# CONSERVATION PRODUCTION SYSTEMS FOR SILTY UPLANDS

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## INTRODUCTION

In 1987, the USDA-ARS National Sedimentation Laboratory, in cooperation with MAFES and Mississippi SCS, initiated an interdisciplinary research project directed at developing economically profitable and environmentally sustainable conservation production systems for silty upland soil resource areas of the mid-South. The project is located on the A. E. Nelson Farm in Tate County, south of Senatobia, MS. Primary studies include measurement of yields and economic returns from several cropping and tillage systems on replicated plots and determination of runoff and erosion amounts from plots and small watersheds. A number of supplementary studies have been added to clarify details of covercrop management, benefits of planting soybean and sorghum in narrow rows, responses of determinant and indeterminant soyhean cultivars to early-April plantings, feasibility of double-cropping tropical corn after wheat or reseeding cover crops, influences of earthworms on water infiltration rates and patterns, management of narrow grass barriers (hedges) to slow runoff and trap eroded sediment, and concentrations of nutrients and pesti-cides in ground and surface waters. This report presents an up-to-date overview of some results obtained from the primary studies.

## METHODS

Fourteen production treatments were evaluated on 40- by 18-ft plots established in the fall of 1987, arranged in a randomized block design, and replicated 10 times. Plots were primarily located on Grenada silt loam (fine silty, mixed, thermic Glossic Fragiudalf), with some areas of Memphis and Loring soils. Three summer crops (cotton, sorghum, and soybean) have been grown under conventional chisel/disk tillage, ridge tillage, reduced (one-pass) tillage, and no-tillage. The no-till soybean treatment was doublecropped with winter wheat, the no-till cotton was planted into a killed wheat cover crop, and no-till grain sorghum was planted into a killed hairy vetch cover crop. An additional no-till treatment, a 2-year rotation of monocrop grain sorghum and wheat doubleeropped with soybean, provided a harvest of three crops in 2 years. All crops were planted in 36-inch rows except wheat and doublecrop soybean, which were drilled in 7" rows. The only no-till plots that were row-cultivated were cotton and sorghum in 1988 due to heavy populations of nutsedges and perennial vines. In the cotton treatments, soil moisture was monitored weekly each year, and soil temperature at 2 inches was recorded hourly for a few weeks before and after planting in 1992. The possibility that compaction of ridge-till beds was limiting yields was tested by paratilling five of the replicates on 5 May 1992 prior to planting crops.

Runoff and erosion from natural rainfall were measured from duplicate sets of eight runoff plots (12 ft wide by 72.6 ft long on a 4% slope) starting in 1990 and from three watersheds (5 to 7 acres in size with slopes ranging from 1 to 8%) starting In 1989. Treatments evaluated on the erosion plots Included conventional till, ridge till, no-till monocrop, and no-till doublecrop soybean; no-till grain sorghum with and without a vetch cover crop; and no-till cotton with and without a wheat cover crop.

All watersheds were farmed identically during 1988 and 1989 with a reduced-tillage soybean production system in which a single pass of a mulch-tinisher was made prior to planting, and rows were cultivated twice. Beginning in 1990, one watershed (#2) was farmed with conventional (chisel, disk twice, cultivate) tillage and the other two with no-till soybean. One no-till watershed (#3) had a grassed waterway established in 1991, and the conventional-till watershed had two 18-ft wide fescue buffer strips established 150 ft apart in 1992.

## RESULTS AND DISCUSSION

### Weather

Rainfall amounts and timing (Table 1) have varied greatly among the years of this study and this has affected the yields, profitability, runoff, and erosion

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Table 1. Rainfall at the Nelson Farm during the past 5 years.

| Year | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Tot. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (in) | | | | | | | | | | | | |
| 1988 | 1.95 | 2.91 | 4.71 | 4.52 | 0.69 | 0.04 | 1431 | 029 | 521 | 1.19 | 6.90 | 638 | 49.1 |
| 1989 | 6.07 | 7.09 | 5.52 | 127 | 3.68 | 13.42 | 8.62 | 2.94 | 5.12 | 123 | 4.19 | 2.93 | 61.9 |
| 1990 | 4.80 | 12.66 | 738 | 5.81 | 8.14 | 2.08 | 2.44 | 0.22 | 1.68 | 5.53 | 3.89 | 13.50 | 68.1 |
| 1991 | 2.12 | 932 | 539 | 15.82 | 6.48 | 335 | 234 | 3.18 | 1.45 | 4.70 | 8.05 | 6.68 | 682 |
| 1992 | 234 | 2.88 | 8.70 | 2.00 | 0.90 | 6.62 | 4.75 | 5.13 | 2.03 | 2.59 | 3.79 | 436 | 46.1 |
| Norm | 4.84 | 4.76 | 5.55 | 5.47 | 5.51 | 3.58 | 3.54 | 2.99 | 3.70 | 228 | 4.80 | 520 | 522 |

