# REDUCING ENERGY INPUTS INTO NO-TILLAGE SYSTEMS

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No-tillage farming is credited with conserving soil, water, on-farm fuel, time, and labor. In addition, it increases yield, improves planting and harvest timing, reduces some weather risks and soil damage, and permits fanning of land too steep to till under conventional systems (Phillips and Young, 1973). If conventional tillage is unnecessary, the elimination of fuel, labor, and material now used to produce, assemble, and deliver the big machinery for conventional tillage would increase savings. Successful no-tillage farming, however, relies heavily on chemicals for pest control, and there is some question as to the overall savings when energy required to produce these chemicals is considered. True savings are best evaluated by comparing the total fuel input against the output of marketable agricultural products.

Many of the advantages attributed to no-tillage farming do occur, hut <u>only when soils are in exceptional physical condition</u>. Such soils are common in virgin lands and in well drained pastures and hay fields that have been well husbanded over many years. These are soils without the pans and crusts typical in fields tilled and trafficked year after year with heavy machinery. After years of conventional tillage and traffic, the structure of topsoil degrades and easily compacts into dense bands. Root systems confined by traffic lanes above impenetrable plowpans have access only to moisture stored between these bands. Water unable to seep rapidly through compressed bands rushes down compacted tire lanes, transporting valuable topsoil and expensive chemicals from the field.

Crops can survive when roots are confined to such narrow "window boxes," but usually fail to produce satisfactorily. And when no-tillage farmed, crops often yield less than in conventionally plowed and harrowed fields. The simple, direct seeding employed in standard no-tillage reduces water and wind erosion, but crops grown in soils in less-than-good physical condition require larger rootbeds than those formed by the slight disturbance provided by standard no-tillage planters. Unless the farmer can make a profit using conservation systems, he cannot afford to save soil, water, and fuel.

## NO-TILL-PLUS

An alternate system of no-tillage farming called "no-till-plus" has been developed to achieve many of the benefits of no-tillage farming on lands in poor physical condition. The system incorporates an additional operation: the "plus" referring to plus subsoiling in a location where seeds are to be planted. Subsoilers are attached to no-till planters to open a narrow channel through the plowpan to create a pathway into the subsoil for deep root development and rapid entry of water and oxygen.

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Since this system does not destroy existing cover or disturb soil between the planted rows, it can be accepted as "no-tillage" in spite of the drastic tillage performed in narrow strips. One might consider that this planter simply prepares a deeper seedbed than that formed by most standard no-tillage planters.

Several equipment manufacturers in the Southeast produce machines for no-till-plus farming. However, no-till-plus planters require additional tractor power to pull the 4-, 6-, or 8-row machines. It is necessary for tractors to supply from *30-35* hp per row to pull these planters in conditions existing in the Coastal Plains area. This forces many farmers in the Southeast to upgrade their tractor sizes to the 140 hp range to handle a 4-row operation. However, many benefits of no-tillage farming can be achieved when fields that are in less-than-ideal physical condition are farmed with no-till-plus equipment.

## ROOTBED CONDITIONING

Soils already in ideal physical condition provide good rootbeds and require no more than enough conditioning to assure good seedbeds for a short period of time. Such fields are exactly in the condition for which the standard no-tillage implements were designed. Standard no-tillage farming, however, is wasteful of fuel when soil and water are not conserved and yields are not at least comparable to those obtained by conventional farming techniques.

When the $A_p$ horizon is not badly degraded and excessive moisture is only a slight problem, a larger seedbed can be beneficial. This may allow sufficient drainage for rapid root development within the loosened soil as other roots slowly penetrate through mildly compressed pans. In many areas of the Coastal Plains, however, the degradation of the $A_p$ horizon is so severe that inadequate rootbeds and excessive runoff are major problems. No-till-plus planters have evolved to provide the conditioning needed to achieve the benefits of no-tillage farming on such soils. Where the physical condition of the subsoil is satisfactory, a narrow, man-made extension from seedbed through the pan to the subsoil can provide an adequate rootbed. The passageway must completely penetrate the plowpan for rapid drainage of excessive moisture and to allow roots access to moisture stored in the subsoil. A good rootbed is essential for successful crop production and must be assured either by conditions already existing or by conditioning provided by machinery.

