	1071	2545	3599	3790	2640	1773
13	1	1	CT	B	L	421	825	2054	3054	2861	2615	2809
14	1	1	NT	B	L	316	1159	2106	2879	3371	2826	2387
15	2	1	NT	B	H	211	1510	2194	3090	2861	2826	1826
16	2	1	CT	B	L	316	1387	2072	2703	2896	2247	1773
17	3	1	NT	B	H	386	1018	2300	2545	2001	2019	1790
18	3	1	CT	B	L	140	597	1738	2370	2616	1755	1948
19	1	1	CT	B	H	281	1194	1896	3107	3283	3458	2686
20	1	1	NT	B	H	369	1246	2282	3230	3423	2809	2932
21	2	1	NT	B	L	386	1667	2984	3546	3072	2229	1914
22	2	1	CT	B	H	316	1088	2475	3423	3124	1808	1896
23	3	1	NT	B	L	263	1071	1598	2633	2598	2388	2299
24	3	1	CT	B	H	245	842	1826	2984	1870	1650	1562
25	1	2	CT	B	H	351	755	1700	2914	1913	2107	2036
26	1	2	NT	B	H	245	1018	1562	2194	2212	1580	1668
27	2	2	NT	B	H	298	1246	1773	2265	1825	1931	2001
28	2	2	CT	B	L	175	667	948	2177	2317	1685	1703
29	3	2	NT	B	H	316	948	1299	1545	2071	2019	1808
30	3	2	CT	B	L	298	374	1597	2335	2142	2124	1475
31	1	2	CT	B	L	281	1088	1984	2932	2721	2212	2159
32	1	2	NT	B	L	333	1475	1826	2563	2317	2072	1825
33	2	2	NT	B	L	684	1510	1913	2809	2633	2036	2387
34	2	2	CT	B	H	404	720	1422	2897	3072	1720	1738

						……………………Penetration Resistance (kPa)……………………						
plot#	tblock	bblock	tillage	burn	fert	0 cm	5 cm	10 cm	15 cm	20 cm	25 cm	30 cm
35	3	2	NT	B	L	439	1281	2106	2826	3037	2704	2036
36	3	2	CT	B	H	351	737	878	2510	2545	1668	2673
37	1	2	CT	NB	H	316	649	1544	2352	2282	1825	2704
38	1	2	NT	NB	L	544	1246	1735	2949	2756	2458	2247
39	2	2	NT	NB	H	439	1773	2563	2844	2721	2703	3563
40	2	2	CT	NB	H	474	1176	2405	2896	2721	2791	3827
41	3	2	NT	NB	L	544	1808	2580	2633	2071	2106	3248
42	3	2	CT	NB	H	210	1281	2457	2651	1966	2142	2335
43	1	2	CT	NB	L	263	579	1492	2879	3002	2490	3370
44	1	2	NT	NB	H	316	877	1633	2581	2265	2528	2668
45	2	2	NT	NB	L	368	1422	2791	3248	2405	1790	3599
46	2	2	CT	NB	L	298	755	1966	2563	2879	2668	2967
47	3	2	NT	NB	H	386	1264	1843	2457	2089	2739	4371
48	3	2	CT	NB	L	369	510	1334	2493	3160	3300	3090

Soil PR at 35 and 40 cm depth (kPa), volumetric moisture content (vol MC) (cm^3 cm^{-3}), and sand, silt, and clay contents (g g^{-1})

