Long-Term Crop Response to Conservation Tillage

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Introduction

In 1987, the United States Department of Agriculture (USDA-ARS) National Sedimentation Laboratory, in cooperation with the Mississippi Agricultural and Forestry Experiment Station (MAFES) and the Natural Resources Conservation Service (NRCS), initiated an interdisciplinary research project to develop profitable and environmentally sustainable conservation production systems for silty upland areas of the Midsouth.

Results from the first 5 years of this project were reported to the SCTC in 1993. Culture details and soil types are listed in the earlier paper (Dabney et al., 1993). Treatments included no-tillage, conventional (chisel, disk, cultivate), ridge, and minimum tillage for cotton, grain sorghum, and soybeans. A wheat-soybean and grain sorghum-wheat-soybean doublecrop (three crops in 2 years) systems were also included. No-tillage cotton followed wheat cover and no-tillage sorghum followed vetch cover. In this phase, both no-tillage cotton and grain sorghum yields improved with time relative to conventional tillage, while crop yields with minimum and ridge-tillage were similar to those with conventional tillage.

We reported earlier that soil loss from runoff plots with no-tillage was in the range of 1 to 2 tons/acre/year, sufficient for conservation compliance. An economic analysis of cropping systems showed the doublecrop wheat-soybean system to be the most profitable, no-tillage cotton was profitable, and all continuous grain sorghum systems were unprofitable (Dabney et al., 1993).

After the fifth crop year, the study was revised. No-tillage replaced minimum and ridge tillage, corn replaced grain sorghum, and full-season no-tillage soybeans and a corn-cotton rotation were initiated (Table 1). The first-phase conventional and no-tillage were retained. New no-tillage corn and cotton were with and without cover crops. The new design permits evaluation of the: (1) time in no-tillage (tillage history), (2) cover crops within no-tillage systems, and (3) crop rotation.

Objectives of this revised study were: (1) to monitor long-term crop responses to conventional and no-tillage, (2) to evaluate crop responses when changing to an untilled environment, and (3) determine the effect of crop rotation on crop productivity in untilled systems. Results from the first 2 years of the revised study are reported here.

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Methods

Treatments were evaluated in 40- by 18-foot plots in a randomized block design with 10 replications. All crops were planted in 36-inch rows except wheat and soybeans, which were drilled in 7-inch rows. Full-season soybeans were planted in May and doublecrop soybeans were planted in early June. Conventional cotton and corn were chisel-plowed and disked in spring, cotton planted on low ridges, a band herbicide application made, and both crops cultivated. Herbicides for no-tillage included preemergence applications of contact and residual materials and postemergence or post-directed applications as needed to maintain weed control. Uncontrolled weeds have not been a factor in crop productivity for this study.

Rates of P and K were based on soil test and were applied broadcast before tillage. Nitrogen rates for corn, wheat, and cotton were in the mid to high range.

The study was located on loess soils in north Mississippi near Senatobia. Soils included Grenada silt loam, (fine silty, mixed, thermic Glossic Fragiudalf), Loring (fine silty mixed thermic Typic Fragiudalf), and Memphis (fine silty mixed thermic Typic Hapludalf). Other details for first-phase methods were published earlier (Dabney et al., 1993).

Table 1. Tillage and cropping treatments for phase two of the tillage and rotation study.

Tillaee and crop	Date tillage system initiated
CTCO Conventional cotton	1988
NTCO-W-1 No-till cotton, wheat cover	1988
NTCO-W-2 No-till cotton, wheat cover	1993
NTCO No-till cotton, volunteer cover	1993
NTCO/CR No-till cotton corn rotation	1993
CTSB Conventional soybean	1988
NTSB No-till soybean, full season	1993
NTSB/W No-till wheat soybean doublecrop	1988
NTSB/W-CR No-till soybean/corn/wheat doublecrop	1988
CTCR Conventional corn	1988
NTCR-V No-till corn, vetch cover	1988
NTCR No-till corn, volunteer cover	1993
NTCR/SB No-till corn/wheat/soybean	1988
NTCR/CO No-till corn/cotton rotation	1993

CT: conventional tillage. NT: no-tillage.

Results

Weather

In 1993, early growing season rainfall was adequate to support excellent corn production but drought later limited both soybean and cotton yields. In 1994, rainfall was adequate and well distributed. Monthly rainfall totals are shown in Table 2 for the two growing seasons.

