Agronomic Practices to Reduce Soil Erosion in Cotton Production Systems in USA

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Abstract: Soil erosion has been attributed to the loss of productivity of cotton producing areas in the U.S. In an effort to limit the erosion, a study was conducted from 1996 to 1998 at the Alabama Agricultural Experiment Station, Belle Mina, Alabama. The treatments consisted of three tillage systems; conventional tillage, mulch-till and no-till; two cropping systems; cotton-winter fallow and cotton-winter rye cropping; three nitrogen levels (0, 100 and 200 kg • N • ha^{-1}) and two nitrogen sources; ammonium nitrate and fresh poultry litter. At each level of N, soil erosion estimates in no-till plots was below 5 t • ha^{-1} • yr^{-1} compared to over 15 t • ha^{-1} • yr^{-1} under conventional till in both years. Plots which received N in the form of poultry litter had significantly less erosion than plots which received the same amount of N in the form of ammonium nitrate. Adoption of no-till or mulch-till systems with winter rye cover cropping and poultry litter application in the current cotton production systems can significantly reduce soil erosion to tolerable levels.
Keywords: erosion, cotton, rusle, cover crop, manure, conservation tillage

1 Introduction

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. According to Brown *et al*. (1985), cotton yields can decline by as much as 4% for each centimeter of top soil loss. Erosion has been suggested as being one of the major causes of static or declining cotton yields in some areas in the southeast USA. In Alabama, soil erosion on crop lands averages about 25 t • ha^{-1} • yr^{-1}, which can potentially decrease cotton yields by 440 kg • ha^{-1} to 670 kg • ha^{-1} , if no remedial actions are taken (Anon., 1991).

Any tillage and planting system that leaves at least 30% of the soil surface covered with crop residues can be called conservation tillage (CTIC, 1994; Gallaher and Hewf, 1997). Conservation tillage, crop rotations, and use of cover crops are acceptable mitigation techniques to soil erosion on highly erodible sites. The 1985 Food Security Act and the 1990 U.S. Federal Farm Bill restricts the production of cotton under conventional tillage on highly erodible sites, for farmers participating in federal commodity programs such as storage loans and subsidized prices on grain and cotton.

The Revised Universal Soil Loss Equation (RUSLE) is an empirical soil erosion model revised from the Universal Soil Erosion Loss Equation (USLE) (Wischmeier and Smith, 1965; 1978; Renard *et al*., 1993). It computes the average annual soil erosion estimates caused by rainfall and its associated overland flow. This paper describes soil loss by erosion estimated by RUSLE under conventional till, no-till, and mulch-till systems with winter rye cover cropping, and N from poultry litter from cotton plots on a Decatur silt loam soil in north Alabama.

2 Materials and methods

The study was conducted from 1996 to 1998 at the Alabama Agricultural Experiment Station, Belle Mina, Alabama (34^{o}41' N 86^{o}52' W). The soil at the study site is a Decatur silt loam soil (clayey, kaolinitic thermic, Typic Paleudults). The study site has a slope of about 1.5%. The treatments consisted of three tillage systems; conventional tillage, mulch-till and no-till; two cropping systems; cotton-winter fallow, that is cotton in summer and fallow in winter, and cotton-winter rye cropping, that is cotton in summer and rye (*Secale cereale* L.) in winter; three nitrogen levels (0, 100 and 200 kg • N • ha^{-1}) and two nitrogen sources; ammonium nitrate and fresh poultry litter. Ammonium nitrate was used at one N rate (100 kg • N • ha^{-1}) only. An additional weed-free (bare) fallow treatment was included. The bare fallow plots were not tilled and cropped. They were kept weed-free by use of Roundup (glyphosate) herbicide. The purpose of these control plots was to get an estimate of soil loss from plots without any vegetation canopy and surface residue protection. The experimental design was a Randomized Complete Block Design with 4 replications. Plot size was 8 m wide and 9 m long which resulted in 8 rows of cotton, 1 m apart.

Conventional tillage included moldboard plowing to a depth of about 15 cm in November and disking in April. A field cultivator was used to prepare a smooth seedbed after disking. Mulch-till included incorporating surface crop residues to a depth of about 5 cm to 7 cm with a field cultivator before planting, without performing any primary tillage. A field cultivator was used for controlling weeds in the conventional tillage system, while spot applications of Round up herbicide were used to control weeds in the no-till and mulch-till systems.

The N contents of the poultry litter used in the study were 27 and 30 g • kg^{-1} • N in 1997 and 1998, respectively, on dry weight basis. The poultry litter was broadcasted by hand and incorporated to a depth of 5 to 8 cm by pre-plant cultivation in the conventional and mulch-till systems. In the no-till system, the poultry litter was surface applied. The ammonium nitrate and poultry litter were applied to the plots 1 day before cotton planting. The experimental plots received a blanket application of 336 kg • ha^{-1} of a 0-20-20 fertilizer to nullify the effects of P and K applied through poultry litter.

