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THE INFLUENCE OF TILLAGE SYSTEMS ON CORN YIELDS AND SOIL LOSS IN OHIO, INDIANA, ILLINOIS AND IOWA

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SUMMARY

Planning efforts underway to improve water quality of the nation's rivers and streams are a result of the Water Pollution Control Act of 1972. Section 208 of that act requires implementation of techniques and procedures recognized as having the ability to control nonpoint pollutants from agricultural lands. The pollutants identified include sediment from soil erosion, plant nutrients and pesticides. Controlled studies of crop management systems have demonstrated the success of various tillage systems to control one pollutant, sediment, from entering the nation's waterways.

Tillage systems that reduce soil loss have been available to farmers for many years. However, implementation of those systems has been limited mainly because of the uncertainty of their effect on crop yields. In order to provide the basis for a more systematic assessment of crop yields that can be expected from various conservation cropping practices, a survey was made of the results from recent site specific controlled studies in the Corn Belt States.

Physical responses of selected soils in the four states indicated a more favorable response to no-till or reduced tillage systems for corn production than did others. Most often the response of that soil in one state could be expected to provide a similar response if located in an adjacent state. Where wide differences exist between soils, site specific comparison studies are required to define the relationships between tillage systems, crop yields and soil loss under each set of conditions. Results of such studies show the following:

Ohio

If a no-till system was used for corn production on a fine textured poorly-drained heavy soil, yields were reduced 24 bushels per acre if corn followed a sod crop and 15 bushels per acre if corn followed corn.

The dark colored and poorly-drained soils of southwest Ohio produced the largest corn yields with tillage systems that provided the greatest amount of soil manipulation (conventional tillage) and the smallest yields with those systems which provided the least manipulation. The no-till system reduced corn yields 17 bushels per acre.

Conventionally tilled corn yielded 23 bushels per acre more than no-till on a Wooster silt loam soil with corn following corn and no soil surface cover. Corn following corn, but with 70 percent of the soil surface covered by plant residue, conventional tillage was favored over no-till by only 3 bushels per acre. Corn following sod with 100 percent soil surface coverage favored the no-till system by 30 bushels per acre over conventional tillage.

In years with low rainfall on slopes of 3 percent or greater, the difference in corn yields between minimum and conventional tillage was approximately 15 bushels per acre greater for minimum tillage than in years with adequate rainfall on the same slope.

Soil loss from a silt loam soil was reduced fivefold using a no-till system with killed sod cover as that lost using conventional tillage.

Soil loss from wind erosion on a northwest Ohio soil was reduced from 2 tons per acre per year to less than one-tenth of a ton per acre per year using a no-till system.

Indiana

Comparison of corn yields on well-drained, fairly well-drained and poorly-drained soils in various geographical regions of the state using seven tillage systems demonstrated a range in yield differences from 20 to 50 bushels per acre.

Reduced tillage systems of rotary till and coulter till plant produced at or near the lowest corn yields from all soils.

Using the no-till system for corn production on the poorly-drained silty clay loam soil reduced yields 24 bushels per acre compared to conventional tillage systems.

Compacted seedbeds from continued use of a no-till system favored increased germination of small seeded weeds, particularly annual grasses, and reduced movement of soil applied herbicides. Not plowing tended to cause a shift from annual to perennial weed species.

When five hundred pounds of plant residue was added to the surface of a Wea silt loam soil with a 5 percent slope soil loss was reduced to approximately one-fourth of that lost from the unprotected soil.

Reduced tillage (wheel-track planting) with no cultivation on a silt loam soil subjected to simulated rainfall was less effective in reducing soil loss during the growing season than conventional tillage. It was superior to all systems after harvest with simulated rainfall.

Over a five-year period, minimum tillage on corn substantially increased infiltration and reduced soil loss. Infiltration averaged 24 percent greater and soil loss 34 percent less from minimum tillage treatments than from conventional tillage.

Illinois

Corn yields from no-till or zero-till systems were generally equal to or slightly better than yields from conventional tillage on medium textured soils. On heavier textured soils with poor drainage, corn yields from no-till systems were as much as 30 bushels per acre less than either reduced or conventional tillage.

Corn response to applied fertilizer was essentially the same from all types of tillage systems on a Proctor silt loam soil. The yield differences between conventional, reduced and no-till was 4 bushels per acre with equal fertilizer rates.

Three years after fertilizer was applied on an Ipava silt loam soil there was a greater accumulation of phosphorus and potassium in the top inch of soil with zero-tillage than with conventional tillage. Corn yields favored zero-till by 8 bushels per acre over conventional tillage.

Zero-till reduced soil loss from 8.3 tons per acre per year (conventional tillage) to 1.1 tons per acre per year on a Catlin silt loam soil with a 5 percent slope.

Iowa

Results of tillage studies on Iowa soils have shown a limited effect on corn yields from substituting reduced tillage for conventional tillage in corn production.

Corn yields from conventional tillage and reduced tillage (wheel-track plant) ranged from 8 bushels per acre in favor of reduced tillage on a Moody silt loam soil to 5 bushels per acre in favor of conventional tillage on a Grundy silt loam soil.

Corn yields may be greater by using reduced rather than conventional tillage on soils susceptible to considerable packing during tillage or rainstorms.

Completely covering the soil surface of a Grundy silty clay loam soil with plant mulch reduced corn yields by 17 bushels per acre.

Simulated rainfall on a Marshall silty clay loam soil has shown the greatest soil loss from all slopes was from conventional tillage with till plant next and ridge-plant (reduced tillage) the least soil loss.

Soil surface mulches, infiltration characteristics in conjunction with other physical relationships can be an effective tool in grouping similar soils with relatively equal erosion potential.

INTRODUCTION

Planning efforts to improve the water quality of the nation's rivers and streams are underway as a result of passage of The Federal Water Pollution Control Act of 1972 (Public Law 92-500). Section 208 of that act focuses on nonpoint sources of pollution from agricultural and forestlands. Techniques and procedures recognized as having the ability to control potential pollutants from agricultural lands are now being incorporated into the planning effort. Those pollutants receiving the greatest attention are sediment from soil erosion, plant nutrients and pesticides. Implementation of control measures for these pollutants will have significant economic implications for agricultural and forestlands.

