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MODELING SOIL EROSION IN CONSERVATION TILLAGE COTTON PRODUCTION SYSTEMS USING THE RUSLE MODEL

V. Jakkula, E.Z. Nyakatawa, and K.C. Reddy
Department of Plant and Soil Science
Alabama A&M University
Normal, AL

Abstract

Soil erosion is a major environmental problem in the U.S. and worldwide and one of the primary pollutants in agricultural runoff is the eroded soil. Large areas of eroded and degraded soils exist in the southeast U.S.A. because of poor row crop production practices and due to intensive tillage practices. The objectives of this study are to evaluate the effects of tillage systems (no-till, mulch-till, conventional till); cropping systems (cotton-winter rye (*secale cereale* L.) and cotton-winter fallow); and nitrogen source (poultry litter, ammonium nitrate) on soil erosion estimates using the RUSLE computer model. The study is being conducted using existing plots and treatments that were established in 1996 at Alabama Agricultural Experiment Station, Belle Mina, AL. Data collected to calculate the cover management factor (C), which is an important component of RUSLE were surface residue cover, effective fall height, canopy cover, root mass, and shoot mass. Percent residue cover in no-till and mulch-till were 63% and 26% higher than that under conventional till system, respectively. No-till plots had higher canopy cover and root mass compared to mulch-till and conventional till systems. Cotton effective fall height, canopy cover, and root mass were higher under cotton-winter rye than cotton-winter fallow cropping system. Cotton plant growth parameters were higher under 200 Kg N ha^{-1} poultry litter compared to 100 Kg N ha^{-1}. The data will be entered in to the RUSLE computer program to calculate C values and soil erosion estimates in cotton plots. Our study demonstrates that cotton under no-till and mulch-till in combination with rye cover crop and poultry litter at 200 Kg N ha^{-1} will increase cotton growth parameters. This may reduce the soil erosion making cotton production in the southeast U.S.A. more sustainable.

Introduction

Soil erosion in agricultural systems is a serious problem that needs attention at national and international levels. Agricultural runoff is surface water leaving farm fields because of excessive precipitation, irrigation, and washing away of valuable topsoil from the fields and resulting in loss of productivity (Vellidis et al., 2003). It is the consequence of unsuitable cultivation practices that leaves land vulnerable during times of erosive rainfall or windstorms. Soil erosion affects both agriculture and the natural environment and is one of the most important environmental problems.

Soil erosion has been attributed to the loss of productivity of soils in the southern piedmont, ranging from southern Virginia through central Alabama, which were once some of the most productive cotton producing areas in the U.S. (Nyakatawa et al., 2001). Large areas of eroded and degraded soils exist in the southeast U.S.A because of poor row crop production practices (Endale et al., 2002; Trimble, 1974; Langdale et al., 1992); and others attribute soil degradation to intensive tillage practices that decrease soil organic matter content which leaves soils vulnerable to the erosive action of intensive rainfall. Erosion has been suggested as being one of the major causes of static or declining cotton yields in some areas in the southeast U.S. (Nyakatawa et al., 2001).

Soil erosion resulting from tillage has necessitated the search for new tillage systems that can reverse the process of soil degradation. The natural approach to this is reduced tillage. In short, reduced tillage of the soil and leaving more crop mulch and cover on fields are what make conservation tillage different from conventional farming. Any tillage and planting that leaves at least 30% of the soil surface covered with crop residues can be called conservation tillage (CTIC, 1994; Gallaher and Hawf, 1997). Conservation tillage systems such as no-till and mulch-till can lead to the build up of surface soil organic matter in addition to reducing soil degradation by erosion (Edwards et al., 1988; Mills et al., 1988). Statistics show that no-till and mulch tillage in the U.S.A has increased nearly fivefold during the past decade (CTIC, 1999). Conservation tillage, such as mulch-till and no-till, reduces soil erosion while maintaining soil organic carbon, which is vital for soil productivity (Bordovsky et al., 1999). Restoration of eroded cropland in the southeastern U.S.A. has been demonstrated with the development of conservation tillage systems, which limit soil disturbance and allow surface residue accumulation (Langdale et al., 1992). It provides a truly sustainable production system, not only conserving but also enhancing the natural resources and increasing the variety of soil biota, fauna and flora, as well as enhancing the biodiversity in an agricultural production system.

Cotton acreage is increasing in South Alabama and South Georgia where broiler production is increasing. This situation creates a potential for use of poultry litter as a source of N and other nutrients for cotton. This could lower the cost of production for cotton producers and lower the environmental risks (Mitchell, 1992). Use of cover crops and organic soil amendments such as poultry litter in conservation tillage systems may increase soil organic matter levels, which in turn would reduce compaction and conserve soil moisture (Nyakatawa et al., 2000).

