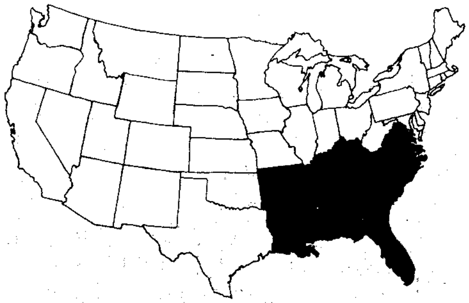

Conservation tillage in the Southeast

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THE Southeast can probably benefit more from conservation tillage than any region in the United States. Conservation tillage provides economically sound tillage methods, an optimum plant environment, and conservation of soil and water resources (*50*). It also assures efficient use of stored water during short-time droughts, particularly in many coarse-textured Coastal Plains soils, which have low water storage capacities and hardpans.

The Southeast generally receives adequate precipitation throughout the year. Because rainfall is adequate and the growing season long, double cropping is one management alternative. Nevertheless, water stress during the cropping season is frequently a serious problem because of poorly distributed rainfall. In early spring, soil water storage generally is high because of winter rains. Most water falling during the spring is lost as runoff with great erosion potential.' During the growing season, recharge is often incomplete, partly because of the high intensity of rainstorms and the often unprotected soil surface.

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Besides the low soil-water storage capacity of the sandy surface soils, many soils of the Coastal Plain have root-restricting layers 20 to 30 centimeters (8-12 in) below the surface. These soils become droughty within 3 to 7 days after rainfall. Frequent water replenishment is necessary for maximum production. On the intensively farmed upland soils of the Piedmont and Appalachian Plateau, erosion hazards are potentially severe, even though infiltration rates may be high, because of steep slopes and high intensity rainstorms.

Conservation tillage practices that modify limiting soil physical properties and use crop residues for surface protection can minimize erosion and enhance infiltration and recharge of soil water storage even though intensive rainstorms do occur. Several kinds of conservation practices are feasible and have been practiced in the region. Contouring and strip cropping are practiced by many farmers, especially in the Piedmont and Upper Coastal Plains. Many terraces still exist in these regions also. Relatively mild winters facilitate growth of winter cover crops and enhance the possibilities for double cropping.

No-till Planting

No-tillage crop production is a major step forward in the conservation of soil and energy. The system drastically reduces the number of field operations and may be the most revolutionary and effective soil conservation practice adopted in this century. No-tillage also has a lower per acre energy requirement, which allows greater cropping flexibility (Figure 1).

Where suitable, no-tillage production offers many advantages over conventional tillage (*13*). Row crops can be grown on sloping land previously considered unsuitable or marginal for intensive conventional tillage. Included are significant amounts of land in Kentucky, Virginia, Tennessee, Georgia, and the Carolinas.

In these areas no-till also reduces the risk in double cropping by conserving soil moisture at seeding, reducing wind and water erosion, and decreasing the labor and time required to establish the second crop. No-till planting in the stubble of the first crop increases available moisture (*26*).

No-till corn production has been widely accepted throughout the Southeast. In Kentucky and Virginia about 25 percent of the corn acreage is in no-till (*36, 40*).

No-till production of soybeans has increased even faster. In 1976 Kentucky and Virginia had an estimated 141,750 and 51,400 hectares (350,000 and 127,000 acres), respectively, in no-till soybeans. About 80 percent of the no-till soybeans in Kentucky are part of double-cropping systems featuring wheat or barley. Farmers in western Tennessee are also showing increased interest in double cropping small grains and no-till soybeans (personal communication with McCutchen University of Tennessee Milan Field Station).

In South Carolina the no-till acre-

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age has increased steadily in recent years to 13,610 hectares (33,604 acres) in 1976 (personal communication with Holden, SCS). Most of this no-till cropping is done on Piedmont and upper Coastal Plain soils. A few acres are no-till planted on South Carolina's middle and lower Coastal Plain.

A primary advantage of no-till is conservation of soil water (*4*, *16*, *26*). Reduced soil water evaporation and increased infiltration makes more water available for transpiration by plants. For example, evaporation of soil water from a conventionally tilled Maury silt loam (Typic Paleudult) from May through September was 2.4 times greater than from the same soil with no-tillage (*31*). This provided 18 percent more water for transpiration by no-till corn compared with conventionally tilled corn (33 versus 28 centimeters per growing season).