By volume, sediment is the single largest source of pollution of all waters of the nation. It is the by-product of soil erosion from all land, from streambanks and from drainage channels. Soil losses from agricultural lands have continued to accelerate in recent years because of more intensive crop management systems such as the monoculture. These management systems encourage additional tillage and agitation of the soil which furthers soil erosion.

Tilling the soil is a standard agricultural practice on most soils for a variety of well documented reasons. Primarily, soil is manipulated to prepare a suitable seedbed for planting. Additional manipulation is used to control weed growth and promote movement of water, air and roots through the soil for plant growth. Soil manipulation also provides an opportunity to incorporate plant residue, fertilizer and pesticide materials with the soil.

In the past, standard tillage techniques have only been altered on those soils that had experienced severe soil losses or other adverse problems. Efforts to conserve the soil focused on keeping the soil in place and thus reduce production losses due to water and wind erosion. Present efforts in soil conservation emphasize the need to improve water quality by preventing sediment from soil erosion and other pollutants from reaching rivers, streams and lakes.

Tillage techniques which encourage soil conservation have been available to farmers for many years. However, widespread adaptation of these techniques has not occurred probably due in part to the uncertainty of crop yields obtained using these systems. Under certain conditions crop yields have been drastically reduced.

In order to provide the basis for a more systematic assessment of crop yields that can be expected from various conservation cropping practices, a survey was made of results obtained from recent site specific research studies. The survey was limited to the four Corn Belt states of Ohio, Indiana, Illinois and Iowa mainly because this section of the United States represents one of the most intensively tilled areas in the country. In addition to crop yields from the various conservation cropping practices a summary of the physical variables associated with each study was made and included soil loss whenever the information was available. Each site specific study considered only physical variables and did not furnish economic data. A separate effort from an ongoing study will be required to accumulate economic data associated with conservation cropping practices.

CLASSIFICATION OF TILLAGE SYSTEMS

Early conservation efforts attempted complete elimination of plowing. These efforts for the most part were unsuccessful. One system promoted disking as a substitute method of seedbed preparation (6).[1/] Another, incorporated mulch tillage for row crop production in Ohio in which a field cultivator was used to stir the soil and kill weeds in preparing the seedbed. This procedure left much of the previous plant residue on the soil surface (4). Present tillage systems are variations of those early efforts.

Tillage has been defined in the broadest sense as the mechanical manipulation of soil for the purpose of changing soil conditions for crop production (1). Tillage systems, regardless of their geographic use, can be classified as (1) conventional tillage, (2) reduced tillage and (3) no-till or zero tillage. The distinguishing feature between tillage systems is whether or not the moldboard plow is used. The general operating techniques of each system can be described as follows.

Conventional Tillage System

A typical sequence of operations for the conventional tillage system would include plowing, completed either in fall or spring, followed by two diskings, harrowing and then planting with a standard planter as a separate operation. Planting may be followed by another harrowing. Other operations normally associated with this system

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1/ Underscored numbers in parentheses refer to references listed at the end of the report.

include chopping stalks, nitrogen, phosphorus or potassium fertilizer broadcast and plowed down when needed, and finally liquid insecticide broadcast and incorporated with the soil during the last disking operations. Starter fertilizer may be used at planting time or split fertilizer application applied at first cultivation. The crop is mechanically cultivated at least twice in the early part of the growing season. Preemergence herbicides may be broadcast at planting time or rod weeders may be used just after plant emergence. The completed sequence will be delayed until spring if fall plowed.

Reduced Tillage Systems

The essential distinguishing feature of any reduced tillage system is the omission of one or more tillage steps normally associated with conventional tillage. The moldboard plow may or may not be used as the primary tillage implement.

Wheel Track Planting

This tillage system includes plowing the soil with the moldboard plow and then planting one or two days later in the wheel tracks with no additional tillage between plowing and planting. Other operations required for this system include chopping the corn stalks or other standing residue, broadcasting the required fertilizer nutrients and plowing them down and broadcasting preemergence herbicides. Dry insecticides and starter fertilizers are usually banded in the row and applied at planting.

Chisel Plow-Plant

This system uses plowing as the primary tillage with a chisel plow rather than the moldboard. The soil remains less disturbed than with the conventional moldboard and there is no disking or harrowing after planting.

Normally, this system involves a single pass fall chisel plowing followed by a single spring pass in which the chisel plow is equipped with seeding units. The normal operating depth of the chisel plow is four to five inches. If deeper tillage is required, longer chisel points are used in the fall to extend the penetration depth. Sweep shovels are used with the spring pass to prepare the seedbed during the planting pass. Fertilizer material is broadcast and plowed down. Other operations including cultivation are the same as the wheel track and cultivator plant systems.

Field Cultivator-Plant

This system is similar to the wheel track planting in that plowing with the moldboard plow is the primary tillage. However, plowing is usually done in the fall for this system followed by a single pass in the spring with a field cultivator-planter combination. Disking and harrowing following planting is eliminated. Other steps in this system are usually the same as those of wheel track planting.

Strip Rotary Till

This system along with the strip coulter till and disk strip till requires the least amount of tillage of all the reduced tillage systems. It requires only one tillage operation.

A rotary tiller is powered from the power takeoff unit to prepare a narrow-tilled strip in which to plant. The tilled strips are prepared in the corn rows of the previous year. Seeding units and other attachments are either mounted on the rotary tiller or the planter is pulled behind. Corn stalks are chopped in a separate operation as well as the broadcasting of fertilizer material. The only incorporation of fertilizer material with the soil occurs in the tilled strips. Herbicides are broadcast preemergence or preplant and liquid insecticides are banded in front of the rotary tiller for incorporation with the soil in the tilled strips. Usually the tilled strips measure about eight inches in width. Mechanical cultivation is not used unless weed growth becomes a serious problem and cannot be controlled by other means.

