Making No-Till "Conventional" in Tennessee

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ABSTRACT

No-till production has become the conventional system for corn, soybean and cotton in Tennessee. No-till is now used on 60 percent of the cotton, 65 percent of the corn and 70 percent of the soybean acreage in the state. This success is the result of improved weed control technology combined with a sustained research and extension effort spanning over 30 years. This effort was a response to some of the most serious soil erosion problems in the USA. Today soil erosion rates on cropland have been reduced by more than half from 1977 levels. Crop yields have increased, and soil quality has improved.

KEYWORDS

Soil erosion, conservation compliance, farm bill, adoption.

INTRODUCTION

No-till is truly the "conventional" tillage system for Tennessee row crops. No-till is now used on 60 percent of the cotton, about 65 percent of the corn and about 70 percent of the soybean acreage in Tennessee. The reasons for this widespread use are related to the historical problems of soil erosion and summer drought.

Most upland soils in Tennessee have silt loam Ap horizons, which are low in organic matter. Surface soil organic matter content is often less than one percent in tilled fields. Annual tillage destroys the structure of these soils and removes the mulch cover from crop residue. In the past, cropped fields were intensively tilled using chisel plows, moldboard plows and disk harrows. This system resulted in very high levels of soil erosion on sloping lands. The average rate of erosion for all cropland in Tennessee in 1977 was 15 tons $acre^{-1}$ $year^{-1}$, and on upland soils it was much higher, sometimes exceeding 50 tons $acre^{-1}$ $year^{-1}$. Most of the highly erodible cropland soils are either Fragiudalfs with fragipans in the subsoil, or Paleudults and Paleualfs with clayey subsoils. These high rates of erosion over a period of years have reduced the depth of soil above these unfavorable subsoil layers. The result is a loss of water storage capacity, and a permanent loss of crop yield potential (Rhoton, 1990).

The high rate of runoff of rainwater associated with this erosion also decreased yield, due to drought. Growing season rainfall in combination with stored soil water from the winter is normally sufficient for successful crop production in Tennessee, on soils with 2 feet of rooting depth or more, but there is not much excess water. If a high proportion of water from rain runs off the field, the probability of yield loss from drought is greatly increased.

Farmers and researchers have long been aware of this situation, but before 1960, tillage was necessary to control weeds. Conservation systems that could adequately control erosion were available, including terracing, rotation with forages, and contour strip-cropping. However, these systems were not widely adopted. They were costly to farmers, either in terms of expense of installation (terraces) or in terms of less intensive, less profitable farming systems (rotation and contour strip cropping). These near-term costs exceeded the long-term benefits, in the opinion of farmers. Therefore, these systems were never used to the extent necessary to adequately control erosion. The development of effective herbicides between 1960 and 1980 changed the situation. When it became possible to control weeds without tillage, researchers at the University of Tennessee and in surrounding states began to develop practical systems of no-till and minimum tillage (Mueller and Hayes, 1996).

No-till has many advantages over traditional systems of soil and water conservation for Tennessee conditions. First, no-till, when combined with high residue cropping systems, is much more effective in control of erosion than traditional systems. Use of contour terraces in cotton production will reduce soil erosion by 50 to 60 percent, but use of no-till with a winter cover crop will reduce erosion by 90 percent. No-till with residue also enhances infiltration and reduces runoff of growing season rainfall compared to traditional systems.

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The no-till system allows the continued use of intensive cropping systems while controlling erosion. Use of no-till does not add significant cost in most cases, and may be less costly for some crops. The possibilities of controlling erosion and increasing yield without additional production cost made no-till a very desirable alternative to traditional conservation systems.

DEVELOPMENT AND ADOPTION OF NO-TILL SYSTEMS

Research in reduced tillage and no-till systems was begun at the University of Tennessee in the late 1950's by Henry Andrews and his graduate students (Andrews and Peters, 1967; Graves, 1996). Attempts at farmer adoption began between 1965 and 1970.