A no-till planter was used to seed the winter rye cover crop, var. Oklon on December 4, 1996 in the first year, which was killed with Round up herbicide on April 8, 1997. In the second year, the winter rye cover crop was seeded on November 24, 1997 and was killed the same way on February 28, 1998. A herbicide mixture of Prowl (pendimethalin) at 2.3 L • ha^{-1}, Cotoran (fluometuron) at 3.5 L • ha^{-1}, and Gramoxone extra (paraquat) at 1.7 L • ha^{-1} was applied to all plots before planting cotton, var. Deltapine NuCotn 33B, on May 8, 1997 and May 5, 1998.

RUSLE incorporates four physical parameters associated with erosion by water: rainfall erosivity, soil erodibility, topography, and land-use management. The model calculates the average annual soil erosion on field plots from the equation A = R.K.LS.C.P, where A = predicted long-term average of annual sheet and rill soil loss from a defined slope (t • ha^{-1} • yr^{-1}), R = rainfall-runoff erosivity factor {(hundreds of ft-tons) inch $acre^{-1}$ • hr^{-1} • yr^{-1}}, K = soil erodibility factor as measured under unit plot conditions {tons $acre^{-1}$ (hundreds of ft tons $acre^{-1}$ inch $hr^{-1})^{-1}$}, LS = the erosion impact of the slope length (L) and steepness (S) on erosion in comparison to unit plot conditions (dimensionless), C = the erosion impact of cover and management schemes on erosion in comparison to unit plot conditions (dimensionless), and P = the erosion impact of conservation support practices (e.g. contour tillage, strip cropping, terraces, and drainage) on erosion in comparison to unit plot conditions (dimensionless).

Among the RUSLE factors, R, K, and LS are nature dependent or intrinsic to the landscape. They do not change when soil conservation practices are applied. Also, installing support practices that reduce the P value requires considerable monetary costs. Therefore, only C is the factor that can be managed with reasonable planning and minimal costs to influence the soil losses in a given field. The RUSLE model consists of three main databases: climate, crop, and soils databases. In this study, the calculations of soil erosion estimates were done by plot for each year, using RUSLE Ver. 1.06 computer program.

Most of the information required for predicting soil erosion using RUSLE, such as rainfall and soil data can be obtained from published records. The exception is the C-factor which varies with season and production system. Conservation tillage such as no-till and mulch-till affect the C-factor by reducing soil degradation, reducing runoff, and increasing infiltration and soil organic matter, which in turn, reduce soil erosion. Crop data collected for the RUSLE C-factor calculation in this study included winter rye biomass, surface residue cover (SRC) after cotton planting, cotton canopy cover, effective fall height from the cotton canopy, and cotton surface root mass. Surface residue cover was measured in all plots using the camline transect method (Renard *et al*., 1993; Reddy *et al*., 1994) immediately after cotton planting. Canopy cover was determined by measuring the width of the crop canopy of each row from the four central rows on each plot using a ruler and expressing the figure as a percentage of the row width. Effective fall height (*FH*) is the distance a raindrop falls after striking the crop canopy. This was calculated from the equation

$$FH = (TH - BH)/2 + BH$$

where *TH* and *BH* are the top and bottom heights of the cotton canopy, respectively.

Root biomass were determined by sampling plants with their roots intact from $0.5m^2$ quadrants from each plot. Roots were extracted out of the soil by removing soil from both sides of the row and lifting the intact plants from the base with a garden fork. The roots were cut from the shoots, washed in water to remove soil and placed in separate bags. The shoot and root samples were oven dried to constant weight at 65℃ for 72 hours before weighing. The cotton crop growth data were taken in each plot at 15 day intervals.

3 Results and discussion

Cotton lint yields: Cotton lint yield under no-till (1,360 kg • ha^{-1}) was 24% and 18% greater than that under conventional till (1,100 kg • ha^{-1}) and mulch-till (1,150 kg • ha^{-1}) systems respectively, in 1997 (Table 1). In 1998, cotton lint yield under no-till system (1,440 kg • ha^{-1}) was 7% greater than that under conventional till (1,350 kg • ha^{-1}). There were no significant yield increases in mulch-till compared to conventional till. Poultry litter at 100 kg • N • ha^{-1} gave similar cotton lint yield to ammonium nitrate, whereas at 200 kg • N • ha^{-1}, lint yields were 23% and 38% greater than those at 100 kg • N • ha^{-1} in the form of ammonium nitrate and poultry litter, respectively, in 1997; and 12% and 25% greater than those at 100 kg • N • ha^{-1} in the form of ammonium nitrate and poultry litter, respectively, in 1998 (Table 1).