Strip Coulter Till

This tillage system does not include plowing as the primary tillage. Instead, a coulter mounted in front of each planter unit tills a narrow strip approximately three inches wide and three inches deep as the seedbed. Plant residue from the previous crop is chopped in a separate operation and distributed over the soil surface. Fertilizer and herbicide materials are broadcast before planting and dry insecticides are usually banded in the row. Mechanical cultivation is not used if weed growth can be controlled by means of chemicals.

Disk Strip Till

Disk hillers rather than the moldboard plow are used for the primary tillage in this system. The disk hillers are used to form ridges to serve as the seedbed. One cultivation with the disk hiller at the time the crop reaches approximately one foot in height maintains the ridges for planting the following year. Plant residue from the previous crop is chopped and spread over the soil surface. Fertilizer nutrients are broadcast and the only incorporation with the soil occurs with the ridging operation and the mixing which occurs during the planting pass. Dry insecticides are banded in front of the covering disk during the planting pass. Herbicides are broadcast prior to plant emergence. This system is also referred to as a disk-plow system of planting.

No-Till Systems

The essential feature of a no-till system is that planting is made directly into an essentially unprepared seedbed. No plowing or other major disturbance of the soil occurs. This system of planting is also known as slot or slit planting, zero tillage and direct planting. Corn is the most widely grown crop without tillage but other crops such as wheat, soybeans, sorghum and cotton have been grown successfully using this system.

With the elimination of all tillage, weed and insection control must be accomplished by chemical means. Herbicides and insecticides are applied as a broadcast application. Fertilizer nutrients may be broadcast before planting and or banded in the planting operation.

Standing plant residue from the previous crop is chopped and distributed over the soil surface as a separate operation.

Planting in the no-till system requires a specially designed planter. The planter must cut through the layer of residue, open a slit in the soil, drop the seed at the proper depth, and insure that the seed is covered. Several types of openers have performed satisfactorily, including knives and disks. Usually these are preceded by coulters which cut surface residue.

INFLUENCE OF TILLAGE SYSTEMS ON CORN YIELDS AND SOIL EROSION

Over the years, corn has responded very favorably to many technological advances. Grain yields have substantially increased through added fertilizer nutrients, hybrid seed and other cultural practices. With recent developments in chemical weed control, there are additional opportunities for beneficial changes in cultural practices. However, the successful application of these changes must rely on the level of acceptance of chemical weed control and the continuing option to use the required chemicals.

Numerous controlled studies have illustrated the impact of various tillage systems on crop yields. However, because of the limited number of these studies some major soil types are inadequately represented. Usually those soils which have the required similarities in those significant physical properties can be grouped because they provide similar responses to each tillage technique. There is, however, a considerable hazard in generalizing expected crop yields from various tillage systems over a wide array of soils. The difficulty is in assessing the degree of similarity required between soils to provide the same level of response to a specific tillage system.

Soils of the Corn Belt States vary widely in their physical characteristics. Each of the important physical properties such as surface texture, drainage, ability to retain water and slope, significantly influence the selection of a successful crop management system. Documentation of these relationships between soils, tillage systems and corn yields vary considerably within the area. Where wide differences exist between soils, site specific comparison studies are required to define those relationships under each set of conditions. Results from such studies in Ohio have suggested a grouping of soils into tillage groups.

Ohio

Corn Yields

Soils in Ohio have been divided into five tillage groups based upon their physical properties. Soil drainage is suggested as one of the most important factors to consider in selecting a tillage system (28). General conclusions from this research study are:

A. Crop yields obtained using a no-till system are equal to yields from conventional systems for most cropping sequences on well and moderately well-drained soils if a satisfactory level of soil surface mulch cover is maintained.

B. The poorly-drained, fine textured, dark-colored soils in Ohio are not suitable for use of a no-till system for corn following corn.

C. Grain yields from continuous corn planted without tillage on poorly-drained soils resulted in yield reductions of 10 to 20 percent compared to continuous corn planted in fall plowed soil. If the soil was plowed the season prior to use of the no-till on continuous corn the yield reduction was not as severe.

D. Grain yields from no-tillage corn following crops other than corn on poorly-drained soils have generally been equal to corn planted in fall or winter plowed soil.

E. When corn planting is delayed into June, grain yields from no-till systems have been higher than yields using conventional tillage with plowing at planting time.

F. For that group of soils requiring a surface mulch cover for satisfactory no-till crop production, mulch must cover 70 to 80 percent of the soil surface at planting time. If the soil cover is 35 percent or less, the soil should be tilled, i.e., disking and mechanical cultivation after planting, to sustain yields.

In another study of corn yields from different sites and soils of Ohio, 211 pairs of tilled plots were compared under identical plant culture except tillage. Plowing was the primary tillage for each of the two systems. One system included conventional tillage while the other used minimum tillage consisting of wheel-track planting in plowed ground (33). While these paired comparisons do not provide a relationship between all tillage variations, they do furnish an estimate of the effect on corn yields if some steps in the conventional system are omitted. Even though specific corn yields or individual soils were not listed, comparisons in the study found:

A. In years with low rainfall on slopes of 3 percent or greater, the difference in corn yields between minimum and conventional tillage was 14.6 bushels greater for minimum tillage than in years with adequate rainfall on the same slopes.

B. As corn yields increased from 50 to 150 bushels per acre, the yield difference between the two systems changed from an 8 bushel advantage for minimum tillage to a 2 bushel advantage for conventional tillage.

C. Weed control, soil surface texture, internal drainage and previous crop did not affect the average yield difference between the two systems.

A significant finding associated with Ohio tillage studies was the influence of the immediate past crop and the amount of available plant residue in relation to the tillage system. One study compared conventional tillage with no-till practices at several locations with different soils and different immediate past cropping history. Data in Table 1 provides a summary of corn grain yields obtained in various studies on different soils with each variable under investigation (29).