Long-term continuous no-tillage often improves the physical properties of silt loam and loam soils. Eleven years of no-till operation increased soil aggregation, soil moisture retention, and organic matter in the upper 5 centimeters (2 in) of soil (*22*). Kentucky and Virginia studies (*22*, *40*, *45*) showed no change in soil bulk density due to long-term no-tillage.

Another advantage of no-till planting is the surface or crop mulch that increases infiltration and reduces erosion. Conventionally tilled plots lost seven times more soil to water erosion than no-tillage plots in soybean trials on a Providence silty clay loam (Typic Fraqiudalf) in northern Mississippi (*21*). The erosion control benefits of no-tillage increased with time as more surface residue accumulated. In general, no-till crop yields compared favorably with conventionally tilled yields. However, some low yields were noted on no-till plots. Success of no-till systems depends primarily on proper seedbed preparation and timely herbicide application, and the weather, of course.

On a Cecil sandy loam (Typic Hapludult) in the Southern Piedmont, no-till corn in tall fescue produced satisfactory yields when irrigated (*8*). Corn plant populations and grain yields were higher in killed sod than in live sod. Corn yields in the killed sod ranged from 9,500 to 12,960 kilograms per hectare (8,500-11,500 lb/a), depending on the amount of nitrogen (N) and poultry litter applied. Subsequent work showed that weekly irrigations of 5 centimeters (2 in) of water resulted in corn grain yields of 8,666 and 10,191 kilograms per hectare (7,700 and 9,100 lb/a) on fescue sod that had been 20 percent strip-killed and 100 percent killed, respectively (*6*). Without irrigation the respective yields were 8,390 and 8,428 kilograms per hectare (7,491 and 7,525 lb/a). On the 20 percent strip-killed sod treatment, fescue forage yield was 4,760 kilograms per hectare (4,250 lb/a). Both sod treatments reduced soil erosion.

No-till planting in North Carolina is used primarily with double-cropping systems. Soybeans follow winter wheat or barley, which are harvested in late June or early July (*18*, *19*). Some barley varieties mature up to 2 weeks earlier than wheat, giving the system additional flexibility. Large growers spread their small grain harvesting and soybean planting by using both wheat and barley.

In 1974 about 2 percent of the 444,450 hectares (1,097,400 acres) of soybeans in the Coastal Plain were no-till planted in early spring. This compared with 6.4 percent of the 137,700 hectares (340,000 acres) in the Piedmont. Nearly a fourth of the soybeans in the Piedmont were no-till planted as the second crop in a double-cropping system, while only 3 percent of the soybeans in the Coastal Plain were part of such a system.

Lewis and Phillips (*19*) reported a 4-year study of no-till planting of corn, soybeans, and grain sorghum for several cropping systems in North Carolina on a Appling sandy loam (Typic Hapludult) and a Norfolk fine sandy loam (Typic Paleudult). The researchers planted continuous corn at both sites with conventional and no-till methods at normal planting times. For double-crop systems, they seeded winter wheat in the fall with conventional tillage or by overseeding in the previous crop residue. The row crops, seeded conventionally and with no-till, followed winter wheat. Atrazine and cyanazine were used for weed control in corn, atrazine in grain sorghum, and linuron in soybeans.[1] Table

[1]Use of trade names in this article does not imply endorsement by the U. S. Department of Agriculture or the North Carolina or Kentucky Agricultural Experiment Stations of the products named over similar ones not mentioned.

Table 1. Four-year average yields in a North Carolina double-cropping study (*19*).

Cropping System		*Yield (Kg/ha)*			
		Piedmont (Norfolk fine sandy loam)		*Coastal Plains (Appling silt loam)*	
Winter	*Summer*	*Winter Wheat*	*Summer Crop*	*Winter Wheat*	*Summer Crop*
	Corn CS[a]		5,143		5,582
	Corn NT[b]		5,268		5,268
Wheat CS	Corn CS	2,486	2,822	1,747	2,383
Wheat CS	Corn NT	2,486	2,641	1,613	3,136
Wheat OS[c]	Corn NT	1,008	4,892	470	2,948
Wheat CS	Soybean NT	2,453	2,016	1,882	1,949
Wheat OS	Soybean NT	991	1,680	403	1,478
Wheat CS	Grain Sorghum NT	2,234	3,450	1,781	2,697
Wheat OS	Grain Sorghum NT	1,331	2,885	988	2,634

[a]CS, conventional seedbed.
[b]NT, no-till planted.
[c]OS, overseeded in previous crop.