						….PR (kPa)…..					
plot#	tblock	bblock	tillage	burn	fert	35 cm	40 cm	vol MC	sand	silt	clay
1	1	1	CT	NB	H	2071	2571	0.45	0.24	0.65	0.11
2	1	1	NT	NB	L	2563	2633	0.42	0.23	0.68	0.08
3	2	1	NT	NB	H	2388	1685	0.39	0.24	0.69	0.07
4	2	1	CT	NB	L	2633	2615	0.39	0.25	0.64	0.10
5	3	1	NT	NB	L	1510	1509	0.40	0.23	0.65	0.11
6	3	1	CT	NB	H	1352	1544	0.40	0.27	0.58	0.14
7	1	1	CT	NB	L	2616	1984	0.41	0.22	0.71	0.07
8	1	1	NT	NB	H	2844	2106	0.43	0.22	0.68	0.09
9	2	1	NT	NB	L	2686	1720	0.39	0.23	0.66	0.10
10	2	1	CT	NB	H	1229	1527	0.40	0.20	0.67	0.13
11	3	1	NT	NB	H	1211	1176	0.41	0.22	0.64	0.14
12	3	1	CT	NB	L	1632	1633	0.41	0.20	0.66	0.14
13	1	1	CT	B	L	2177	1071	0.40	0.24	0.64	0.12
14	1	1	NT	B	L	1896	1650	0.40	0.22	0.66	0.12
15	2	1	NT	B	H	1703	1791	0.44	0.22	0.59	0.19
16	2	1	CT	B	L	1755	1878	0.43	0.24	0.58	0.18
17	3	1	NT	B	H	2036	2019	0.40	0.24	0.59	0.17

						....PR (kPa).....					
plot#	tblock	bblock	tillage	burn	fert	35 cm	40 cm	vol MC	sand	silt	clay
18	3	1	CT	B	L	1738	1948	0.40	0.22	0.58	0.21
19	1	1	CT	B	H	1562	1457	0.45	0.23	0.64	0.13
20	1	1	NT	B	H	1984	1685	0.41	0.16	0.67	0.17
21	2	1	NT	B	L	2019	1931	0.44	0.18	0.65	0.18
22	2	1	CT	B	H	1668	1738	0.43	0.20	0.63	0.17
23	3	1	NT	B	L	2457	2282	0.41	0.23	0.60	0.17
24	3	1	CT	B	H	1650	2264	0.41	0.13	0.56	0.31
25	1	2	CT	B	H	1703	2019	0.43	0.18	0.64	0.19
26	1	2	NT	B	H	1878	1826	0.42	0.13	0.66	0.21
27	2	2	NT	B	H	1826	2054	0.41	0.16	0.67	0.17
28	2	2	CT	B	L	2019	1931	0.41	0.21	0.60	0.19
29	3	2	NT	B	H	2580	3054	0.43	0.15	0.66	0.19
30	3	2	CT	B	L	3335	2896	0.42	0.18	0.65	0.18
31	1	2	CT	B	L	2071	2036	0.41	0.18	0.64	0.18
32	1	2	NT	B	L	2106	2879	0.39	0.20	0.62	0.19
33	2	2	NT	B	L	2388	2546	0.40	0.23	0.66	0.11
34	2	2	CT	B	H	2054	2159	0.41	0.20	0.64	0.16
35	3	2	NT	B	L	2212	2300	0.42	0.21	0.61	0.18
36	3	2	CT	B	H	3102	3616	0.42	0.19	0.66	0.15
37	1	2	CT	NB	H	3002	3897	0.44	0.22	0.62	0.17
38	1	2	NT	NB	L	2387	2686	0.41	0.22	0.64	0.15
39	2	2	NT	NB	H	3862	3476	0.41	0.19	0.64	0.17
40	2	2	CT	NB	H	4389	3511	0.43	0.20	0.61	0.19
41	3	2	NT	NB	L	3388	2651	0.41	0.17	0.65	0.18
42	3	2	CT	NB	H	2282	2581	0.41	0.17	0.66	0.17
43	1	2	CT	NB	L	4073	3897	0.43	0.18	0.66	0.16
44	1	2	NT	NB	H	3722	3721	0.41	0.19	0.63	0.18
45	2	2	NT	NB	L	4547	5723	0.38	0.21	0.62	0.17
46	2	2	CT	NB	L	2967	5232	0.42	0.21	0.62	0.17
47	3	2	NT	NB	H	3686	3634	0.41	0.19	0.62	0.19
48	3	2	CT	NB	L	3774	3862	0.38	0.20	0.64	0.17