Table 1. Summary of 1960-62 corn grain yields comparing conventional versus no-tillage on a number of Ohio soils

Soil type	Year	Previous Crop	Surface cover	Mean corn grain yields: Conventional tillage	Mean corn grain yields: No tillage
			Percent	Bushels/Acre	
Canfield silt loam	1960	Sod	50-60	138	132
Canfield silt loam	1962	Sod	100	83	99
Crosby silt loam	1962	Barley	5	142	134
Hoytville silty clay loam	1961	Corn	0	80	84
Hoytville silty clay loam	1961	Sod	40-50	107	98
Hoytville silty clay loam	1962	Corn	50	79	81
Hoytville silty clay loam	1962	Sod	60	86	84
Meigs silt loam	1961	Corn	50	94	113
Meigs silt loam	1962	Corn	60	139	160
Meigs silt loam	1961	Sod	60-70	124	128
Ravenna silt loam	1962	Sod	50-60	87	74
Toledo clay	1962	Sod	75	77	85
Toledo clay	1962	Sod	75	93	100
Upshur clay	1962	Sod	40	107	119
Wooster silt loam	1960	Corn	0	106	83
Wooster silt loam	1961	Corn	0	140	127
Wooster silt loam	1962	Corn	0	70	64
Wooster silt loam	1962	Corn	40	85	69
Wooster silt loam	1961	Corn	70	112	109
Wooster silt loam	1962	Corn	70	71	73
Wooster silt loam	1962	Wheat	70-80	85	72
Wooster silt loam	1962	Corn	90	70	85
Wooster silt loam	1962	Sod	100	80	110

Source: (29) Triplett, Van Doren and Johnson, 1964.

Year to year variations can be noted on the same soil at different locations with the same previous crop. Overall, there was no significant difference in the average corn grain yield between tillage systems when all years, amount of soil surface covered, soils, previous crops and locations are considered. The difference between the two tillage systems was slightly more than one bushel per acre. On specific soils, however, there were substantial yield differences between the two tillage systems. These differences were due primarily to the previous crop and/or the amount of the soil surface covered by plant residue. For example, conventionally tilled corn yielded 23 bushels per acre more than no-till on the Wooster silt loam soil with corn following corn and no soil surface cover. On the same soil with corn following corn, but with 70 percent of the soil surface covered by plant residue, conventional tillage was favored over no-till by only 3 bushels per acre. On the other hand, corn yields with corn following sod and 100 percent of the soil surface covered favored the no-till system by 30 bushels per acre over conventional tillage.

Leaving plant residue on the soil surface protects that soil against erosion. The ideal situation is one that provides maximum erosion protection with sacrificing corn yields. From data in this summary, if no soil surface coverage is available for the Wooster silt loam soil maximum corn yields would only be obtained by using conventional tillage. If, however, up to 70 percent of the soil surface can be covered by plant residue, comparable corn yields can be gained using either tillage system. Less than 70 percent coverage with no-till will reduce yields below conventional tillage. If more than 70 percent of the soil surface is to remain covered then a no-till system will benefit corn yields the most. The data further points out the significance of matching soil erosion protection (as expressed by soil surface coverage) to the tillage system that provides maximum corn yields on each specific soil.

A similar but more comprehensive study on a Wooster silt loam soil compared three tillage systems (conventional, reduced and no-till) for a six-year period (30). Corn grain yields obtained in that study (Table A-1) with corn following a sod crop were significantly greater with no-till followed by reduced tillage with the lowest yields obtained using conventional tillage. The study further concluded that soils which respond to tillage and surface mulches, such as the Wooster silt loam, tillage intensity must be increased as soil surface cover decreases to maintain corn yields. Furthermore, when water was limited during the growing season, the maximum tillage intensity was not sufficient to conserve water as effectively as did 75 to 100 percent soil cover. With sufficient water, tillage intensity and soil mulch cover will not influence yields. The obvious crop management practice from a yield standpoint when corn follows a sod crop is the no-till system. Conversely, if the previous crop such as corn for silage or soybeans provides little surface residue cover, an alternate management system such as reduced tillage is needed.

Additional studies on the Wooster silt loam soil have demonstrated the significance of providing adequate plant residue for soil surface coverage with a no-till system (31, 32, 34). When normal or greater amounts of plant residue from the previous crop was allowed to remain on the soil surface, the no-till system for corn production on the Wooster silt loam soil was superior to either the conventional or reduced tillage systems (Tables A-2, A-3).

The dark colored and poorly-drained soils of southwestern Ohio are tillage problem soils. A representative of this group of soils is Brookston silty clay loam. A tillage study conducted on this soil evaluated various tillage systems including conventional, several forms of reduced tillage and no-till for corn production (3). Corn grain yields from the various systems are shown in Table A-4. Significant information gained from this study shows the largest corn yields were obtained from those tillage systems which provided the greatest amount of soil manipulation, i.e., conventional tillage with fall or spring plowing. The smallest yields were obtained with those tillage systems which provided the least soil manipulation. Using a no-till system on this soil reduced corn yields 17 bushels per acre.

Hoytville silty clay loam, a fine textured poorly-drained soil is another tillage problem soil. Fall plowing is the preferred tillage method for this soil and its use produced the highest corn yields of any tillage system evaluated (Table A-5) (30). Using a reduced tillage or no-till system for corn production significantly reduced yields from this soil. Corn production by no-till rather than conventional tillage reduced corn yields 24 bushels per acre if corn followed a sod crop and 15 bushels per acre with corn following corn.

Sandy soils in Ohio are also tillage problem soils which require additional erosion protection from wind as well as water. Corn yields obtained using conventional and no-till systems were compared on Spinks sand and Colwood fine sandy loam (30).

Over a 5-year period, average corn yields with conventional tillage were 62 bushels per acre for the Spinks sand and 123 bushels per acre for the Colwood soil. The no-till system on the same soils produced 75 and 109 bushels of corn per acre. Crop residue available from the no-till system successfully reduced soil movement by wind on each soil. At the same time, corn yields were significantly increased on the Spinks sand (13 bushels per acre) and significantly decreased (14 bushels per acre) on the Colwood soil.