Table 2. Four-year average net return[a] to land and management for four cropping systems at two locations in North Carolina (*19*).

Cropping System[b]	*Net Return ($/ha)*	
	Piedmont (Appling sandy loam)	*Coastal Plains (Norfolk fine sandy loam)*
Continuous corn	230	161
Wheat-corn	91	−54
Wheat-soybeans	237	165
Wheat-grain sorghum	119	10

[a]Based on average annual price (1971-1974) in North Carolina for each crop and variable production costs per year. All production charges were included except land and management.
[b]Wheat planted in conventionally prepared seedbed, second crop no-till planted.

1 gives the 4-year average crop yields at the two locations (*19*).

In the Piedmont, continuous corn planted early resulted in similar yields for the no-till and conventional seedbed preparations. In the double-crop system, no-till corn outyielded conventionally tilled corn by 4 percent. Depletion of moisture reserves by evaporation during and after seedbed preparation accounted for the yield decline under conventional tillage. Double-cropped no-till corn yields were 7 and 10 percent less than the early planted no-till and conventionally planted corn yields, respectively. In all cases, winter wheat overseeded in the residue of the previous crop yielded 40 to 60 percent less than conventionally planted winter wheat. Second-crop yields of soybeans and grain sorghum were greater when no-till planting followed conventionally planted winter wheat than following overseeded wheat.

In the Coastal Plain the 4-year average grain yield of early, conventionally planted corn on Norfolk fine sandy loam was 314 kilograms per hectare (280 lb/a) greater than no-till corn. Second-crop corn yields were greater when no-till planting was compared with conventional planting, although observed differences were not as great as those in the Piedmont. Second-crop no-till corn yielded 31 percent more than conventionally seeded corn (3,136 versus 2,383 kg/ha). No-till soybeans following conventionally planted wheat yielded 471 kilograms per hectare (420 lb/a) more than no-till soybeans following wheat overseeded directly in the previous corn crop residue. Lewis and Phillips (*19*) speculated that residual fertilizer, surface broadcast on the preceding corn crop, may have been mixed into the conventionally prepared seedbed, thus benefitting soybeans.

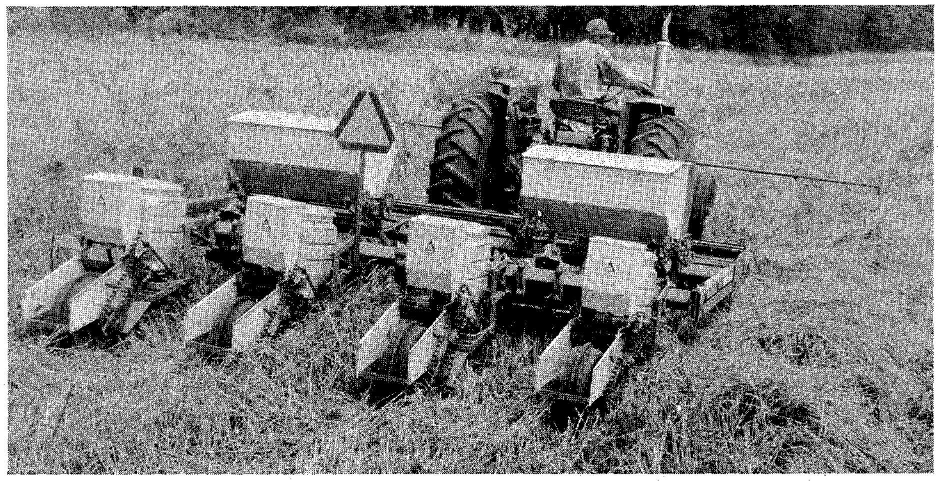

Photo by Jarvis Knight

Figure 1. No-till planting of corn conserves soil and water while saving labor and energy. Herbicides suppress unwanted vegetation.