## NO-TILL-PLUS PLANTERS

No-till-plus planters currently incorporate a tandem arrangement of multiple conditioning tools, followed by a planting device. Early models were essentially assemblages of commercially available tools to perform needed tasks. Stringing out these tools, especially in multiple-row units, created a load difficult to lift from the soil to a travel position. Some tractors could barely lift the cantilevered load, although they had the power to pull the planters. Planters were condensed through closer assembly, or through modification and elimination of some tools. The load is now centered closer to the tool bar, easing the stresses on beams and the hydraulic lift unit.

As with most no-tillage planters, the no-till-plus planter requires a coulter. Soils in various physical conditions require different coulter features to slice through various cover crops, sod or stubble, and chopped stalks, grain straws, or other vegetal matter on the surface. Coulters are essential to reduce the buildup of trash and roots on the subsoiler shank and to free debris from the path of the planter, but they also assist in the pulverization needed for a good seedbed. Problems caused by large clods, massive soils, and binding root systems must be reduced by proper coulter action. Size and type of coulter, as well as the action required to form a particular seedbed, depend upon implement design and many soil and weather factors. Coulters, as well as each of the subsequent tools, must work the soil sufficiently and be set deep enough to aid in seedbed preparation since there is only one opportunity to form the seedbed. The proper coulter setting is too important a step to neglect in no-tillage farming.

A subsoiler or deep chisel follows the coulter in all no-till-plus planters. It is needed to form an opening that penetrates the plowpan <u>in a location where soil will remain loosened</u> during the development of the crop. Subsoilers loosen sections of soil that are V-shaped down to 8-12 inches, and at deeper depths the subsoiler point creates a channel point-width wide, completing a cross section resembling a "Y." Usually, soil sheared from the profile by this tool is thrown forward, upward, and to the sides of the center of action. As the tool passes by, some lumps of soil fall back into the narrow groove at the tail of the "Y" and bridge the gap. This temporarily supports the remaining soil that is returned to the loosened zone, leaving a large void near its bottom.

To prevent downward sifting of soil, seeds, and seedlings into the void during later rains, enough soil must be returned to fill the channel or the loosened soil above the void must be stabilized. Although it must be firmed to support a seedbed, it should not be firmed so much as to adversely affect air, water, or root permeability. Accomplishing this firming action is where the design principles currently used in various no-till-plus planters differ, Some planters use rotary tillers, a pair of firming wheels, or an array of tools that apply either a constant band of pressure or spot pressure to the seedbed, After firming, some manufacturers add implements to return loosened soil (thrown too far during subsoiling) to the narrow band that is to be planted, but with a minimum of loose straw and root material that would foul the planting devices. Usually, additional secondary tillage is then performed to assure the well granulated seedbed required for satisfactory seed germination. The last tool is usually a planting device designed to work in conventionally prepared fields.

The actions performed by the implements between the coulter and planting device are not necessary in standard no-tillage. These actions require additional power inputs which increase the fuel expenditure and cost of no-till-plus farming. Farmers require income from practices implemented, thus expenditures for extra work are justified only when sufficient conservation and additional production are assured.

## <u>FORCE REDUCTION IN NO-TILL-PIUS PLANTING</u>

There are techniques and designs that can reduce the fuel demanded For an acceptable no-ti1l-plus operation. However, certain applications depend upon soil and climatic conditions and are specific for the crops sown. It should be remembered that forces increase as work is performed, and where some work is useful and needed, some is wasteful or even harmful. Forces applied to soils by tools should accomplish only needed reactions.

### a. Coulters

Proper coulter action is valuable to all no-tillage systems. Draft of 14 coulter types has been measured in the soil bins at the National Tillage Machinery Laboratory. When traveling at a speed of 4.5 mph, in firm soil without cover, draft was increased about 350% as depth was increased from 2 to 6 inches, and about 20% more weight was needed to maintain depth. When greater depth is not required, force is wasted. Under similar test conditions, increasing speed from 2.4 to 7.1 mph increased draft by only 7% when the coulters were set at a depth of 4 inches, but the coulters did little beneficial work with the additional force.