Soils lacking in plant nutrients must be supplemented with commercial fertilizer to sustain high crop yields. The fertilizer is generally broadcast over the ground surface with the conventional tillage system and incorporated with the soil at some point during seedbed preparation. With the no-till system, fertilizer is surface-applied but not incorporated.

A study was undertaken on a Canfield silt loam soil to determine the impact on yields of conventional and no-till fertilized corn. Average grain yields for the six-year period of this study shows that no-till corn was more responsive to increasing levels of applied nitrogen than conventional tilled corn (Table A-6). However, as a potential for nonpoint pollution the broadcast application of phosphorus and potassium tended to accumulate near the soil surface with the no-till system. Nitrogen, on the other hand, being more mobile moved to lower depths in the soil.

Consideration for the long term crop response to tillage systems is as equally important as the immediate crop response. One study investigated the long term effects of continued use of a reduced tillage system on crop yields relative to a plow-based system (30). Three crop rotations and three tillage systems were compared at four locations on six soils.

The six soils included three well-drained soils (Spinks sand, Crosby silt loam and Wooster silt loam) and three poorly-drained soils (Colwood fine sandy loam, Hoytville silty clay loam and Toledo clay). The results are grouped according to soil drainage in Table 2.

Table 2. Long term corn yields as affected by no-till and conventional tillage under different rotations and drainage situations in Ohio expressed as no-till minus conventional tillage1/

Rotation	Well Drained	Poorly Drained
	Bushels-gain or loss	
Corn, oats, meadow	+11	- 1
Corn, soybeans	+11	- 3
Continuous corn	+12	-13

1/ Average difference of fifth through seventh year.
Source: (30) Triplett, Van Doren and Johnson, 1970.

The tillage systems included conventional, reduced (plow-strip, plant and cultivate) and no-till (spray-plant). Specific corn yields in each rotation were not provided. Instead, the overall results were compared on the basis of yields from no-till corn minus conventional tillage yields.

Corn grain yields in each rotation were greater without tillage on the silt loam well-drained soils. On the high clay soils, yields were essentially equal for all systems in the corn-oats-meadow but slightly higher with conventional tillage for the corn-soybeans rotations. With continuous corn, yields were significantly lower for the reduced and no-till systems.

Findings from this study illustrates the interrelationships between soil physical properties, cropping systems and tillage. In general, a similar crop response to each tillage system can be expected on soils with like physical properties. The necessary specific physical likeness between soils such as, fair to good internal drainage, characteristic soil surface sealing to form a crust during rainfall, sloping surface and low organic matter provides a criteria for grouping soils according to their reaction to various tillage systems. As an example, a surface mulch of plant residue is required on one group of Ohio soils to maintain continuous corn yields with a no-till system. On the other hand, soils with characteristics similar to Hoytville, i.e., poor internal drainage, high organic matter content, and little or no surface slope cannot maintain continuous corn yields with a no-till or reduced tillage system.

The Influence of Tillage Systems on Runoff and Soil Erosion in Ohio

One of the most important benefits attributed to the use of conservation tillage systems is a reduction in soil erosion and sediment production. However, there is disagreement over the amount of soil loss reduction that can be accomplished from the wide range of tillage systems available. This is because most comparisons of soil loss are usually made between tillage system extremes, i.e., conventional tillage (plow, disk, plant, cultivate) with maximum soil agitation and minimum soil agitation as represented by no-till systems. Variations in tillage between the two extremes seldom receive much attention as to their effect on runoff and soil loss.

Comparison of the effect that the two tillage systems had on runoff and erosion were made over a five-year period at the North Appalachian Experimental Watershed on Coshocton, Ohio (12, 13). Results from the two tillage systems, shown in Table 3, indicates the superiority of the no-till system over conventional tillage in reducing soil loss from erosion. While the particular soil in the study was not identified it has a silt loam texture and a 9 percent slope.

During some years of the study, runoff was not particularly significant from either tillage system. However, in those years which did show runoff substantial quantities of soil were lost from the conventional tillage system and insignificant amounts from the no-till system. Even though the amount of soil lost (2.8 tons/acre) with the conventional tillage system was large, it would probably be

Table 3. Corn yield, erosion, and runoff from conventional and no-till watersheds, 1964-68, Coshocton, Ohio (May-September)

Year	Corn yields		Erosion		Runoff	
	Conventional tillage	No-till	Conventional tillage	No-till	Conventional tillage	No-till
	Bushels/Acre		Pounds/Acre		Inches	
1964	95	136	5,690	118	0.60	0.20
1965	106	106	129	0	0.14	0.0
1966	97	117	0	0	0.0	0.0
1967	117	109	1,940	0	1.10	0.0
1968	104	113	0	0	0.37	0.0

Source: (12) Harrold, Triplett and Edwards, 1970.

within the allowable loss limit per year for this soil. Corn grain yields with the two tillage systems were comparable.

With increasing amounts of runoff soil loss can be significantly greater. One study on a Wooster silt loam soil compared water runoff and erosion losses with a conventional and a no-till system (24). Soil loss from the conventional tillage system (Table 4) was more than six times greater than the no-till with a killed sod cover. The no-till no cover system was only slightly better for controlling soil loss than the conventional tillage system indicating the significance of an adequate surface mulch (previous crop influence) in association with a no-till system for this soil.

An additional part of the same study compared soil loss from wind erosion with various tillage systems. Soil loss from the clean-tilled fall plowed conventional tillage system was more than twice

Table 4. Runoff and erosion losses under natural rainfall from tillage runoff plots on a Wooster silt loam in Ohio (May-November 1963-64)

Soil surface condition	Average runoff	Average soil loss
	Inches	Tons/Acre
No-tillage, killed sod cover	0.86	2.17
No-tillage, no cover	2.78	10.39
Conventional (plow, disk, harrow, cultivation)	2.08	13.94

Source: (24) Schmidt, 1970.

the spring plowed system. Soil loss from both systems had significantly greater losses than the no-till system (Table 5). The quantity of soil lost from wind movement over the unprotected surface of this loamy fine sandy soil again demonstrates the need for leaving previous plant residues in place. The presence of a surface mulch in

Table 5. Average wind erosion with various tillage systems on Ottokee Loamy Fine Sand, Wood County, Ohio, 1968-69

Tillage	Average soil loss April-August
	Pounds/Acre
Fall plowing	3,940
Spring plowing	1,940
No-tillage	190

Source: (24) Schmidt, 1970.

the no-till system kept the sandy soil in place and prevented the sand grains from damaging the growing vegetation and thus reducing corn yields (24).