In this early period, there were many problems. Planting equipment of the time was designed to operate in soft, tilled soil (Graves, 1996). It was inadequate for proper seed placement and coverage in firm, untilled soils, and it did not operate well if there was crop residue present on the soil surface. Herbicides had made no-till possible, but initially there were relatively few herbicides available and there were many weed species that could not be controlled without tillage. In particular, johnsongrass (*Sorghum halepense*) was a major limitation on the use of no-till in Tennessee from 1960 to 1980 (Graves, 1996; Mueller and Hayes, 1996).

In addition to these problems, there were other concerns and uncertainties in this early era. These included soil compaction, adequacy of surface application of lime and fertilizer, buildup of insects and diseases, and concerns about accumulation of a thick, unmanageable layer of mulch over time.

During the period from 1960 to 1980, great progress was made in all of these areas. Effective no-till planters were developed. These planters were heavier, to increase durability and to improve penetration of seed placement mechanisms in firm soils. They included a mechanism for slicing through crop residue to prevent accumulation of plant material on the planter frame. Normally, this was a disk coulter mounted in front of the seed placement mechanism in each row. Seed was placement was accomplished by disk openers following the coulter. Adequate soil-seed contact and coverage of the seed was accomplished by covering mechanisms with narrow, firm press wheels and large amounts of down-pressure. By 1980, commercial row planters were available which could successfully place seed in untilled soil in most situations. Improved drills were also becoming available.

At the same time, the number of herbicides available to farmers for use on major crops increased greatly in the period from 1970 onward. By 1985, a wide spectrum of herbicides made no-till production of corn, soybeans and cotton feasible in almost all situations in Tennessee. The most notable of these were the post-emergence grass control herbicides (fluaziflop, sethoxydim, clethodim, quizalofop), which made control of johnsongrass possible in no-till cotton and soybean (Mueller and Hayes, 1996). In the 1990's, advances in biotechnology lead to another important advance: the development of glyphosate-tolerant cotton and soybeans. This greatly simplified the control of weeds in no-till systems and led to increased use of no-till in both crops.

Soil compaction was a major concern in the early years. Most farmers and many researchers and Extension personnel believed that compaction would be a major problem in long-term no-till. This thinking was influenced by the results of subsoiling and compaction research from the Coastal Plain, which showed serious compaction problems on the sandy soils commonly found there, and a distinct advantage when deep tillage was utilized.

Experimental results and farmer experience had clearly shown by the early 1980's that soil compaction was not a major problem in the silt loam and silty clay loam soils that make up much of Tennessee's cropland. Research in tilled systems showed no yield advantage in subsoiling or other deep tillage as compared to shallow tillage (Mullins *et al*, 1974; Tyler and McCutchen, 1980). Studies comparing no-till and tilled systems found that soil compaction was not a problem in no-till systems. Soil physical properties were at least as favorable for root development in no-tilled as in tilled systems and often were better (Tyler *et al*, 1983), and yields generally equaled those from tilled systems, including deep tillage.

There was a general belief in the early 1970's that surface application of lime and phosphorus would not be adequate to maintain soil pH and soil nutrients at optimum levels without occasional mixing by tillage. However, research showed that surface application of lime and of P and K without incorporation was adequate for optimum yield, even over long periods in continuous no-till (Howard and Tyler, 1987; Howard et al, 1996). Rates of lime, P and K recommended for tilled systems were adequate for no-till as well.

With regard to nitrogen, it was found that when solid urea or urea-ammonium nitrate was applied to the soil surface, reduced yields were obtained due to volatilization losses. Surface applied ammonium nitrate was found to be equal to injected nitrogen (Howard and Tyler, 1989). Therefore, injected UAN, surface applied ammonium nitrate or anhydrous ammonia became the recommended system for nitrogen fertilization of no-till corn and soybean.

Legume cover crops were found to provide the equivalent of 50 to 70 pounds per acre of nitrogen to succeeding no-till crops (Duck and Tyler, 1996). However, because of economics and problems of timely establishment, systems utilizing legumes have not been widely adopted.