from all cropping systems. In 1988, very dry weather during May and June was followed by heavy rains in July and then another period of drought in August. Wet weather during June 1989 promoted soybean disease (stem canker) development, which subsequently was aggravated by dry weather. Unusually dry weather from June through September 1990 limited yields of all crops. Exceptionally wet weather during April 1991 delayed conventional tillage land preparation, hut timely rains in August salvaged yields of most crops. Well-distributed rainfall during June through August 1992 resulted in good yields.

## Crop Yields

Productivity of no-till fields has sometimes increased with length of time that no-till practices were followed. This has been the case with cotton at the Nelson Farm. No-till cotton yields were lower relative to those from conventional tillage in the first year (1988) but were greater after the second year (1990 through 1992) (Table 2). In the second year (1989), all cotton was damaged by contamination in the first insecticide application, and no significant differences in yield resulted. Since the third year, no-till-planted cotton has grown faster and plants have been larger and fruited earlier than those of other tillage systems. Increased water use by these larger plants has resulted in drier soil conditions under no-till as monitored by a neutron gage.

In the spring of 1988, organic matter content in the top inch of soil was 1.8 to 1.9% in all plots. By the spring of 1992, it had increased to 2.8% in the no-till cotton treatment and decreased to 1.6% in the conventional cotton treatment. In 1992, soil in no-till plots was usually cooler than that in conventionally bedded plots in the afternoon hut was warmer at 8:00 AM. Higher minimum temperatures, less herbicide injury (because of higher soil organic matter), less crusting and sealing following hard rainfall, greater water holding capacity, and better fertility status in the top inch may all have contributed to the enhanced early seedling growth of no-till-planted cotton. This growth enhancement was observed during the wet springs of 1990 and 1991 and the dry spring of 1992. Serious erosion was visually evident on many of the conventionally tilled cotton plots. This may have contributed to decreased yields and a reduced soil organic matter fraction relative to no-till plots.

**Table 2. Yield of DES 119 cotton[1] on Nelson Farm plots, 1988 through 1992.**

| system | 1988 | 1989[2] | 1990 | 1991 | 1992 |
|---|---|---|---|---|---|
| | Seed Cotton Yield (lb/A) | | | | |
| Conventional tillage | 1830 | 1230 | 1125 | 1540 | 2480 |
| Ridge tillage | 1560 | 960 | 825 | 1460 | 2275 |
| One-pass tillage | 1430 | 1080 | 1130 | 1740 | 2425 |
| No-till (wheat cover crop) | 1560 | 890 | 1335 | 2200 | 3000 |
| | (days after planting) | | | | |
| *Growing* season length | 190 | 210 | 147 | 162 | 182 |

[1] Fertilized with 90 lb N/A as $NH_4NO_3$ 1988 to 1991, 115 lb N/A in 1992.

[2] All 1989 cotton treatments were damaged by a contamination in tbe first insecticide application during July 1989.

A similar trend of improved no-till yields relative to conventional tillage developed in the grain sorghum plots (Table 3). This trend started in the second year of the study and continued up to 1992. A cover crop or a crop rotation was utilized in both no-till sorghum systems, and these practices may have contributed to the increased yield of the no-till systems.

Table 3. Yields of DPL G-1602 sorghum from Nelson Farm plots, 1988 through 1992.

| system | 1988 | 1989 | 1990 | 1991 | 1992 |
|---|---|---|---|---|---|
| | (lb/A) | | | | |
| Conventional tillage1 | 3990 | 4240 | 2640 | 4370 | 4610 |
| Ridge tillage' | 3710 | 3920 | 2280 | 3890 | 3450 |
| Onepass tillage2 | 3930 | 4250 | 2050 | 3960 | 3910 |
| No-till (vetch cover)' | 3580 | 4780 | 2930 | 5250 | 4660 |
| No-till (soybean rotation)' | 3160 | 5290 | 3160 | 5210 | 4720 |

[1] Fertilized with 120 lb N/A as $NH_4NO_3$
[2] Fertilized with 45 lb N/A as $NH_4NO_3$ 1988 to 1990 and 70 lb N/A in 1991 and 1992.