Occasionally rainstorms with intensities of an inch or more of rain per hour may occur. Usually these storms are of short duration but may continue for several hours in some cases. Results from one such storm in which 5 inches of precipitation fell in 7 hours are shown in Table 6 (11). The increase in total precipitation from an intense storm such as this can greatly multiply erosion damages from unprotected soil surfaces. Severe erosion on the steep slopes in this study was avoided only by intense use of surface mulches. The no-till corn on a 21 percent slope was planted in killed sod from a permanent pasture that had also received an additional application of 8 tons of wet manure. A similar study also emphasized the need for surface mulch to reduce runoff (12).

Table 6. Runoff and sediment yields from land planted in corn near Coshocton, Ohio, July 5, 1969

Tillage	Slope	Rainfall	Runoff	Sediment Yields
	Percent	Inches	Inches	Pounds/Acre
Plowed, clean-tilled, sloping rows	6.6	5.50	6.6	45,300
Plowed, clean-tilled, contour rows	5.8	5.50	2.3	6,430
No-till contour rows	20.7	5.07	2.5	63

Source: (11) Harrold and Edwards, 1972.

Indiana

Corn Yields

Studies to assess the influence tillage systems have on corn yields from Indiana soils have demonstrated very selective responses from individual soils. One study compared various tillage-planting systems on five Indiana soils (9, 10). Tracy, a sandy loam soil, was located in northeastern Indiana, Runnymede loam, a poorly-drained soil in northern Indiana, Blount silt loam and Pewamo silty clay loam in eastern Indiana and a Bedford silt loam in southern Indiana.

Summary results of the various systems reiterates the difficulty of selecting one tillage system for the many and varied soils (Table 7). No single tillage-planting system was superior for all soils nor was soil productivity equal for all soils. Some systems such as the strip-coulter-plant and rotary-plant produced at or near the lowest corn yields for all soils. The till plant yields were near the top yields of all the systems except on the Blount and Pewamo soils. The range in corn yields among the systems on this soil was as much as 52 bushels. Yield differences between some of the systems would not justify their use in corn production under any circumstance and would certainly require considerable selectivity in choosing the tillage-planting system on the other soils.

This study found that the amount of tillage and percent of soil cover associated with different tillage systems affect soil temperature, plant growth, maturity and yield potential of the corn crop. The effect on these parameters is highly dependent on soil type, drainage

Table 7. Corn yields with different tillage systems on five Indiana soils (1967-1970) four-year mean yields

Tillage system	4-Year average yields (1967-1970)				
	Tracy Sandy Loam	Runnymede Loam	Blount Silt Loam	Pewamo Silty Clay Loam	Bedford Silt Loam
	Bushels per acre				
Conv. sp. plow	125	136	129	109	96
Field cult.	126	141	132	100	--1/
Wheel track	129	135	117	104	98
Chisel	130	132	116	96	100
Till	143	137	110	85	101
Rotary	129	128	80	83	100
Coulter	125	118	86	80	98

1/ System not recommended for this soil.

Source: (10) Griffith, Mannering, Galloway, Parsons and Richey, 1973.

and climate. Results also indicated a need for better than average management to achieve success with a tillage system that omits plowing. In choosing a tillage-planting system, weed, insect and disease control, equipment costs, timeliness of operations, erosion control potential and management ability must all be considered in addition to crop yield.

Tillage influences root growth and development regardless of the soil type or location. Plowing the soil encourages a more extensive root system and stimulates development to a lower depth in the soil. Past evidence, however, has suggested that without plowing and the presence of surface residue depresses root growth.

Information on the effect of tillage practices on corn root development and distribution was obtained from a study on a Raub silt loam soil in Indiana (2). In this study, the quantity and depth of corn roots was reduced by tillage treatments. However, the smallest amount of root development was sufficient to adequately provide for a reasonable corn yield.

Corn yields show a reduction in yield over an eight-year period but no effect for the shorter period (Table 8). Quantity of residue did influence corn yields. The deciding factor relative to the quantity of root growth required depends on what is needed to obtain sufficient plant nutrients and water to provide maximum yields. In years of below average precipitation, the quantity and depth of root development could be significant.

An alternative to changing tillage techniques for soil erosion control is to increase ground cover by reducing the horizontal distance

Table 8. The effect of tillage treatment on corn yields on a Raub Silt Loam soil

Tillage treatment	Corn yields	
	1962-1967	1968-1970
	Bushels/Acre	
Conventional	139	148
Conventional - residue	138	147
Conventional + 2 residue	136	142
Chisel	143	149
Rototill	138	148
No-till	132	144
Conventional (no crop for six years)	--	157
No-till	--	148

Source: (2) Barber, 1971.

between crop rows. The usefulness of this alternative, however, is confined to the crop growing period unless combined with tillage changes.

An Indiana study compared corn performance in relation to row spacing on several soils (26). Results of this study indicate that for all soils and in each year except one (Blount, 1967) narrow row spacings increased corn yields (Table 9). These results suggest that changing from 30-inch to 40-inch rows would increase grain yields an average of 4 to 5 percent. An additional 3 percent increase can be expected from reducing row width from 30 inches to 20 inches. Reducing the width of row spacings provides additional soil surface protection and, therefore, influences runoff and soil erosion. This variable, however, was not investigated in this particular study.

Effective weed control is an essential production step in insuring maximum crop yields. Mechanical cultivation associated with conventional tillage has long been an effective method for controlling undesirable vegetation. Weed control for no-till systems requires chemical herbicides.