Cotton Yields

Long-term no-tillage cotton following wheat cover yielded 53% greater than long-term conventional tillage in 1993 (Table 3). Yields of first-year no-tillage treatments equalled conventional, regardless of cover crop or rotation. Thus, during this season with limited moisture first-year no-tillage did not equal the longer term no-tillage. During 1994, long-term no-tillage cotton yielded 29% greater than long-term conventional tillage. Yields of all second-year no-tillage treatments were greater than conventional.

Soybean Yields

In 1993, all soybean treatment yields were equal (Table 4). In 1994, full-season no-tillage soybean yields were 31% greater than conventional while both doublecrop systems were lower than full-season no-tillage but not different from the conventional. Conventional and doublecrop systems were not significantly different.

Corn Yields

In 1993, long-term no-tillage corn in the corn/wheat/soybean rotation yielded 34% greater than conventional tillage while all other treatments were equal to conventional tilled or greater. During 1994, with ample moisture, conventional corn yields equalled all other treatments and were greater than no-tillage corn following vetch cover. No-tillage corn following vetch suffered a stand loss and was replanted in May with the later planting likely reducing yield potential (Table 5). Yields of better treatments were in the 120-to 130-bushel range during both years, a profitable level based on our economic analysis.

Wheat Yields

During 1993, wheat yields averaged 39 bu/A and in 1994 wheat in the doublecrop system (two crops each year) averaged 38 bu/A. Wheat following corn yielded 51 bu/A, significantly greater than the continuous doublecrop system.

Discussion

This research is identifying crop management systems for highly erodible soils that both sustain crop productivity and reduce soil loss to an acceptable level. The positive yield response of cotton to no-tillage that we report differs from reports by Brown et al. (1985), and Stevens et al. (1992). These studies, and a study by Burmeister et al. (1993) in which conventional tillage was equal to or better than no-tillage, occupied sites previously tilled for annual cropping for several years. Neither the Brown nor Stevens studies were continued for more than 3 years. In both phases of our study, first-year no-tillage cotton yields were either equal to or less than conventional yields and at least 2 years of no-tillage were required for yield differences to become strongly evident.

Lack of immediate response to no-tillage implies that phys-

Table 2. Growing season rainfall at the study site, inches/month.

Year	May	June	July	Aug	Sep
1993	3.08	3.94	0.27	5.01	6.53
1994	3.12	6.44	5.43	5.84	0.37

Table 3. Yield of DES 119 cotton as influenced by tillage and rotation, 1993 and 1994.

System	Tillage duration 1994	Seed cotton yield 1993	Seed cotton yield 1994
	(years)	(lb/acre)	(lb/acre)
CTCO	7	770 bc	1,700 b
NTCO-W1	7	1,180 a	2,190 a
NTCO-W2	2	920 bc	1,960 a
NTCO	2	830 bc	2,000 a
NTCO/CR	2	980 b	2,130 a

Within columns, means followed by the same letter do not differ at the 0.05 significance level using Duncan's multiple range test.

Table 4. Soybean yields as influenced by tillage and rotation, 1993 and 1994.

System	Tillage duration 1994	Soybean yield 1993	Soybean yield 1994
	(Years)	(Bu/acre	(Bu/acre)
CTSB	7	20 a	29 b
NTSB	2	25 a	38 a
NTSB/W	7	22 a	25 b
NTSB/W-CR	7	22 a	21 b

Within columns, means followed by the same letter do not differ at the 0.05 significance level using Duncan's multiple range test.

Table 5. Corn yields as influenced by tillage and rotation, 1993 and 1994.

S-ystem	Tillage duration 1994	Corn yield 1993	*Corn* yield 1994
	(Years)	Bu/acre)	(Bu/acre)
CTCR	7	95 c	133 a
NTCR-V	7	110 abc	106 b
NTCR	2	97 bc	123 ab
NTCR/SB	7	127 a	130 a
NTCR/CO	2	117 ab	130 a

Within columns, means followed by the same letter do not differ at the 0.05 significance level using Duncan's multiple range test.

ical, chemical, or biological soil conditions must evolve in some way before the full potential of the system is manifest. Langdale, working on an ultisol in Georgia, reports a requirement of several years before no-tillage cotton yields exceeded those of conventional tillage (G. W. Langdale, personal communication). The relative response of tillage systems to growing season rainfall indicates moisture availability is a likely component in tillage response. Similar results with corn were reported in a long-term study on a soil similar to ours (Dick et al., 1991).