The Revised Universal Soil Loss Equation (RUSLE) is an empirical soil erosion model revised from Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1965; 1978). It has been widely used in the USA and other countries to predict rainfall erosion losses resulting from various crop management options. In this study, we plan to use RUSLE model to estimate soil loss under different treatments so that the information can be used as a tool for planning soil conservation strategies.

Materials and Methods

The study is being conducted using the existing plots and treatments (Table 1.), which were established in 1996, at the Alabama Agricultural Experiment Station, Belle Mina, AL. The soil at the study site is a Decatur silt loam soil (Clayey, Kaolinitic thermic, Typic Paleudults) and the site has a slope of about 1.5%.

The experimental design is a Randomized Complete Block Design with four replications and twelve treatments in an incomplete factorial design. Plot size is 8 m wide and 9 m long, resulting in 8 rows of cotton, which are 1 m apart. A winter rye cover crop was planted using no-till planter in fall, and killed by Roundup™ (glyphosate) herbicide in spring. Conventional tillage included moldboard plowing in fall, followed by disking in spring (April). A disk cultivator was used to prepare a smooth seedbed after disking. Mulch-till included tillage with a cultivator before planting.

Poultry litter was broadcast by hand and incorporated to a depth of 5 cm by pre-plant cultivation in the conventional and mulch-till systems and in no-till system the poultry litter was surface applied. A herbicide mixture of Prowl™ (pendimethalin) (2.3L/ha), Cotoran™ (fluometuron) (3.5L/ha), and Gramoxone™ extra (paraquat) (1.7L/ha) was applied to all plots before planting. Cotton was planted in all plots except in the bare fallow (control) treatment using no-till planter immediately after poultry litter and ammonium nitrate fertilizer application.

Data Collected to Calculate C- Factor

The cover management factor (C) plays a vital role in RUSLE, as it varies with season and production system unlike other factors such as soil erodibility (k), slope length (L), slope steepness (S) which are generally not affected by season and production systems. Surface residue cover was determined by using camline transect method (Renard et al., 1993; Reddy et al., 1994) immediately after cotton planting. Effective fall height (EFH) is the distance a raindrop falls after striking the crop canopy (Nyakatawa et al., 2001). It was determined by measuring the plant top height (TH) and bottom height (BH) using the following formula:

$$\text{EFH} = 1/2\ (\text{TH}-\text{BH}) + \text{BH}$$

Crop canopy width was measured using a ruler and it was calculated in percentage of total row width. In order to find the shoot and root biomass, roots were extracted from the soil intact from each plot (3 plants per plot). The roots were separated from the shoots, cleaned and placed in bags. The shoot and root samples were oven dried at 65^{0}C for 72 hrs before weighing. All the data was collected from the central four rows of each plot from four weeks after emergence to maturity of cotton. Weather data was taken from an automatic weather station at the experiment station. The data will be entered in to the RUSLE computer program to calculate C values and soil erosion estimates for each individual plot.

Statistical Analysis

Data were analyzed using SAS (SAS 8.2).

Results and Discussion

Surface Residue Cover

Percent residue cover in no-till and mulch- till were higher by 63% and 26% than that under conventional till system, respectively (Conventional till 30.3%, Mulch-till 56.8%, No-till 93.7%). This trend is consistent with the early research work at the site (Nyakatawa et al., 2000). This can be attributed to the fact that in no-till system, residues are not incorporated with the soil and partial incorporation of residues has taken place in mulch-till systems. These factors indicate that erosion rate would be expected to be low in no-till and mulch-tillage systems where residues are more.

Plots under cotton-winter rye cropping system (93.7%) had higher residue cover percentage than that under cotton-fallow cropping system (65%). Crop residues protect the soil surface from physical raindrop impact, which can reduce the formation of surface seals and increase the infiltration rate (Unger and Stewart, 1983). Consequently the more the residues, runoff will be low in no-till and mulch till systems than in conventional-till systems. These factors indicate that erosion rate would be assumed to be low if the residue percentage is more.