Economics of No-tillage

Many farmers can farm more acres with little increase in labor, machinery, or land costs by double cropping suitable land. Virginia studies (*20*) showed that annual land costs (interest and taxes), most machinery costs, and labor costs generally are fixed. They do not increase when double cropping stubble land. In general, for typical double-cropped soybeans, any return over variable costs increases profits. The variable or added costs of producing double-crop soybeans represent less than 50 percent of total production costs.

In a Kentucky study, total corn production costs per acre for no-tillage nearly equalled the costs for conventional tillage (*2*). Labor, wage, and overhead costs were less for no-tillage, but chemical costs were higher. Yield comparison studies (*27*) in central Kentucky showed that 25 farms with no-tillage corn produced an average of 1,180 kilograms per hectare (1,050 lb/a) more than 18 farms using conventional tillage corn in 1975 (a dry year). Studies in Virginia (*16, 17, 22, 40*) showed higher yields for no-tillage corn compared with conventional tillage systems.

Table 2 provides economic data from North Carolina (*19*) for the four cropping systems in table 1. A double-crop system of no-till soybeans following conventionally planted winter wheat produced the largest net return to land and management. However, there was little difference between continuous corn and the wheat-soybean double-crop system in both the Piedmont and Coastal Plain.

Fertilization

No-tillage practices required a second look at the management of fertilizer and lime amendments (*41*). Thomas (*44*) described fertilization practices for no-tillage row crops as similar to fertilization of grass and forage legumes. Previously, phosphorus (P) fertilization was particularly suspect because of its low mobility in many soils. However, research (*3, 37*) showed that P was readily available when surface-applied under no-tillage. P covered with surface mulch was more effective than P disked in (*37*).

Generally, N fertilization is not a problem with no-tillage production (*23*). Injection of anhydrous ammonia and other methods of application have been used successfully. Researchers in Kentucky (*44, 45, 46*), however, report that careful attention should be given to N fertilizer because of potential nitrate leaching losses during and after early summer storms. Postemergence applications of N fertilizers (4 to 6 weeks after planting) gave excellent results on wetter soils and showed some advantage on well-drained soils.

Soil acidity should be measured frequently under continuous no-tillage. More frequent applications of lime may be required to prevent rapid acidification of the surface soil layer. Researchers in Virginia (*24, 25*), reported corn yield increases as a result of broadcast lime applications on no-tillage plots. Lime studies in Kentucky (R. L. Blevins, unpublished data) showed that soil pH could be adjusted and maintained by surface applications of lime without incorporation.

Insect Management

No-tillage cultural methods create insect problems because of the more stable habitat provided (*13*). The major insect threat to no-tillage corn in Kentucky is the corn root aphid. A greater probability of insect problems is associated with corn following fescue sod (*14*) and other sod types or crop residue mulches. Gregory and Musick (*14*) found that common stalk borer damage was more prevalent in no-tillage cornfields than in conventionally tilled fields in Kentucky. Virginia workers (*48*) reported that armyworms are a serious pest in no-till corn, but that Furadan applied at the row provided effective control. Raney (*32*) listed wireworms, white grubs, and bean leaf beetles as the prevalent soil insects in his observations of double crop, no-till soybeans following small grain. The bean leaf beetle population increased when the soil was not disrupted by tillage.

Insecticides belonging to the organophosphate and carbamate groups are effective when applied as an in-furrow treatment at planting. The effectiveness of systemic insecticides in no-tillage management is also encouraging; and insect stress currently does not seem to be a limiting factor in no-tillage production of corn and soybeans. However, lack of effective insect control is one of the main reasons no-till is not used in cotton production in the Southeast (*15*).

Weed Control

Special weed control problems are developing in continuous no-till fields. Crop rotations, using the proper herbicide combinations, help alleviate this problem. Young (*51*) reported success with a 2-year rotation that included corn-small grain and double-cropped soybeans. Virginia researchers caution against using no-tillage in fields infested with johnsongrass, nutsedge, broomsedge, and bermudagrass. Rieck and Herron (*33*) reported that areas heavily infested with certain perennial weeds in Kentucky should not be used for no-tillage farming. The most predominant problem weeds there are johnsongrass, bullnettle, bindweed, horsenettle, nutsedge, climbing milkweed, and trumpet creeper.