In the first phase of this study, no-tillage grain sorghum-soybean rotation yielded more than continuous grain sorghum. Increased grassy weeds in wheat in continuous wheat-soybean doublecrop increased herbicide costs and reduced yields. Second-phase crop rotations have been a component of this study for only two seasons, too little time to fully assess the value of this practice. Wheat and corn had significant rotation effects for one year. Aside from crop yield response, there are several valid reasons for rotating crops. Problem weeds in corn can be controlled with herbicides available for soybeans or cotton, and the reverse is also true. Corn or grain sorghum provide more residue than cotton or soybeans, an important factor in conservation compliance on sloping sites,

Our results indicate that on this well-drained highly erodible soil, crop yields are being maintained with no-tillage cropping in systems that comply with soil loss restrictions. This study will be continued for several years to fully assess long-term yield trends.

Varied crop yield results from full-season no-tillage have been reported by several participants at the Southern Conservation Tillage Conference. We suggest that these results be considered collectively and an effort made to identify situations where no-tillage systems succeed or fail, and why. Certainly, with the highly erosive rainfall in the Midsouth, we need systems that will protect our soil resource. As a given, any system must have adequate stands and weed control. If either of these fail, we need look no further to explain yield differences. Where stands and weed control are adequate, other reasons for differences include the following:

1. Soil type x tillage interactions

Possibly, some soils should be tilled for optimum crop productivity while others may be better left undisturbed. If such situations are identified, this does not mean that some form of reduced tillage is not possible, and no-tillage may be desirable for reasons other than yield. Systems that maintain yields while protecting our soil resource need to be developed. In some Midwest studies, poorly drained soils are seemingly less suited to no-tillage than better drained soils (Dick et al., 1991). In poorly drained soils, a mollic epipedon seems to further reduce positive crop responses to no-tillage (Griffith et al., 1988). Triplett and Van Doren (1985) reported that plowing in alternate years maintained corn yields on a poorly drained mollic soil (rotating tillage). In the lower coastal plains, in-row subsoiling seems necessary for successful no-tillage.

2. Cropping sequence

Rotating crops may have a positive effect on no-tillage yields. Dick et al. (1991) reported reduced yields for continuous no-tillage corn on a poorly drained soil. If corn was rotated with soybean, yields were maintained equal to fall plowing. Crop rotation permits selection of herbicides that aid in control of weeds that are problems in monoculture.

3. Nitrogen fertility

Tillage increases the rate of organic matter oxidation and release of nitrogen. Thus, nitrogen rates for no-tillage may need increasing to realize the full potential of the system. Fox and Bandel (1986) reported lower corn yields for no-tillage at low rates of nitrogen and higher yields at increased nitrogen rates. Eventually, an equilibrium should be reached with the two systems as the organic matter content of the no-tillage system increases.

4. Mulch cover

Mulch serves to reduce soil erosion and increase water infiltration but can interfere with planting and harbor disease and insect pests. Water management, increased infiltration during the growing season, may be a major contribution of mulch on some soils. Conversely, mulch may be less important on vertisols that crack when dry. Winter weed growth in the Midsouth provides cover before crop planting. However, allowing vegetative growth late in the planting season can deplete soil moisture and reduce crop productivity. Thus, time of weed kill is an important factor in crop management in no-tillage systems.

5. Length of time in no-tillage

As agronomists, we commonly conduct field studies for three seasons to reasonably sample years. In this study, no-tillage was initiated twice and, in one case, the first-year results were less than conventional, and equal in the other. Crops grown with no-tillage improved with time. Dick et al. (1991) reported long-term improvement of no-tillage relative to conventional, even on poorly drained soils. Langdale et al. (1992) also needed several years for full response to no-tillage to develop. Thus, short-term studies may be inadequate to assess the full effect of the system. Continuous no-tillage reduces soil loss and contributes to other changes in the soil environment. At present, there is inadequate evidence to determine cause and effect relationships for yield trends.

6. Cropping history

Tilled cropping degrades soil physically and chemically. No-tillage initiated on a site cropped for several years may not respond the same as when following sod. The study reported here was in sod for a short time before the research was initiated. Perhaps soil conditions, including tillage history, should not be overlooked when evaluating response to no-tillage.

7. Soil biology

Invertebrates such as earthworms, which serve to form stable macropores, are reduced under tilled systems. There may be a period of time required before these and other organisms are fully functional when converting to no-tillage, especially when following tilled cropping. Mycorrhiza are receiving increasing attention as a possible factor in no-tillage crop response. These and other systems must be considered.

We do not consider this list is necessarily complete, but hope that it will serve to initiate dialogue among members of this group.

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