A series of tests conducted in a moist, sandy loam soil compared experimental coulters with standard smooth coulters. All coulters were 17 to 18 inches in diameter, 3/16-inch thick, worked at a 4-inch depth, and traveled at 4.5 mph. A 1-inch fluted coulter increased draft by about 60%, and about 50% more weight was required to maintain depth. A 2-inch fluted coulter increased draft 90% and required 80% more weight. Wide flutes increase soil disturbance and are sometimes necessary for adequate pulverization. Where increased width and pulverization are needed, more soil can be disturbed per unit of force by fluted coulters. The rippled coulter disturbed a band of soil about one-third as wide, yet required almost as much power as the 1-inch fluted coulter. Angling the flutes in coulters at about 45" increased their draft about 10%. Large diameter coulters were not tested, but they take up more space and should need more weight to force them into the soil. If space is not a factor, however, their use should improve the cutting of trash and reduce draft.

The dominant purpose of the coulter is to cut through trash, sod, and roots, but this could not be tested under controlled conditions. Table 1 shows the response obtained from 3 soils without cover using 7 types of coulters in the 17- to 18-inch diameter range. The force for a single smooth coulter, traveling at 4.5 mph (shown in Table l), would convert to about 2 hp, and a 4-row unit would then utilize about 8 hp to cut through soil without roots, sod, or stalks. Four 2-inch fluted coulters, working under the same conditions, would require 12 hp, so 4 additional horsepower would be needed for a 4-row unit just to widen a cut through the soil.

### b. Subsoilers

The subsoiler on a no-till-plus planter produces a pathway for air, water, and roots through compacted Ap horizons. Since subsoiling requires most of the on-farm energy used by no-till-plus planters, it is in the subsoiling operation that proper use and design offer the greatest possibility for fuel reduction. Two major factors affecting draft during subsoiling--depth and speed--are under the farmer's control.

Research under uniform soil conditions at the Laboratory suggests an exponential increase in draft with increased depth. Table 2 shows the mean values for four chisel designs working in a Norfolk sandy loam soil and compares them with calculations squaring the depth value. When the depth is doubled, for example, the draft increases about fourfold--the table shows that doubling the depth produced a measured draft of 8.4 N which compared closely to the calculated 9.6 N value. In fields, however, moisture content and soil condition are rarely constant with depth. Evidence shows, nonetheless, that draft is increased substantially with each additional. increment of depth. In subsoils where roots can develop easily, barely piercing the plowpan is as effective as deep subsoiling in encouraging root proliferation. In material in which roots cannot develop, the volume of soil loosened by deep subsoiling is insufficient. If no benefit is to be derived, why extend subsoiling depth?

Increasing speed from 2.2 to 4.9 mph increased draft about 40% when subsoiling at a 14-inch depth in the Norfolk sandy loam bin (Table 3). Much of that energy was expended throwing soil further to the sides, necessitating additional energy to return it to the seedbed. Almost no increase in volume of soil disturbed could be verified for this expenditure of fuel, and the increase in pulverization was negligible.

Extrapolating forces obtained from a single subsoiler working 14 inches deep and converting them into horsepower requirements to subsoil 4 rows should convince anyone that speed costs money. Calculations with the sandy loam in Table 3 indicate that at 2.2 mph, 36 hp is required to accomplish subsoiling, and at 4.9 mph 112 hp is needed to accomplish the same task. Table 3 shows that it takes more force to subsoil at greater speeds, and since it takes more energy to develop the higher speed, horsepower requirements escalate rapidly. Farmers must decide if advantages from increased speed while planting are worth more fuel and increased wear and tear on equipment.