In contrast to cotton and sorghum, soybean yields have not been significantly influenced hy tillage (Table 4); however, all no-till soybean treatments were planted later (after wheat harvest) than those of other tillage systems. Full-season soybean yields have been disappointing, largely due to the influence of drought in July and August that limited reproductive development of large soybean plants. Double-crop yields have been similar to yields of full-season beans. The timeliness of planting wheat in the continuous double-crop system was improved when the soybean cultivar was switched from 'Centennial' (Group VI) to 'DPL-415'(Group V) in 1990. Weed control has required less herbicide in wheat and soybeans grown in rotation with sorghum than in the continuous double-crop system.

Paratilling in 1992 loosened and dried out the soil, slowed seedling establishment, and resulted in reduced yields of cotton and sorghum where no rain fell between paratilling and no-till planting (Table 5). In contrast, paratilling resulted in increased yields of soybean planted after beds were settled and moistened by 0.75 inches of rainfall. The benefit of occasional paratilling in no-till systems on silt loam soils deserves further research.

Table 4. Yields of soybean' and wheat (Florida 302) on Nelson Farm plots, 1988 through 1992.

| system | 1988 | 1989 | 1990 | 1991 | 1992 |
|---|---|---|---|---|---|
| | | | (bu/A) | | |
| | | | **Soybean** | | |
| Conventional tillage | 20.5 | 20.2 | 14.8 | 31.8 | 35.7 |
| Ridge tillage | 20.4 | 21.9 | 173 | 31.6 | 43.6 |
| One-pass tillage | 23.5 | 19.6 | 14.4 | 28.1 | 41.8 |
| Continuous double crop | 24.7 | 26.7 | 133 | 31.6' | 42.1 |
| Sorghum/double croprotation | – | 24.0 | 14.1 | 34.6 | 43.0 |
| | | | **Wheat** | | |
| Continuous double crop | 81.0 | 29.7 | 44.1 | 0² | 49.1 |
| Sorghum/double crop rotation | 77.4 | 40.2 | 44.7 | 24.6 | 45.0 |

[1] Soybean cultivars were Bedford (monocrop, 1988-89); Centennial (double crop, 1988-89); or DPL415 (1990 to 1992).
[2] Wheat was killed with herbicides due to severe weed infestation, and soybean was drill-planted at time of monocrop plantingin 1991.

Table 5. Influence of Paratill on yield of ridge-tilled crops, 1992

| Crop | Planting Date | Rainfall' | Yield Paratill | No-Paratill |
|---|---|---|---|---|
| | | (in) | (@/A) | |
| Cotton | 5/12 | 0 | 2050 | 2550 |
| Sorghum | 5/14 | 0 | 3010 | 3800 |
| Soybean | 5/20 | 0.75 | 2950 | 2410 |

[†] Rainfall between paratilling (4 May 1992) and planting.

## Economic Returns

Economic analyses have been completed only for the first 4 years of the study (Table 6). Tbey have indicated that cropping systems involving wheat have been the most profitable. Continuous doublesrop soybean and wheat has been the single most profitable system despite a complete failure in one wheat crop due to inadequate weed control. Interrupting the buildup of grass weeds (ryegrass, little barley, cheat) in wheat by occasionally killing the wheat as a cover crop and

Table **6.** Net returns to land and management from production treatments for **1988** through **1991.**

| Treatment | 1988[1] | 1989[2] | 1990[3] | 1991[4] | Average[5] |
|---|---|---|---|---|---|
| | dollars/A | | | | |
| | | | Cotton | | |
| Conventional tillage | 61.06 | no | -112.08 | 54.17 | 1.05 |
| Ridge tillage | 11.98 | meaningful | -145.46 | 56.78 | -2556 |
| Minimum tillage | - 23.92 | data | - 99.70 | 11639 | - 2.41 |
| No-till with wheat cover crop | 2.54 | obtained | - 88.40 | 151.80 | 21.98 |
| | | | Grain Sorghum | | |
| Conventional tillage | - 16.95 | - 1433 | - 5926 | 21.85 | -17.17 |
| Ridge tillage | - 3138 | - 32.90 | - 66.82 | 16.08 | -28.76 |
| Minimum tillage | - 34.68 | - 238 | - 6835 | 16.88 | -2230 |
| No-till with vetch cover crop | - 5227 | - 3.55 | - 64.41 | 31.01 | -2230 |
| No-till (SB/W rotation) | - 88.75 | 20.78 | - 44.84 | 4827 | -16.14[6] |
| | | | Soybean | | |
| Conventional tillage | 13.05 | - 25.12 | - 4627 | 68.88 | 2.64 |
| Ridge tillage | - 536 | 8.82 | - 3125 | 86.62 | 14.70 |
| Minimum tillage | 12.74 | 1730 | - 40.18 | 60.80 | 12.66 |
| No-till with wheat double crop | 229.93 | 64.01 | 5259 | 28.26[7] | 93.70 |
| No-till with wheat (GS rotation) | 21737 | 61.23 | 59.96 | 131.33 | 117.47[6] |

[1] Ricer paid based on 1988 prices and prices received are based on a 5-year average (1984-88): cotton Lint ($0.59/lb); cotton seed ($0.03/lb); grain sorghum ($4.11/cwt); wheat ($3.21/bu); and soybeans ($5.95/bu).