In no-till double-cropped soybean production in Virginia, narrow row spacing enabled soybeans to compete with weeds (*1*). Row spacings of late-planted no-till soybeans should be reduced to 38 to 51 centimeters (12 to 20 in) compared with the 90- and 95-centimeters (35- and 37-in) spacings of early-planted soybeans. As planting is delayed, the maximum attainable height and width of the canopy decreases because shorter day length promotes flowering and limits vegetative growth. Narrow rows not only maximize sunlight interception but decrease the time needed to obtain a closed canopy.

Combinations of herbicides usually are required for effective weed control in soybeans. New post-emergence herbicides, such as Basagran and Dyanap, provide more control of important broadleaf weeds in double-cropped soybeans. Grasses are still a serious problem though. Embark, a new material for grass control, may help.

Pasture Renovation

Sod seeding as a means of pasture renovation has aroused much interest in the Southeast. The benefits of pasture renovation include higher productivity, better quality feed, less soil loss, and conservation of N fertilizer. No-tillage forages are used more widely in the Piedmont and mountain pasture areas (*49*). Renovation involves reestablishing legumes in cool season grass sods and interseeding cool season annuals in dormant bermudagrass or bahiagrass in the fall.

Many pastures in the Southeast feature shallow soils and steep slopes. Erosion becomes a serious problem when these soils are tilled, and soil moisture is lost as a result of this tillage. Based on research (*43*) involving herbicides and strip tillage, a prototype pasture renovator that tills, seeds, cultipacks, and applies herbicide in narrow strips in one operation has been designed (*39*). Tests show the renovator requires about one-fifth as much tractor fuel and can renovate about six times more land than conventional techniques.

Subsoiling and Chiseling

Traffic Pans

Hardpans that limit root penetration below plow depth are a widespread problem in many soils of the Southeast. These hardpans frequently are traffic pans. Some are genetic in origin, such as high bulk density A2 horizons and fragipans.

Traffic pans are caused by agricultural machinery on medium- and coarse-textured soils. Generally, tractor wheels and tillage implements cause the compacted layer, which occurs immediately below the depth of tillage (*12, 47*). Root penetration into such layers is inhibited by excessive soil strength. In extreme cases this mechanically induced barrier confines root development to the Ap horizon, a zone of low water storage capacity and, perhaps, inadequate fertility. In other cases this impedance slows root growth to 6 to 8 millimeters (.23 to .32 in) per day as compared with observed root growth of 50 to 70 millimeters (2 to 2.8 in) per day in loose soil.

Because of this reduced root growth, root development through a compacted layer may take several weeks. Drought during this growing period can severely restrict plant growth because roots cannot extract deeply stored moisture rapidly enough to maintain adequate growth. Once roots penetrate the barrier, normal growth resumes with the aid of subsoil moisture. Examination of root systems late in the season may fail to reflect the earlier impedance as roots passed through the compacted layer.

The barrier decreases the amount of precipitation that penetrates to the subsoil. Considerable water, therefore, is lost as runoff or remains in the upper soil layer where it evaporates. Efforts must be made to increase the uptake and retention of soil moisture.

Two machines developed to loosen compacted layers and plant seeds directly over the loosened area currently are being evaluated by researchers and farmers in the Southeast. The first, known as the "ripper-hipper," subsoils the intended plant row, forming a ridge over the slit with hillers or bedders. Since the bed marks the position of the slit, seedling location directly over the loosened subsoil is assured. This combination of contour ridges and furrows can be used on slopes to control runoff.

A second machine, the subsoiler-planter, employs a coulter to cut plant residues on the soil surface, a subsoiler to rupture the compacted layer, treading wheels to firm the soil in the loosened slit, and a flexible-unit planter. Used in fields with plant residue, this machine leaves the soil with some cover to reduce erosion and runoff.

Subsoiling loosens the hardpan immediately below the Ap horizon, thus reducing mechanical impedance and improving water and air relations. Subsoiling may also enhance water infiltration while reducing runoff and erosion. Plants, in turn, establish deeper root systems, which results in higher yields during years when drought occurs at critical stages of growth.

The bedding operation causes soil material to fall into the subsoil slit as the soil settles, thus preventing seedlings from being buried in the slit. Bedding may also provide better drainage and somewhat warmer seedbed temperatures early in the season.