Insects and disease were major concerns of researchers in the early years of no-till research. Research and experience have shown that insect and disease problems are no greater in no-till than in tilled systems. However, the problems may be different. Damage from nematodes, for example, is often less in no-till, while diseases caused by organisms that live in decaying crop residue may be worse. (Lentz *et al*, 1996; Tyler *et al*, 1983; Tyler *et al*, 1987).

By the late 1970s, researchers had developed practical, sustainable systems of no-till production for major crops that were ready for commercial adoption. At this point, the Extension Service and the Soil Conservation Service began major efforts to encourage adoption of no-till. These efforts included field days, on-farm demonstrations, public meetings, publications and incentive payments to farmers, as well as one-on-one direct contact with growers.

The Conservation Compliance provisions of the 1985 Farm Bill gave no-till a considerable boost in Tennessee, especially in cotton production. These provisions required the adoption of improved erosion control methods in highly erodible land to remain eligible for USDA program benefits. Since the majority of cropland in Tennessee falls in the highly erodible category, Tennessee farmers were heavily impacted. Conservation Compliance did not require no-till as the erosion control method, but the cost advantages of no-till compared to other methods of erosion control quickly became apparent, and most farmers in Tennessee chose to use no-till to meet this requirement. After this policy began to be seriously enforced in 1991, adoption of no-till increased quickly for a few years.

As a result of research, extension and government efforts, no-till has been widely adopted as a production system on Tennessee farms. Table 1 shows the proportion of the areas of corn, soybeans and cotton planted using no-till from 1983 until 2001. From this table, three major stages of adoption become apparent. The first stage, prior to 1990, represents early adoption by more advanced farmers. This phase reached 10 to 20 percent of the planted area. During the period from 1990 to 1995 there was a rapid increase in no-till use. This was a result of Conservation Compliance, increasing confidence of farmers in the system, and the development of improved post-emergence herbicides. The development of effective post-emergence herbicides for control of johnsongrass in corn (nicosulfuron, primisulfuron) was especially important. In this phase of adoption, use of no-till reached 45 to 50 percent of planted area in corn and soybean, and 25 percent to 30 percent in cotton. In the 1998 to 2001 era, glyphosate-tolerant GMO varieties became widely available for cotton and soybean.

Table 1. Percentage of the area of major Tennessee crops planted using the no-till system, 1985-2001. No data were available for cotton production prior to 1992. Source: Tennessee Agricultural Statistics Service

Year	Corn	Soybean	Cotton
1985	13	16	–
1986	11	12	--
1987	10	11	--
1988	10	15	--
1989	9	20	--
1990	14	23	--
1991	22	26	--
1992	29	30	14
1993	44	38	25
1994	46	44	23
1995	50	55	27
1996	45	50	33
1997	37	47	24
1998	46	48	24
1999	54	50	32
2000	58	65	53
2001	65	71	61

This greatly simplified no-till weed control, and has led to another large increase in adoption, up to 60 to 70 percent of planted area.

It is interesting to note that from the time research first began around 1960, 15 to 20 years were required to develop commercially viable systems, and another 15 to 20 years were required before the new technology was adopted on half of the planted area. The success of no-till in Tennessee is a classic example of the Land Grant approach to agricultural production problems. A problem was identified (soil erosion), a viable solution was developed through research (no-till), and the solution was adopted on the land as a result of Extension education programs.

TOM MCCUTCHEN AND THE MILAN NO-TILL FIELD DAY

No story of no-till in Tennessee can be complete without mention of Tom McCutchen and the Milan No-Till Field Day (Dore, 1996). The Milan Experiment Station was established in 1963, with the specific objective of conducting field-scale research in cropping systems of western Tennessee. Tom McCutchen, who had been a county agent in Obion County, became its first superintendent. Tom was greatly concerned by the soil erosion he observed in West Tennessee fields. In the mid 1960's, he became convinced that no-till was the best solution, and he began work in developing no-till systems. In the early years, he was virtually on his own, facing skeptical farmers, researchers and administrators. But he persevered and as the technology improved more and more people came to agree.