Observations from no-plow tillage systems tested in one Indiana study concluded that the type of tillage system influenced both the kind and number of weeds (9). No-plow systems tended to cause a shift from annual to perennial species. The compacted seedbed favors increased germination of small seeded weeds, particularly annual grasses, and reduces movement of soil-applied herbicides. The buildup of perennial weed species with no-plow systems may require a

Table 9. Effect of row spacing on corn yields for five Indiana soils

Soil type	1966			1967			1968		
	Row spacing in inches								
	20	30	40	20	30	40	20	30	40
	Bushels/Acre								
Runnymede loam	--	--	--	111	--	106	135	131	126
Tracy sandy loam	82	78	66	95	--	96	139	132	122
Blount silt loam	112	106	109	69	70	70	117	116	108
Chalmers silty clay loam	142	143	137	144	143	137	145	141	140
Shoals silt	184	178	167	--	--	--	134	133	130

Source: (26) Stivers, Griffith and Christmas, 1971.

change to different and more costly herbicides or possibly other weed control procedures.

The Influence of Tillage Systems on Runoff and Soil Erosion in Indiana

Reducing the space between crop rows or altering the surface residue by means of the tillage system may influence soil erosion and water infiltration in several ways. One, it changes the micro relief of the soil surface because of the greater number of planter row tracks and the wider surface coverage. Second, it provides earlier crop cover for the soil surface and greater protection from raindrop impact; and third, the closer spacing of plant roots and crowns may influence runoff velocities and thus reduce soil detachment. An Indiana study measured the effect of row spacing and infiltration (17).

The study was located on a moderately eroded Russell silt loam soil with an average slope of 5 percent. Soil loss measurements were made at four time intervals during the growing season, two of which are shown in Table 10. Three row widths were compared for corn and soybean crops.

The percent of ground surface covered by plant material was determined at full growth. Corn row widths of 40, 30 and 20 inches provided 59, 78 and 88 percent of the ground surface with cover. Soybean row widths of 40, 20 and 7 inches provided 98, 99 and 94 percent ground cover.

Infiltration and soil loss measurements at four time intervals provided the following conclusions. From 2 to 5 weeks after planting,

Table 10. Soil loss from various row spacing of corn and soybeans on a Russell Silt Loam soil

Row width	Crop	7 to 8 weeks after planting: soil loss	After harvest soil loss	Yield
Inches		Tons/Acre		Bu./Acre
40	Corn	12.85	2.14	148
30	Corn	12.00	2.19	146
20	Corn	9.77	0.89	149
40	Soybeans	12.71	0.89	44
20	Soybeans	8.25	0.18	52
7	Soybeans	6.56	0.31	53

Source: (17) Mannering and Johnson, 1969.

row spacing had no significant influence on infiltration or soil loss for corn or soybeans. For the 7 to 8 week period after planting. infiltration was significantly greater on the 20-inch soybean row spacing than on any of the corn spacings. At harvest, the 20-inch row spacing for corn increased infiltration more than 20 percent and reduced soil loss by almost 60 percent from corn with wider row spacing. With identical row widths, infiltration was significantly greater for soybeans than for corn. This greater infiltration plus a higher percent of surface cover resulted in significantly less soil loss from soybeans than from corn with similar row spacings. Neither corn nor soybean yields were adversely affected by altering row spacings.

Plant residue, when left on the soil surface as a mulch, is very effective in controlling soil erosion. However, it is essential to utilize the minimum quantity of residue which will effectively control erosion because higher rates may depress crop yields (2).

A study to determine the minimum effective level of surface mulch was established on a Wea silt loam soil with a 5 percent slope (18). Simulated rainfall was applied at the rate of two and one-half inches per each application. A total of four applications applied 6.25 inches of water in four time periods, one of 60 minutes and three of 30 minutes each. The soil surface covered and the soil loss with each mulch rate is listed in Table 11. In this study, adding just five hundred pounds of residue to the soil surface reduced soil loss to approximately one-fourth that lost from the unprotected

Table 11. Soil loss from simulated rainfall in various rates of applied mulch on a Wea Silt Loam soil in Indiana

Rate of surface mulch	Total water applied 4 runs	Soil surface covered by mulch	Total soil loss 4 runs
Tons/Acre	Inches	Percent	Tons/Acre
0	6.25	0	12.42
¼	6.25	40	3.23
½	6.25	60	1.42
1	6.25	87	0.30
2	6.25	98	0
4	6.25	100	0

Source: (18) Mannering and Meyer, 1963.

soil. The mulch was surface applied but not incorporated with the soil. Additional protection could be expected if some incorporation with the soil was made.

A similar study measured soil loss from three tillage systems with simulated rainfall applied at three stages of crop growth (19, 20). Simulated rainfall intensity for each run was 2.6 inches per hour. The initial run lasted 60 minutes followed the next day with two 30-minute runs separated by a 15-minute interval. The wet run and very wet run shown in Table 12 represent the latter two (19).

The tillage system tested included conventional tillage (plow, two diskings with trailing harrow, plant) with two cultivations. Plowing was completed one month prior to planting. The minimum tillage systems included either plow-plant or wheel-track plant with and without cultivation.

Table 12. Soil loss from simulated rainfall from minimum tillage (cultivated and not cultivated) and conventional tillage (cultivated) in tests after the first cultivation of corn and after harvest on a Russell Silt Loam soil

Tillage treatment	Average soil loss Year of run 1959-61-63	
	After first cultivation	After harvest
	Tons/Acre	
	Initial run (60 min.)	
Conventional till-cultivation	4.6	1.0
Minimum till-cultivation	3.9	0.4
Minimum till no cultivation	7.9	0.3
	Wet run (30 min.)	
Conventional till-cultivation	4.3	0.6
Minimum till-cultivation	2.8	0.4
Minimum till no cultivation	4.1	0.1
	Very wet run (30 min.)	
Conventional till-cultivation	5.6	0.6
Minimum till-cultivation	3.6	0.4
Minimum till no cultivation	4.3	0.1

Source: (18) Mannering, Meyer and Johnson, 1966.

The study compared various forms of minimum tillage with conventional tillage and their effects on erosion and infiltration, effects of secondary cultivation on erosion, residual effects of minimum tillage over time and the effect of surface mulches to other treatments.