[2] Prices based on 1989 prices and prices received are based on 5-year average (1985-89): cotton lint ($0.56A/lb);cotton seed ($0.03/lb); grain sorghum ($3.62/cwt); wheat ($3.24/bu); and soybean ($5.91/bu).

[3] Input prices based on 1989 prices and prices received are based on 5-year average (1986-90): cottou Lint ($0.57/lb); cotton seed ($0.04/lb); grain sorghum ($3.95/cwt); wheat ($3.26/bu); and soybeans ($5.86/bu);

[4] Input prices based on 1991 prices paid and prices received are based on 5-year average (1987-91): cotton Lint ($0.59/lb); cotton seed ($0.04/lb); grain sorghum ($4.03/cwt); wheat ($3.25/bu); and soybeam ($6.03/bu).

[5] Three years for cotton, 4 years for other crop combinations.

[6] Average return per acre per year from all three crops is $50.67.

[7] Wheat crop terminated due to severe weed pressure following planting without burndown herbicide application.

planting a rotation crop, such as no-till cotton (see below), into the killed residue may be a sound management practice.

The 2-year rotation of monocrop sorghum with doublesrop soybean following wheat was the second most profitable system. While the soybean and wheat crops were more profitable in rotation than in the continuous double-crop system, the grain sorghum crop generated a net loss in some of the alternate years. In a related study, a 4-year average yield from continuous corn was 119 bu/A (datanot presented). Such a yield, if sustainable, would make corn a more profitable rotational crop than grain sorghum on this soil.

No-till cotton planted flat into a killed wheat cover crop has been, on average, a profitable system. It has been the most profitable of all cotton systems, but all have shown great variability in profit or loss among years. Future research will address the possibility of using dense cover-crop residues to reduce herbicide costs in no-till cotton production.

Runoff, Erosion, and Sediment Yield

As expected, the average monthly runoff for all plots was significantly related to monthly rainfall with $r = 0.80$ ($p \geq 0.99$). To a large degree, this significance reflects general coherence between rainfall amounts and intensities, with minimal variance attributable to antecedent soil water conditions. Only two monthly values exhibited large deviations. These two outliers occurred in April 1991 (runoff of 20% for 15.8 in. of rainfall) and June of the same year (runoff of 20% for only 3.4 in. of rain). This latter outlier resulted primarily from one large event on June 12 and 13, whereas the relatively low runoff in April resulted from prolonged low-intensity rainfall (26 different storms occurred) with a paucity of high-intensity rains. Excepting these two outliers, the correlation would have been $r = 0.90$.

Although only 2 years of results are available, several tendencies are apparent based on the annual runoff from the eight management systems (Table 7). Grain sorghum with a vetch winter cover produced the least runoff, about 82% of rainfall for these 2 years. This lesser runoff is attributed to the increased water consumption by vetch in late winter and early spring, increased soil mesofauna activity, and the dense ground cover, which limited surface crusting or sealing. In contrast, runoff from conventionally tilled soybean plots was about three times larger, averaging 23% of rainfall for these 2 years. Runoff percentages for both grain sorghum systems, the conventionally tilled soybean system, and the double-cropped soybean-wheat system did not vary between years. The two no-till cotton and the no-till soybean treatments, however, had about an 8% runoff reduction the second year. This reduction coincided with better cover crop growth (wheat or volunteer) following the 1990 cotton harvest.

Watershed runoff (Table 8) was generally greater than from runoff plots. The maximum monthly runoff percentage varied from 0 to 80% (data not shown). The 1989 average yearly runoff percentages were 52, 44, and 38% for Watersheds 3, 2, and 1, respectively, when reduced conventional tillage was used for all watersheds. The yearly runoff percentages for 1990 and 1991 presented no clear trends. No-till planting was employed in Watersheds 1 and 3, and annual runoff percentages declined marginally from the 1989 values. Watershed 2 was tilled conventionally in 1990 and 1991, and although the 1990 runoff percentage was slightly reduced relative to the 1989 value, the 1991 percentage was actually 7% larger than the 1989 value. The 3-year average runoff percentages for Watersheds 1, 2, and 3, respectively, were 35, 45, and 47%, again reflecting primarily topographic and soil controls.