Effective Fall Height (EFH)

Effective fall height of cotton plants under different tillage systems at two-week intervals in 2003 is presented in Figure 1. Effective fall height ranged from 15 to 65 cm. In the following weeks, effective fall height was higher for plants under no-till and mulch-till (MT) than conventional till Fig. 1). Higher effective fall height indicates better growth and better canopy cover which in turn can reduce soil erosion. Cropping systems (cotton-winter rye and cotton- winter fallow) had no difference in their effective fall height (Fig.2). Cotton plants which received nitrogen in the form of poultry litter at 200 kg N ha^{-1} had higher effective fall height than those for plants which received 100 kg N ha^{-1} in the form of poultry litter (Fig. 3). This difference might be due to the difference in the rate of poultry litter. Plots that received 100 kg N ha^{-1} in the form of ammonium nitrate had higher effective fall height than those of poultry litter at 100 kg N ha^{-1}. This can be attributed to the slower availability of nitrogen from poultry litter compared to ammonium nitrate (Fig. 3). Cotton plants, which received 100 kg N ha^{-1} in the form of ammonium nitrate, had similar effects compared to the treatment poultry litter at 200 kg N ha^{-1} (Fig. 3).

Canopy Cover (CC)

During four and six weeks after planting, canopy cover was lower for plants under no-till than conventional-till (Fig. 1) indicating initial slow growth in this system. During 14 and 16 weeks after planting, CC was higher for plants under NT and MT than that for plants under CT. Higher canopy cover was observed for the plants that received nitrogen in the form of poultry litter at 200 kg N ha^{-1} and 100 kg N ha^{-1} in the form of ammonium nitrate than that of plants which received nitrogen in the form of poultry litter at 100 kg N ha^{-1} during the entire growth period of cotton (Fig. 3). The main effect of the canopy cover is assumed to be the absorption of energy of the falling raindrops that can lower its impact on soil erosion.

Root Mass

During the sixteenth week after planting, root weight for plants under no-till was 11% and 7% higher than that for plants under mulch-till and conventional till systems respectively (Fig. 1). This indicates the good effect of no-till on the plant growth parameter. Plants under cot ton-winter rye cropping system had higher root mass than that for plants under cotton-winter fallow during 14-16 weeks after planting (Fig. 2). It indicates the positive effect of cover crop on cotton, which increases the soil moisture and residues potentially reducing the runoff.

Effect of nitrogen source and its rate on root weight is represented in Fig. 3. Plants that received nitrogen in the form of ammonium nitrate at 100 kg N ha^{-1} and poultry litter at 200 kg N ha^{-1} had higher cotton root mass throughout the growth period. However, at sixteenth week, plants under ammonium nitrate had highest root mass. Poultry litter at 100 kg N ha^{-1} had lower root mass than that of plants which received nitrogen in the form of ammonium nitrate at 100 kg N ha-1 and poultry litter at 200 kg N ha^{-1}. Plant roots can physically hold the soil particles together and help in the formation of soil aggregates. The more the soil aggregates, the lower would be runoff.

Conclusions

Our study indicates cotton grown under no-till and mulch-till systems in combination with rye cover crop and poultry litter at 200 Kg N ha^{-1} have positively influenced cotton growth parameters. These may potentially reduce the soil erosion there by making cotton production more sustainable in the soils of southeastern U.S.A. where erosion is a severe problem.

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Table 1. Treatments used in the cotton study, Belle Mina, AL, 2003

Treatment	Tillage	Cropping System	N source	N rate(Kg/ha)
1	Conventional-till	Summer cotton/Winter rye	None	0
2	Convention-till	Summer cotton/Winter fallow	Ammonium Nitrate	100
3	No-till	Summer cotton/Winter fallow	Ammonium Nitrate	100
4	Conventional-till	Summer cotton/Winter rye	Ammonium Nitrate	100
5	Conventional-till	Summer cotton/Winter rye	Poultry Litter	100
6	Mulch-till	Summer cotton/Winter rye	Ammonium Nitrate	100
7	Mulch-till	Summer cotton/Winter rye	Poultry Litter	100
8	No-till	Summer cotton/Winter rye	Ammonium Nitrate	100
9	No-till	Summer cotton/Winter rye	Poultry Litter	100
10	No-till	Summer cotton/Winter fallow	None	0
11	No-till	Summer cotton/Winter rye	Poultry Litter	200
12	Bare Fallow	Bare fallow	None	0