Design features of the better currently available commercial subsoilers can reduce draft by about 25% over the poorest designed units on the market. If low draft subsoilers are to be selected, certain features should be considered. The subsoiler shank has a minor effect on draft as long as its length is adequate for the needed depth and allows for clearance of loosened soil and trash beneath the tool bar. The thickness should give needed support under tractor driving conditions and withstand impact with rocks, tree roots, or other buried objects. Increasing shank thickness has little effect on draft when point width allows for adequate lateral clearance between the undisturbed soil and shank. Beveling the leading edge of a shank can reduce subsoiler draft by about 5% in lumpy soils, but the reduction is at the expense of decreased pulverization. With beveling, large draft reductions are possible when roots or trash tend to build around blunt shanks.

Where the leading edge of a shank has the proper slant--often more than 15" greater than vertical--and the point extends more than 10 inches in front, lumps and trash usually slide up the non-beveled shank and are easily cleared. This feature alone reduces draft about 30% below that of the old vertical shanked subsoilers. When soils adhere strongly to a shank, more slant and greater lateral clearances are needed. The practice of welding a hard facing; to reduce wear can extend the life of a shank but does so at the expense of draft. It may be less expensive to replace worn shanks than to buy fuel to pull the soil surrounding a shank through every mile of subsoiling. Under many conditions in the Coastal Plains, the subsoiler shanh on a no-till-plus planter can be 3/4 to 1 inch thick and about 4 inches deep. Less depth of section in the shank decreases strength, and increasing its depth increases material costs and adds weight to the unit, but with little effect on draft.

Width of the subsoiler channel where it pierces the plowpan appears to be of little consequence to either taprooted or nodal-rooted crops as long as the channel remains open. However, under some soil and climatic situations, wide channels may improve drainage, but forming channels wider than needed wastes fuel doing unnecessary work and increases the ease of serious recompaction. In many soil conditions, a channel created by a point 2 to 2.5 inches wide appears suitable. Narrow channels are prone to easy closure by lateral fcrces from interrow traffic. Wide channels lead to excessive settlement and are easily compacted during later interrow travel.

Studies involving width of subsoiler points are inconclusive due to the effects of other features in point design, shank geometry, and soil factors. Although inconclusive, point width per se appears to exert a small effect on draft, but loosening more soil than required wastes fuel. Draft is affected substantially by other design features involving the point. The top surface of points with an angle between 20" and 30" from horizontal gives the lowest draft value in many soils. Low draft is commonly produced when the bottom of the point makes a 5" to 10" angle with the floor of the subsoiled channel. With these dimensions designed into subsoiler points, soils are lifted adequately and shear with a minimum of force wasted on compression and adhesion along the top of the point, In addition, energy expended in confinement and compaction of soil behind and beneath the point is reduced.

The variety of firming devices on no-till-plus planters has not been evaluated under test conditions. Our limited observations indicate that some devices cause excessive soil puddling and recompaction, whereas othhrs produce low draft values by doing an inadequate job. Draft measurements of planting devices and their attachments have not been initiated.

## TRACTION IMPROVEMENT

Improving tractive efficiency while pulling no-till-plus planters is equal in value to reducing their draft. Tractors are the source of power used while planting, and engine tuning and power transmission to wheels are important, but power is transferred from wheel rotation to forward drive through forces applied to soils. After loose soil is firmed during a first pass of a tractor, about **30%** more pull can be developed traveling in the same pathway during the second trip, and often an additional 10% can be gained during the next trip. Pull in plowed fields can be increased more than 100% in firm, untilled soil with dry sod; thus, no-tillage is conducive to improved traction. Besides improving traction, driving on firm, untilled soil can increase the opportunity to plant, control pests, and harvest at the proper times. Traction becomes difficult to evaluate when cover crops are involved because results can vary with crop condition. In dense, recumbent, succulent cover, pull can be effectively reduced, while the same tractor might scarcely slip on sparce, dry, clipped, stable-stooled sod.