Moisture content (MC)in the 40-cm depth, soil organic matter concentration (OM) (g g^{-1}), bulk density (BD) (g cm^{-3}), average PR at 10 to 15 cm depth (PR 10-15cm) (kPa), soybean yield (Mg ha^{-1})

plot#	tblock	bblock	tillage	burn	fert	MC(g/g)	OM	BD	PR 10-15cm	soybean
1	1	1	CT	NB	H	0.26	22.1	1.27	2712	3.12
2	1	1	NT	NB	L	0.25	18.8	1.20	2361	2.68
3	2	1	NT	NB	H	0.25	21.0	1.18	2440	2.79
4	2	1	CT	NB	L	0.25	18.2	1.28	2308	3.24
5	3	1	NT	NB	L	0.22	19.3	1.09	2756	2.65
6	3	1	CT	NB	H	0.25	22.3	1.26	2519	3.24
7	1	1	CT	NB	L	0.24	19.4	1.17	3010	2.85
8	1	1	NT	NB	H	0.26	20.6	1.19	2706	2.83
9	2	1	NT	NB	L	0.25	22.3	1.21	2238	2.79
10	2	1	CT	NB	H	0.24	19.3	1.26	2896	3.21
11	3	1	NT	NB	H	0.25	23.4	1.22	2019	2.87
12	3	1	CT	NB	L	0.24	21.2	1.23	3072	3.50
13	1	1	CT	B	L	0.24	21.3	1.27	2554	3.75
14	1	1	NT	B	L	0.23	18.1	1.24	2492	3.96
15	2	1	NT	B	H	0.25	21.4	1.28	2642	4.02
16	2	1	CT	B	L	0.25	19.8	1.24	2387	4.38
17	3	1	NT	B	H	0.25	19.1	1.25	2422	3.98
18	3	1	CT	B	L	0.25	20.1	1.12	2054	3.63
19	1	1	CT	B	H	0.25	27.9	1.30	2501	3.31
20	1	1	NT	B	H	0.22	21.4	1.23	2756	3.52
21	2	1	NT	B	L	0.23	19.2	1.30	3265	3.14
22	2	1	CT	B	H	0.25	21.2	1.20	2949	3.93
23	3	1	NT	B	L	0.24	19.4	1.12	2115	3.59
24	3	1	CT	B	H	0.25	20.7	1.20	2405	3.83
25	1	2	CT	B	H	0.26	24.7	1.25	2307	2.00
26	1	2	NT	B	H	0.26	23.1	1.26	1878	0.97
27	2	2	NT	B	H	0.25	25.5	1.27	2019	0.78
28	2	2	CT	B	L	0.29	24.9	1.17	1562	0.89
29	3	2	NT	B	H	0.26	23.0	1.13	1422	1.09
30	3	2	CT	B	L	0.25	24.4	1.17	1966	1.08
31	1	2	CT	B	L	0.25	22.9	1.24	2458	1.68
32	1	2	NT	B	L	0.25	24.4	1.28	2194	0.97
33	2	2	NT	B	L	0.25	24.3	1.21	2361	1.12
34	2	2	CT	B	H	0.24	24.0	1.10	2159	1.04

plot#	tblock	bblock	tillage	burn	fert	MC(g/g)	OM	BD	PR 10-15cm	soybean
35	3	2	NT	B	L	0.244886	23.6	1.27	2466	0.94
36	3	2	CT	B	H	0.254841	23.0	1.16	1694	1.31
37	1	2	CT	NB	H	0.273075	25.4	1.25	1948	2.03
38	1	2	NT	NB	L	0.250966	19.1	1.26	2342	0.89
39	2	2	NT	NB	H	0.243721	23.9	1.27	2703	1.25
40	2	2	CT	NB	H	0.251279	24.9	1.27	2650	0.43
41	3	2	NT	NB	L	0.248768	26.2	1.24	2607	0.64
42	3	2	CT	NB	H	0.250275	26.6	1.30	2554	0.88
43	1	2	CT	NB	L	0.239136	28.9	1.19	2186	1.87
44	1	2	NT	NB	H	0.24057	29.2	1.29	2107	1.57
45	2	2	NT	NB	L	0.243287	30.2	1.27	3019	1.1
46	2	2	CT	NB	L	0.247466	26.8	1.22	2264	0.47
47	3	2	NT	NB	H	0.240826	28.6	1.28	2150	1.24
48	3	2	CT	NB	L	0.241767	25.5	1.20	1913	1.45

Plot# = plot number
tbblock = tillage block
bblock = burn block
tillage = tillage [conventional tillage (CT) and no-tillage (NT)]
burn = burning [burn (B) and no burn (NB)]
fert = N fertilizer rate/residue level [high (H) and low (L)]