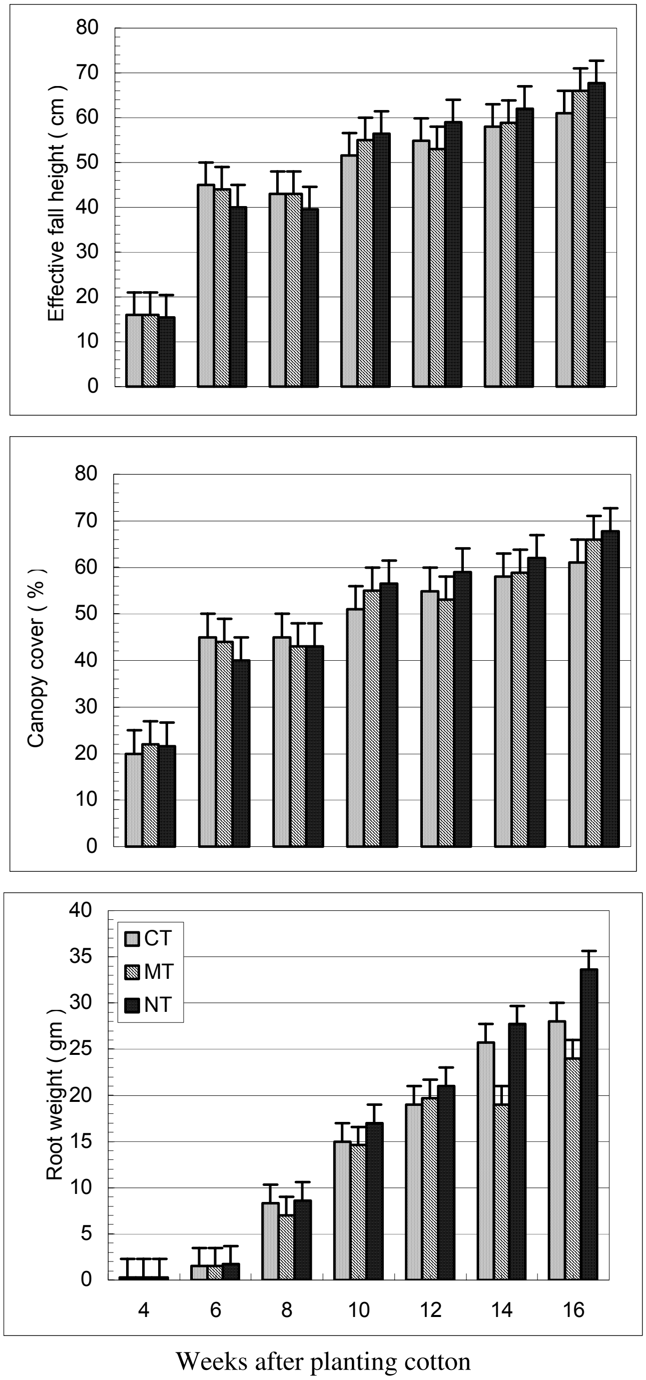

Figure 1. Effect of conventional till (CT), mulch-till (MT), and no-till (NT) systems on effective fall height, canopy cover, and root weight of cotton, Belle Mina, AL, 2003 (Line bars represent the standard error).