Once the subsoil-bedding operation has been completed (1 to 5 weeks before), the beds prevent further disking and associated compaction. Many times, disking in conventional seedbed preparation, especially in the Coastal Plain, is done at a time when the soil water content at the base of the blades is too wet. This results in a second compacted layer at a depth of about 10 centimeters (4 in). The upper part of the beds are well-drained. This allows farmers to plant up to 5 days ahead of conventionally prepared seedbeds in both the Coastal Plain and Piedmont areas. During planting, the upper 10 centimeters (4 in) of the 15- to 25-centimeter (6- to 10-in)-high bed is usually scraped off and the seed planted in moist soil.

The effectiveness of subsoiling and chisel plowing in reducing the mechanical impedance of a hardpan at the depth of 20 to 28 centimeters (7.8 to 11 in) in a Norfolk sandy loam (Typic Paleudult) on the North Carolina Coastal Plain was recently reported (*9*). Figure 2 shows qualitatively the extent of profile modification by subsoiling. The excavated soil indicates zones of low mechanical impedance (Figure 3). Mechanical impedance was measured in a soybean field with a hydraulically driven penetrometer on May 21 and June 27, 1975. Penetrometer readings were taken at seven locations perpendicular to the row for three preparation treatments: conventional or normal tillage (moldboard plowing plus three diskings), chisel plowing (no subsequent disking), and subsoiling plus bedding.

South Carolina researchers (*29*, *30*, *42*) indicated that increased yields of corn, soybeans, and cotton can be expected from subsoiling under the plant row during some and probably most years on soils with a hardpan compact enough to seriously interfere with root development. Suman and Peele (*42*) found that subsoiling a Dothan loamy sand (Plinthic Paleudult) without irrigation increased soybean yields 4 out of 6 years. The yield increases ranged from 3.7 to 9.3 bushels per acre. Subsoiling the same soil increased corn yields an average of 5 bushels per acre with irrigation and 12.4 bushels per acre without irrigation (*30*). Subsoiling increased the rooting depth of corn, enabling it to make greater use of subsoil water.

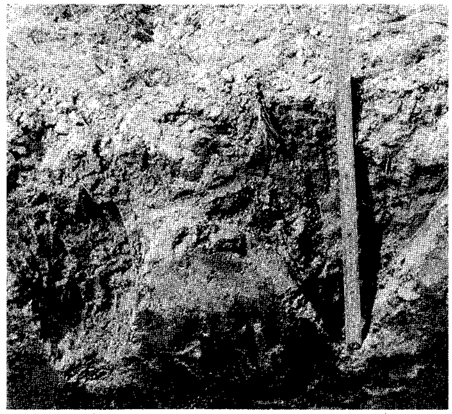

Figure 2. A profile of Norfolk sandy loam showing soil disruption by subsoiling.

Similar subsoiling work in the sandy soils of Georgia increased soybean yields (*35*). Parker and associates (*28*) noted a 60 percent yield increase in a relatively dry year due to subsoiling, but very little increase in a year with adequate soil moisture. The researchers also noted deeper penetration by the nematode population in the subsoiled plots, which could be a problem unless the proper nematicide is incorporated. In a study of its effect on cotton production in a Marlboro loamy sand (Typic Paleudult), subsoiling under the row enhanced root penetration, increased moisture and nutrient availability, and helped overcome the effects of cotton stunt (*5*).