By 1981, commercially viable systems of no-till corn and soybeans had been developed at Milan. The University was ready to promote no-till as the solution to soil erosion, so Tom staged the first Milan No-Till Field Day in July 1981. This event drew 2,000 in its first year, and grew steadily for the next 15 years until attendance reached 11,000 in 1995. The Milan Field Day is world famous, and has been a major factor in the adoption of no-till in the United States.

Tom McCutchen met an untimely death in 1983, but his work lives on. His successor, John Bradley, continued and expanded the work in no-till and the Field Day, becoming an internationally recognized no-till authority. The tradition continues today under Blake Brown. This year, for the 22nd year in a row, everyone involved in row crop production in western Tennessee knows exactly where he will be on the fourth Thursday in July.

ADVANTAGES OF NO-TILL PRODUCTION FOR TENNESSEE

Crop yields

On cropland with high yield potential (generally gently sloping to level, with deep, well-drained soils), yields of major crops from no-till are about the same as from conventional tillage (Graves *et al.*, 1993; Hoskinson and Gwathmy, 1996). Initially, there was concern that yield would eventually decline in continuous no-till systems, due to compaction, disease, insect infestation, depletion of phosphorus, or acidification of the soil. These concerns have proven to be unfounded in Tennessee. Table 2 shows yield of cotton at the Milan Experiment Station under no-till and tilled conditions from 1983 to 1993. While in any one year, the yield from either no-till or conventional tillage may be higher, the long term average is about the same. In general, no-till yields tended to increase relative to tilled yields over time.

Table 2. Cotton yield from tilled and no-till systems planted in residue from the previous crop. Milan, Tennessee, USA, 1983-1993

Year	No-till	Tilled
	---- kg lint ha^{-1} -----	
1983	599	590
1984	1158	1480
1985	1185	1151
1986	894	875
1987	1193	1104
1988	859	773
1989	943	773
1990	736	910
1991	1144	978
1992	1478	1381
1993	841	618
11 yr. average	1003	967

Soil Erosion

The initial purpose for development of no-till systems was for soil erosion control. No-till is quite effective in controlling erosion as long as there is adequate surface cover from crop residue or cover crops. For individual storm events at certain times during the growing season, the reduction in erosion from no-till can exceed 95 percent. For example, at the Milan Experiment Station in western Tennessee on June 11, 1981, a single large rainfall event of 64 mm resulted in soil loss of 26 Mg ha^{-1} on tilled soybean plots, compared to 0.4 Mg ha^{-1} on no-tilled plots. In five simulated rainfall events in 1982 (generated using a sprinkling rainfall simulator) soil loss from a no-till soybean system totaled 0.8 Mg ha^{-1} compared to 10.4 Mg ha^{-1} from a tilled system (Shelton *et al.*, 1983) The Revised Universal Soil Loss Equation predicts soil loss reduction of 50 to 90 percent from use of no-till in cropping systems in Tennessee. Experimental results confirm large reductions in erosion.

Table 3. Effect of tillage systems on the organic matter content of the upper 6 inch depth of a western Tennessee soil in soybean production.

Soil depth	No-till	Tilled
--- inches ---	---- g kg^{-1} soil ----	
0 - 3	24	11
3 - 6	12	13
0 - 6	15	13

Soil Organic Matter Content and Soil Quality Parameters

No-till systems increase soil organic matter content in the layers near the soil surface over a period of time (Tyler *et al.*, 1983). Table 3 shows the organic matter content of the Ap horizon (0-6 inches) of a silt loam soil in western Tennessee after five years of no-till soybean production as compared to a tilled soil. The increase is concentrated near the surface. This is very important to the infiltration of rainwater. The higher organic matter content near the surface promotes more stable soil aggregates with stable macropores, which are resistant to closing by surface soil sealing under raindrop impact. This promotes higher infiltration rates and less runoff through the growing season.