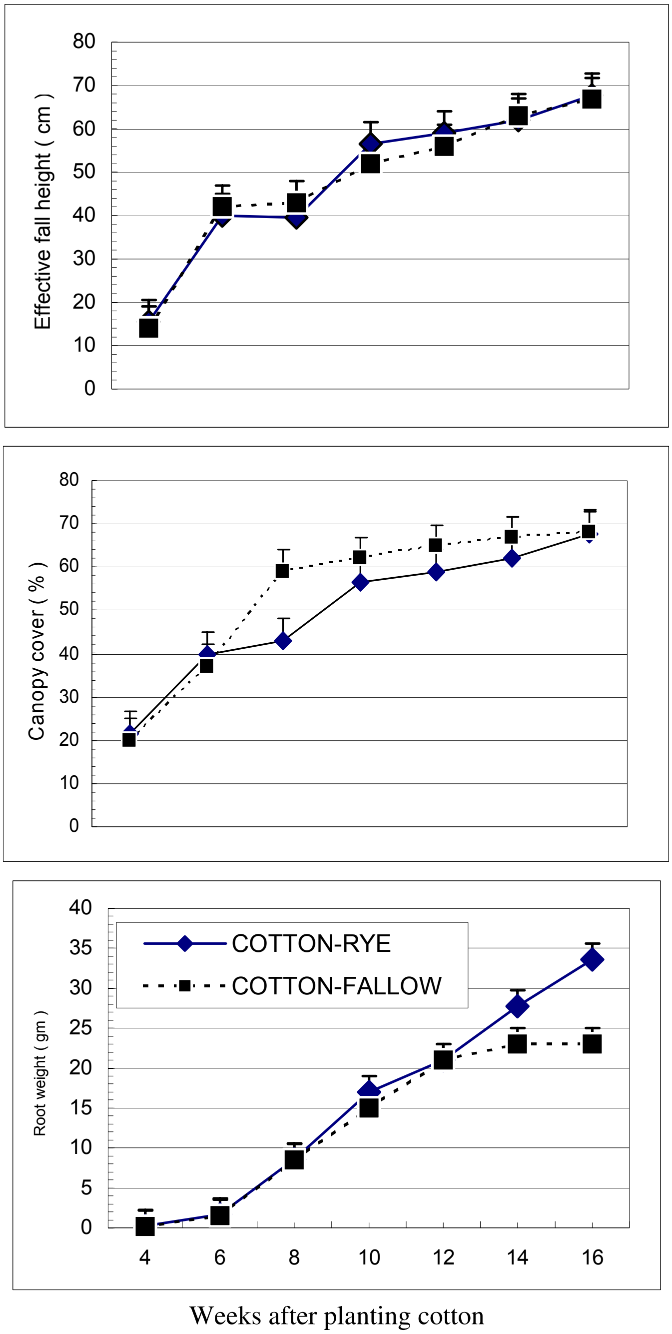

Figure 2. Effect of cotton-rye and cotton-fallow cropping systems on effective fall height, canopy cover, and root weight of cotton, Belle Mina, AL, 2003 (Line bars represent the standard error).

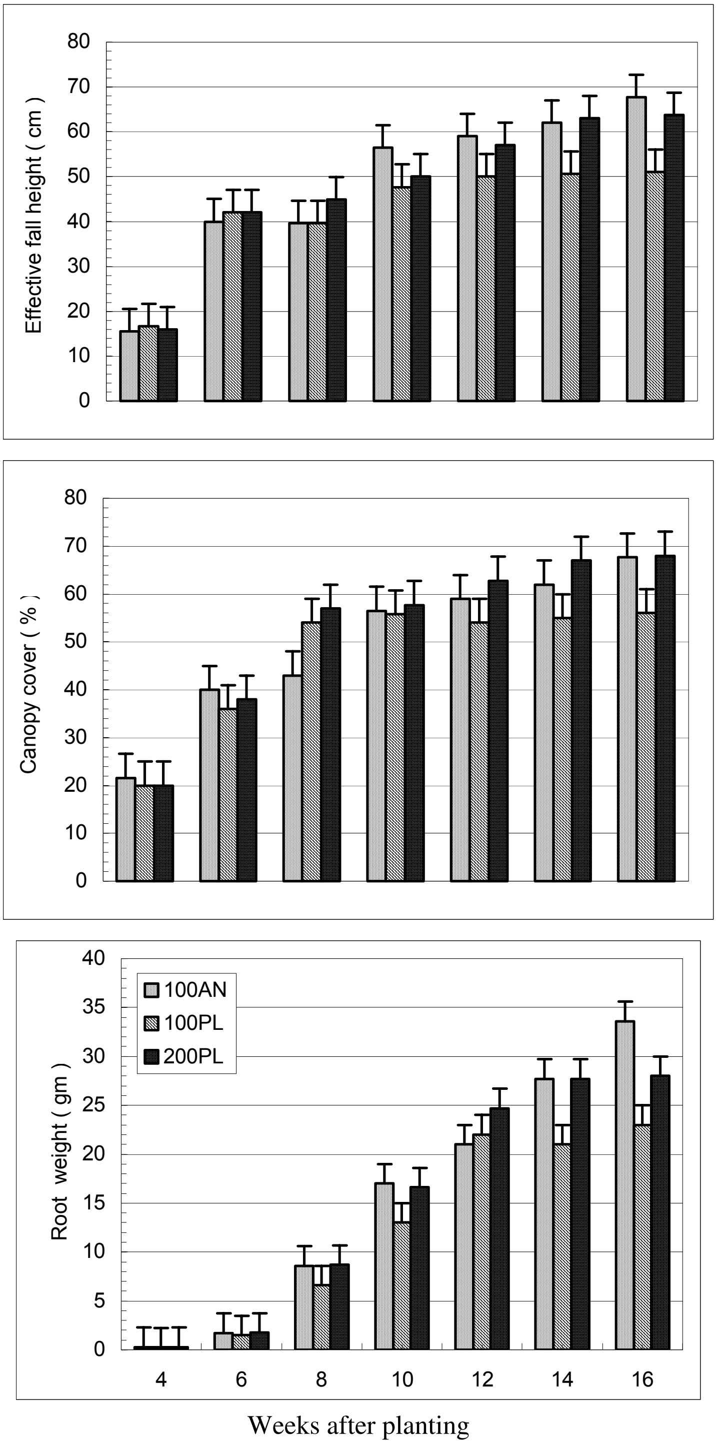

Figure 3. Effect of ammonium nitrate (AN) and poultry litter (PL) at different rates on effective fall height, canopy cover, and root weight of cotton, Belle Mina, AL, 2003 (Line bars represent the standard error).