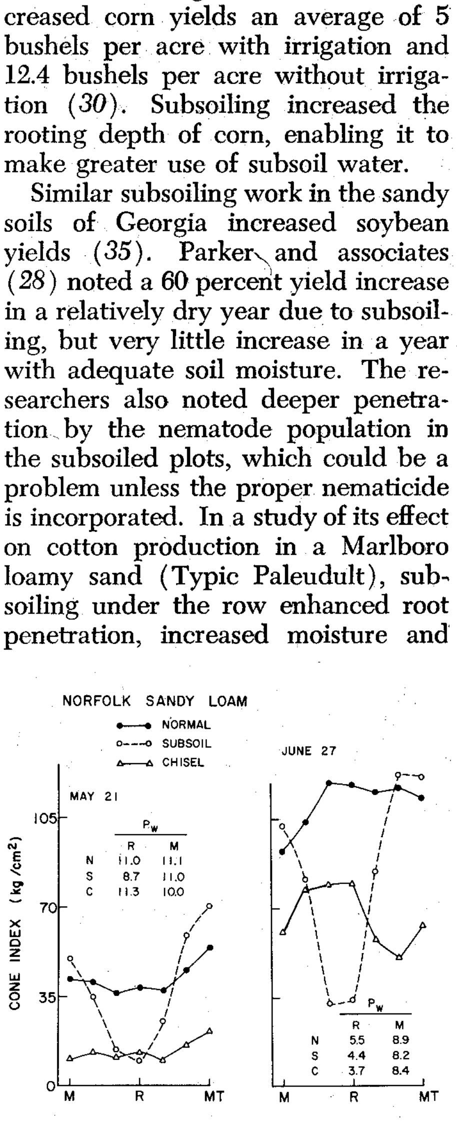

Figure 3. Cone index on May 21 and June 27, 1975, for the 14- to 28-cm depth in Norfolk sandy loam as a function of position normal to row. Tabular data refer to water content (g/g) in the row (R) and in the nontrafficked mid-row (m).

Even with minimum compaction under conventional tillage, the presence of a genetic A2 horizon can restrict root penetration. Plants use soil moisture only from the surface layers in many fields; and with erratic rainfall, moisture stress occurs frequently during the growing season. Chiseling a Varina sandy loam (Plinthic Paleudult) to a depth of 38 centimeters (15 inches) sufficiently disrupted the A2 horizon (*10*). Over a 4-year test, the average increase in dry matter yields for millet and sweet corn, above the check treatment, was 18.5 percent for an irrigation treatment, 17.1 percent for a chiseled treatment, and 25.6 percent for the two treatments combined. The researchers concluded that chiseling alone to disrupt the A2 horizon resulted in a net return that equalled that from irrigation.

Subsequent work (*34*) showed that chiseling decreased plant water stress, especially when the water table was near the bottom of the root zone. In addition to increasing rooting depth, and thus the amount of water available to plants, chiseling also increased the oxygen content of the soil during extremely wet periods (*10*). Oxygen levels in chiseled soil were greater during wet periods than in conventionally tilled, irrigated plots. During wet periods, chiseled soil permitted water to infiltrate and percolate to greater depths, thus decreasing the degree of saturation in the upper root zone. This confirms earlier observations on the effect of chiseling on infiltration (*7*).

Tillage and Controlled Traffic

Subsoiling to disrupt the traffic pan is not effective if machinery subsequently recompacts the loosened soil. Neither does the random operation of machinery in conventional tillage promote carryover effects of subsoiling.

Traffic control techniques have been developed where tractor tire paths are confined to permanent strips within a field (*47*). The technique minimizes tractor wheel compaction that might interfere with plant growth. In one experiment cotton yields increased about 300 kilograms per hectare (267 lb/a) when the soil was chiseled to a depth of 45 centimeters (17.7 in). However, where machinery was allowed to pass over the chiseled area, the yield difference declined rapidly. When all variables except traffic were controlled, plots with controlled traffic produced about 3,600 kilograms per hectare (3,214 lb/a) of seed cotton. This compared with a yield of about 3,000 kilograms per hectare (2,678 lb/a) on plots with unrestricted traffic, a 20 percent difference.

While chiseling to 38 centimeters (15 in) and subsoiling to 45 centimeters (17.7 in) look promising, not all soils lend themselves to these operations. Many soils in the Southeast contain toxic levels of soluble aluminum (Al), particularly in the acid subsoils. These Al levels inhibit root development of sensitive crops into the subsoil, even in the absence of compacted layers. Disrupting the compacted layers in this situation will not increase yields as much as if the subsoil acidity were not so high. Deep placement of lime with subsoiling may be necessary to overcome this effect.