Comparison of a 25-year no-till field at Milan to a tilled field showed higher infiltration rates, greater aggregate stability, and many more earthworms in no-till soil. Bulk densities of the upper 3 inches were the same (Seybold *et al*, 2002). Earthworm populations increased from negligible in tilled to over 100 per m^2 in no-till. Aggregate stability and infiltration rate were an order of magnitude higher in no-till.

Management Factors

No-till production requires less labor for tillage, planting and in-season weed control. The total investment in machinery is less over the long run. The power requirements are lower, and the hours of machinery use are lower. Less fuel is required as well.

No-till helps with timeliness of operation as well. Under Tennessee conditions, there is a relatively short period of time in spring (April-May) suitable for successful planting of warm season crops. The days available for land preparation and planting are reduced by rain during this period. No-till production eliminates the need to use some of these days for seedbed preparation, allowing all suitable days to be used for planting. This assists with timely planting in years when rainfall is above normal in the spring.

Because of more stable structural aggregates, no-till soils have better trafficability at harvest time as well. This also allows for timelier machine harvest when the fall period (September-November) is unusually rainy.

CONTINUING CONCERNS IN NO-TILL IN TENNESSEE

Weed Control

With the development of a wide range of herbicides and glyphosate-resistant varieties over the past 30 years, weed control is no longer a major obstacle to use of no-till in cotton, corn or soybeans. However, it is a limitation in many other crops, especially vegetables, which occupy a small total planted area. Herbicide choices are very limited for many of these crops, and hand weeding is usually required. Apparent glyphosate resistance is appearing in marestail in Tennessee fields, threatening the sustainability of continuous glyphosate tolerant crops in no-till.

Inadequate Biomass for Mulch for Erosion Control

Effective control of erosion in no-till requires the production of enough plant biomass to form a mulch layer on the soil surface that will persist until the next crop is established. This is a problem in some cropping systems that produce relatively little biomass. It is also a problem in systems where all of the biomass is removed at harvest, such as corn silage. This problem can be overcome by changing to a cropping system with more biomass, or by using cover crops, which are grown in the interval between crops for the purpose of providing biomass for surface mulch. Lack of residue is a particular problem in continuous cotton. Even with no-till, residue cover is inadequate for erosion control on slopes of more than 4 percent (Denton and Tyler, 1997). Cover crops or rotations are needed, but economic factors continue to limit the effectiveness of these systems.

Disease and Insects

Experience in Tennessee has shown that disease and insect problems are not usually increased in no-till as compared to tilled systems. There may be problems, however, with diseases that persist in the residue of crops if those crops are grown continuously, or if the residue from the crop persists throughout the cropping sequence. This has been a problem in Tennessee with wheat. While some farmers here had success with no-till wheat, in general yields have been lower than in minimum tilled systems. In part, this is due to disease.

Inadequate Planting Equipment

Adequate planting equipment is still a problem for transplanted crops, and for small grains (wheat, barley, etc.) if there is a large amount of residue cover. For small farmers, the expense of no-till planting equipment is a significant barrier to use. This has been overcome in some cases by using cooperatives to purchase equipment for rental.

SUMMARY

In Tennessee, no-till has proven to be a very successful production system. It has allowed intensive crop production on highly erodible land with little soil erosion. Costs of production are not increased, and may be lower in some cases. Yields of crops have been maintained or increased. Soil quality has improved. The widespread soil degradation occurring on hundreds of thousands of acres in western Tennessee in 1975 had been greatly reduced, with average erosion rates dropping by 60 percent or more. No-till has become conventional in Tennessee.

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Tyler, D.D. and T.C. McCutchen. 1980. The effect of three tillage methods on soybeans grown on silt loam soils with fragipans. Tennessee Farm and Home Sci. 114:23-26.Table 1. Percentage of the area of major Tennessee crops planted using the no-till system, 1985-2001. (no numbers are available for cotton before 1992)