soil erosion estimates: Higher C-factor values indicate higher soil erosion loss since the C-factor is a ratio of soil loss in a cover-management sequence to soil loss from the unit plot. C-factors for cotton-winter rye cover cropping under conventional till were significantly reduced by 15% (0.487 vs 0.423) and 28% (0.525 vs 0.410) compared to cotton-winter fallow cropping in 1997 and 1998, respectively (Table 2). C-factors under conventional till were about four times greater than those under no-till, under cotton-winter fallow cropping in 1997 and 1998, respectively (Table 2). However, under cotton-winter rye cropping, C-factors under conventional till were up to seven times greater than those under no-till both years. The main factor which caused differences in the C-factor is SRC since most of the other parameters such as rainfall and soil factors are constant for all the treatments. The SRC plays an important role of slowing surface runoff and protecting soil from the direct impact of raindrops whose energy breaks the soil particles apart which can then be carried away by moving water. The reduced C-factors explain the 15% lower (15.7 vs 18.0 t • ha^{-1} • yr^{-1}) and the 25% lower (15.8 vs 19.7 t • ha^{-1} • yr^{-1}) soil erosion estimates in conventional till in cotton-winter rye cover cropping compared to cotton-winter fallow cropping in 1997 and 1998, respectively.

In both years, soil erosion rates under mulch-till system were four times lower than those under conventional till. The highest soil erosion of about 20 t • ha^{-1} • yr^{-1} was estimated in the bare fallow plots. At each level of N, soil erosion estimates in no-till plots was below 5 t • ha^{-1} • yr^{-1} compared to over 15 t • ha^{-1} • yr^{-1} under conventional till at 0 or 100 kg • N • ha^{-1} ammonium nitrate levels in both years. Plots which received 100 kg • N • ha^{-1} in the form of poultry litter had 10, 3, and 3 t • ha^{-1} • yr^{-1} less soil erosion rates under conventional till, no-till and mulch-till systems respectively, compared to plots which received the same amount of N in the form of ammonium nitrate in 1997. Similar figures for 1998 were 9, 2, and 3 t • ha^{-1} • yr^{-1}. Doubling the N rate through poultry litter to 200 kg • N • ha^{-1} under no-till system gave the lowest soil erosion estimate levels of less than 2 t • ha^{-1} • yr^{-1} in both years.

Table 1 Cotton lint yield (kg • ha^{-1}) as influenced by tillage systems and source of N, Belle Mina, AL, 1997 and 1998

	Lint Yield (kg • ha^{-1})	
	1997	1998
Tillage Systems		
Conventional-till	1,100a†	1,350a
Mulch-till	1,150a	1,420ab
No-till	1,360b	1,440b
N-Levels		
0 kg • N • ha^{-1}	920a	1,040a
100 kg • N • ha^{-1} (AN)	1,310b	1,320b
100 kg • N • ha^{-1} (PL)	1,160b	1,350b
200 kg • N • ha^{-1} (PL)	1,610c	1,695c

Means for tillage systems, cropping systems, or N level within a column, followed by different letters are significantly different at the 5% level.

4 Conclusions

Soil erosion estimates under conventional till and continuous cotton cropping system with the use of ammonium nitrate fertilizer were similar to that in weed free fallow plots, which are about twice the tolerance levels for northern Alabama. Adoption of no-till or mulch-till systems with winter rye cover cropping and poultry litter in the current cotton production systems can significantly reduce soil erosion to tolerable levels and help utilize the waste generated by the burgeoning poultry industry in the SE USA.

Table 2 Cover management (C) factors of cotton as influenced by conventional-till and no-till systems under cotton-winter fallow and cotton-winter rye cropping systems and ammonium nitrate (AN) and poultry litter (PL) sources of N, Belle Mina, AL, 1997 and 1998

	Conventional-till		No-till	
	1997	1998	1997	1998
Cropping Systems				
Cotton-winter fallow	0.487a†A††	0.525aA	0.130bB	0.136bB
Cotton-winter rye	0.423bA	0.410bA	0.056aB	0.050aB
LSD(0.05)	0.019	0.031	0.019	0.031
CV(%)	4.0	6.4	4.0	6.4
N-Sources				
0	0.440aA	0.430aA	0.131bB	0.136bB
100AN	0.423aA	0.410aA	0.129baB	0.056aB
100PL	0.189bA	0.220bA	0.068aB	0.052aB
LSD(0.05)	0.079	0.040	0.079	0.040
CV(%)	9.5	12.4	9.5	12.4

Means for cropping systems or N sources for the same year, followed by different lower case letters are significantly different at 0.05% level.

Means for conventional and mulch-till systems within a cropping system or N source for the same year, followed by different upper case letters are significantly different at 0.05% level. CV = coefficient of variation

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