Root Penetration of Compact Layers

Research also has looked at perforating compacted soil layers with deep-rooting plants. Not all plants are capable of growing in dense soils; hence, some crop rotations may not have an ameliorating effect on compacted soil layers. Elkins (*11*) reported that Pensacola bahiagrass penetrated compacted soil layers in a Cahaba loamy sand (Typic Hapludult); and upon decay of the root systems, the root channels remain open for penetration by cotton roots. After 4 years in grass, cotton grown in the same field had a considerably deeper rooting system; and cotton yields increased from 1,353 to 3,894 kilograms per hectare (1,208 to 3,476 lb/a). This effect persisted over 4 years of continuous cotton following incorporation of the bahiagrass sod by plowing. Sods established for longer periods of time probably have a still greater ameliorative effect. Research is underway to determine if fescues grown in cooler areas have the same potential as bahiagrass to penetrate compacted soil layers.

Research Priorities

There are two main areas of interest in conservation tillage in the Southeast. One is erosion control through the use of no-till planting, primarily in the upper Coastal Plain and in the Piedmont and Appalachian uplands. The other is the use of chiseling and subsoiling, primarily in the Coastal Plain, to loosen compact layers that inhibit root penetration into the subsoil. Immediate research is needed in both areas on the management and economic aspects of these practices in relation to specific soil conditions. Conservation tillage practices must be tailored to individual farm needs, even to individual soil conditions in a field, just as fertility recommendations are determined on a field-by-field basis.

Development of new and improved tillage systems that better fit these variable situations deserve further research also. The economics of these systems must be evaluated with respect to immediate cash benefits and long-term benefits derived from improved soil and water conservation.

Conservation tillage is relatively new in the Southeast. Many of its aspects are not fully understood. Soils, climate, and farms differ widely, making the design of one conservation tillage system to fit all conditions unrealistic. More research is needed on ways of relating the soil and climatic properties quantitatively with the crop and environmental responses. As new agricultural practices are developed, their impacts on the environment and energy use will need to be evaluated critically to insure their compatibility with society's needs.

Research is needed on the development, application, and economics of herbicides in double-cropping systems, especially those involving soybeans. Furthermore, disease and insect control are important in the Southeast where freezing is less of a retardent to development of insect and disease problems. Although some data indicate that insects are not a serious short-term problem in double-cropping systems that include soybeans and corn, the long-term effects of insects in no-tillage systems have not been studied. There is also a need for research on insect control in no-till cotton production.

No-till systems with plant residue on the surface decrease evaporation and increase infiltration. Research is needed to evaluate the effectiveness and best use of no-till as a tool for maximizing use of available water.

Wind erosion is a common problem on sandy soils of the Coastal Plain in the spring. The consequences of this erosion and its sandblasting effect on small plants needs further study.

There is little information available on compaction problems associated with continuous use of no-till systems. The effects of compaction are particularly important near the soil surface, where fertilizer and crop roots usually concentrate more than with conventional tillage systems.

Additional research is needed on lime requirements in no-till production. Continuous application of high rates of N fertilizer can acidify the surface 5 centimeters (2 in) of soil and impair herbicide effectiveness. Crop residue effects on seed germination and subsequent weed growth need to be evaluated. Development of equipment capable of operating in anchored and loosened surface residues without clogging is also needed. Such equipment would enhance conservation tillage by managing surface residues for their erosion control and water conservation benefits.

Chiseling and subsoiling to increase rooting depth is rapidly gaining popularity in the Southeast, and primarily in the Coastal Plain. Yield responses are weather dependent, with increases most likely in dry years, when water stress occurs at critical stages of plant development. Equipment locally referred to as the "ripper-hipper" has received acceptance. The bedder component of this tool results in improved water and soil temperature relationships that aid in seed germination early in the spring. The in-row subsoiler serves to loosen hardpans as previously described.

Another promising piece of equipment used in the Coastal Plain is the "super seeder," which subsoils under the row with minimum disruption of surface residue. However, as with any deep tillage operation, there is a relatively large power requirement.

More research is needed to increase efficiency of energy use in deep tillage operations. Information is needed on minimum depth and energy requirement for deep tillage necessary to achieve specific objectives for various soil types and profile characteristics. Little is known about the duration of subsoiling and how frequently this rather costly practice can be justified to maintain soil conditions for optimum crop production.

The development of nematode populations deeper in the profile resulting from subsoiling is another problem that may very well require new fumigation techniques.

The effect of traffic-induced recompaction after deep tillage has not been sufficiently evaluated. Information is also needed on natural recompaction of sandy soils due to rainfall. This research is particularly important in this region where high intensity rains may result in compaction and where little if any frost action exists to reloosen the soil.

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