Runoff and erosion differences between the plot and watershed studies are sizeable (Tables 7 and 8). Runoff relations for the plots are materially influenced by management-system effects on the plot surface and near-surface conditions. Conditions at greater soil depths are not of great importance due to free drainage of infiltrated waters out of the plot areas. A fragipan is close to the soil surface in the toe- or foot-slope landscape positions in the Nelson watersheds. Waters infiltrated upslope within the watershed are returned to the surface at these locations of minimum depth to the pan, contributing to surface flow and/or prolonged saturation of the soils in the swale position (immediately downstream of the toe slope). Both of these influences directly contribute to the higher runoff rates from the watersheds relative to the plots.

Annual soil losses for the erosion plots were greatest for the conventionally tilled soybean system with volunteer winter cover (4.6 to 5.0 t/A) and least for the no-till treatments with vetch following grain sorghum or wheat following soybean (0.3 to 0.6 t/A). Soil loss from cotton plots was greater, in 1990, where a wheat cover crop was planted than from the volunteer cover treatment. Poor wheat growth resulted following the late 1989 planting, and this did not compensate for the increased erosion caused by disturbance of the cotton residue by the no-till grain drill. In 1991, a better wheat cover crop reduced soil loss compared with the volunteer-cover treatment.

Annual sediment yields for the two no-till watersheds averaged 0.5 t/A. In contrast, the 2-year average sediment yield from the conventionally tilled watershed was 9.6 t/A, well above the T-value of 3 t/A. Three-year (1990 to 1992) soybean grain yields averaged 29.0 and 27.1 bu/A for the no-till and conventionally tilled watersheds, respectively.

## CONCLUSIONS

Ongoing research has identified several conservation production systems that appear to limit soil erosion to tolerable levels while allowing profitable production of agronomic crops on silty upland soils in the mid-South. Systems involving winter wheat as a crop or cover crop were the most profitable during the first 5 years of this study. No-till planting techniques and winter cover cropping improved growth and yield of cotton, reduced runoff and erosion rates, and increased economic net returns.

Table 7. Annual runoff and erosion from Nelson Farm erosion plots'.

| Crop | Treatment | 1990 Runoff | 1990 Soil Loss | 1991 Runoff | 1991 Soil Loss |
|---|---|---|---|---|---|
| | | --(in)-- | ---(t/A)--- | --(in)-- | --(t/A)--- |
| Cotton | No-till with wheat cover | 18.9 | 3.0 | 11.8 | 1.2 |
| Cotton | No-till with volunteer cover | 11.8 | 1.6 | 8.0 | 1.6 |
| Sorghum | No-till with vetch cover | 5.6 | 0.4 | 5.5 | 0.6 |
| Sorghum | No-till with volunteer cover | 11.1 | 0.8 | 12.6 | 1.0 |
| Soybean | Ridge-till w. volunteer cover | 12.1 | 1.2 | 9.5 | 1.8 |
| Soybean | Double cropped w. wheat | 10.6 | 0.3 | 11.0 | 0.3 |
| Soybean | No-till w. volunteer cover | 14.5 | 0.6 | 8.8 | 0.8 |
| Soybean | Conventional w. volunteer cover | 15.0 | 4.6 | 16.8 | 5.0 |

† 1992 results are not complete at this time.

Table 8. Annual runoff and sediment yield from Nelson Farm watersheds'.

| Watershed number | 1989 IRainfall=61.9 in) Treatment | Runoff | Sed. Yield | 1990 (Raint'all=68.1 in) Treatment | Runoff | Sed. Yield | 1991 (Rainfall=682 in) Treatment | Runoff | Sed. Yield |
|---|---|---|---|---|---|---|---|---|---|
| | | --(in)-- | -(t/A)- | | --(in)-- | -(t/A)- | | --(in)-- | -(t/A)- |
| 1 | Reduced/ Conventional | 23.4 | 8.3 | No-till | 212 | 0.5 | No-till | 24.8 | 02 |
| 2 | Reduced/ Conventional | 272 | 19.6 | Conventional | 272 | 4.5 | Conventional | 34.7 | 14.6 |
| 3 | Reduced/ Conventional | 32.4 | 13.3 | No-till | 30.6 | 1.0 | No-till with grassed waterway | 31.7 | 0 3 |

† 1992 results are not complete at this time.