All wheels slip as they develop pull, but more traction can be developed with less slip on stable soil. Tire slippage not only increases wear, but consumes fuel doing work not converted into forward motion. Tire specialists feel that each percent of slip increases fuel consumption by about an equal percentage. Although maximum traction is not achieved, a pull at 12% slip wastes close to 12% fuel. By increasing weight on tires, slippage can be reduced and pull increased. In a plowed strip, for example, a 13.6 X 38 tire inflated to 22 psi produced 120%:more traction at 10% slip when carrying 3,630 lbs than when carrying 1,820 lbs. This is equivalent to developing about 40 hp more pull with a two-wheel-drive tractor. However, increasing load can increase sinkage in loose soils. Sinkage wastes power compacting soil in the ruts formed beneath tires. In addition, the wheel. must climb the small rise in front of the tire or expend energy flattening it. Here is where tire geometry becomes an important factor. Wide tires flatten a wide band of soil to their front, and duals flatten two mounds, both requiring additional power. Duals and wide tires are used to reduce sinkage and improve flotation. However, supporting a load on a greater area of soil reduces pressure which affects traction. Both lengthening the contact and increasing its width gain flotation, but lengthening decreases the energy lost in compacting a wide band of soil. Contact length can be increased with wheels of a larger diameter; tracks (steel or pneumatic); by reducing air pressure in tires; and by arranging wheels in a tandem design so rear wheels will drive on soil firmed by the front wheels. Radial tire construction is gaining prominence. On firm soil, radials can produce about 10% more traction than bias tires, but the advantage is reduced in loose soil.

Results are always variable when forces are applied to soil. The resistance a soil offers a tillage tool and the support given to a tire depend upon soil strength. And strengths of all soils can be monumentally altered by relatively small changes in moisture content.

## CONCLUSION

Many fields in the Coastal Plains of Southeastern USA can be no-tillage farmed only if root access to the subsoil is assured. Although no-till-plus planters can provide this, they expend more energy than standard no-tillage planters. Major draft reductions and improved tractor traction can be implemented by the farmer--reductions due to equipment design are less dramatic. No-till-plus offers benefits of no-tillage farming to farmers whose fields are in less-than-ideal physical condition.

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## REFERENCE

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TABLE 1

EFFECT OF COULTER TYPES ON MEAN DRAFT*

| Coulters | Draft Force (kN) Sandy Loan | Clay Loam | Silty Loam |
|---|---|---|---|
| 1-in. fluted | 1.01 | 1.20 | 0.98 |
| 2-in. fluted | 1.08 | 1.27 | 1.04 |
| Smooth | 0.63 | 1.10 | 0.68 |
| 1-in. bubble | 1.03 | 1.28 | 1.10 |
| Concave | 1.11 | 1.35 | 1.24 |
| Ripple | 1.01 | — | 1.08 |
| 45° angled flute | 1.06 | 1.30 | 0.99 |

* Speed = 4.5 mph; Depth = 4 in.; Dia. = 17 & 18 in.

TABLE 2

EFFECT OF DEPTH ON MEAN DRAFT*

| Depth | Actual Draft (N) | Calculated Draft (N) |
|---|---|---|
| X | 2.4 | $2.4 \times 1^2 = 2.4$ |
| 2x | 8.4 | $2.4 \times 2^2 = 9.6$ |
| 3x | 18.1 | $2.4 \times 3^2 = 21.6$ |
| 4x | 34.0 | $2.4 \times 4^2 = 38.4$ |
| 6X | 73.8 | $2.4 \times 6^2 = 86.4$ |
| 8X | 157.8 | $2.4 \times 8^2 = 153.6$ |

* Norfolk sandy loam using 1-in. wide chisel.

TABLE 3

EFFECT OF SPEED ON MEAN DRAFT AND HORSEPOWER*

| Speed (M/s) | Speed (mph) | Norfolk sandy loam Draft (kN) | Norfolk sandy loam Horse-power | Decatur clay loam Draft (kN) | Decatur clay loam Horse-power |
|---|---|---|---|---|---|
| 1.0 | 2.2 | 7.0 | 9 | 12.0 | 16 |
| 1.4 | 3.1 | 8.0 | 15 | 16.0 | 30 |
| 1.8 | 4.0 | 8.8 | 21 | 19.0 | 46 |
| 2.2 | 4.9 | 9.5 | 28 | 21.0 | 62 |

* At 14-in. depth.