Simulated soil losses from two crop periods are shown in Table 12. Minimum tillage on corn substantially increased infiltration and reduced soil loss during the 5 years of study. Infiltration averaged 24 percent greater and soil loss 34 percent less from minimum tillage treatments than from conventional tillage. Plow-plant or wheel-track plant produced about the same amount of erosion control. The erosion-reducing effectiveness of minimum tillage as compared with conventional tillage declined from 44 to 34 to 27 percent. Destruction of surface crusts by cultivation greatly reduced both soil and water losses from those obtained without cultivations. Surface crusting greatly influenced soil and water loss in this study as in others. Soil surface protection was compared in the early part of the growing season as plant canopy and as residue after harvest.

The effect of surface mulch on soil loss with simulated rainfall, was observed in another study of three soils with differing slope characteristics (8). Observed or measured soil loss from each soil was compared with predicted loss with five levels of surface mulch.

Observed soil loss compared with predicted loss provided reasonable agreement for some mulch rates but not all. Predicted soil loss from the Wea silt loam with a 5 percent slope was consistently greater than the actual soil loss. Results summarized in Table 13 indicate that soil loss from these three soils could be predicted more accurately at the higher mulch rates than from the lower rates.

Table 13. Comparison of predicted soil loss with observed soil loss from simulated rainfall on various rates of surface mulch (wheat straw) on three Indiana soils

Mulch rate	Fox Loam 15 percent slope		Xenia Silt Loam 3 percent slope		Wea Silt Loam 5 percent slope	
	Observed	Predicted	Observed	Predicted	Observed	Predicted
	------Tons/Acre------					
¼	0.32	0.47	0.40	0.39	0.25	0.45
½	0.31	0.34	0.25	0.27	0.16	0.27
1	0.19	0.19	0.12	0.14	0.03	0.09
2	0.04	0.06	--	--	--	--
4	0.02	0.02	--	--	--	--

Source: (8) Foster and Meyer, 1972.

Illinois

Corn Yields

Selected soils in Ohio and Indiana responded more favorably to no-till or reduced tillage systems for corn production than did others. The same can be said for Illinois soils.

One study compared corn yields from various tillage systems on five Illinois soils (14). Yields from no-till or zero-till systems were generally equal to or slightly better from all soils except the Drummer silty clay loam (Table 14). Zero-till on this slightly heavier textured soil, produced corn yields significantly lower than either reduced tillage or conventional tillage.

Table 14. Corn yields from various tillage systems on five Illinois soils, continuous corn

Tillage System	Symerton silt loam 1971-73	Drummer silty clay loam 1968-71	Proctor silt loam 1970-73	Cisne silt loam 1971-73	Grantsburg silt loam 1967-73
	----Bushels/Acre----				
Fall plow, disk, plant	116	136	139	--	--
Spring plow, disk, plant	116	--	--	104	111
Spring plow, plant	--	--	--	103	119
Fall chisel, plant	118	132	138	--	--
Zero-till	116	100	142	107	121

Source: (14) Illinois Agronomy Handbook, 1976.

Yield results listed in Table 14 are directly related to the physical properties of each soil and climatic conditions of the area where the soils are located. Soil descriptions of the Symerton and Proctor silt loam soils indicate similar profile characteristics. The soils are characterized as dark-colored, good internal drainage and free of root restricting zones in the upper three to four feet of soil. The Drummer silty clay loam is also dark in color but has poor drainage. The plow layer is sticky and compacts readily if tilled when wet. Providing a surface mulch by chisel or zero-tillage lowers soil temperatures, results in slow early growth, and consistently reduces corn yields. Moisture conservation is a significant factor for both the Cisne silt loam and the Grantsburg silt loam. Providing a surface mulch from the zero-till system on these soils reduces moisture stress in corn plants which often occurs with conventional tillage. Yields in dry years are often higher than those obtained with conventional tillage.

Adequate utilization of required fertilizer nutrients is essential for maximum corn yields from any tillage system. When fertilizer is broadcast on the surface and not incorporated with the soil, as with no-tillage systems, adequate utilization could be a problem. Investigations to determine whether this would be a problem for Illinois soils was conducted at several locations (5, 7, 14).

The effect of tillage systems and fertilization on corn yields were compared on a Proctor silt loam soil for three years (14). Summaries of these comparisons are shown in Table 15. Average yields from all fertilizer rates for each tillage system indicate little effect of tillage systems on corn yields from this soil. The zero-till system produced an average corn yield of 142 bushels per acre compared with 138 bushels for the reduced tillage and 139 bushels from the conventional tillage system. Fertilizer response was essentially the same from all tillage systems.

Another Illinois study compared tillage and fertilizer effects from two soils, three tillage systems and two fertilizer treatments. Yields from the tillage systems are shown in Table 16. Year-to-year yield variations were found on both soils between the various tillage systems. These differences were due to plant cultural problems with the no-till system. Yield differences from the Ipava silt loam soil were related to yearly variations in plant populations. Plant numbers

Table 15. Effect of tillage system on corn response to phosphorus and potassium fertilizers on a Proctor silt loam soil, 1970-73, Illinois

Fertilizer rates $N + P_2O_5 + K_2O$	Tillage systems 1/		
	Fall plow, spring: plow + harrow, plant, cultivate	Fall chisel, spring: disk + harrow, plant, cultivate	Zero-till: chop stalks in fall, plant
Lbs/Acre/Yr.	-----Bushels/Acre-----		
240 + 0 + 0	131	128	126
240 + 60 + 60	142	140	142
240 + 120 + 120	144	144	150
240 + 180 + 180	139	145	148
Average	139	138	142

1/ Continuous corn.
Source: (14) Illinois Agronomy Handbook, 1976.

Table 16. Corn yields as affected by fertilization and tillage system for two Illinois soils

Tillage system	Annual fertilizer rate			Corn yields					
				Ipava S.L.		Clinton S.L.			
	N	P	K	1969	1970	1969	1970	1971	3-year mean
	Pounds/Acre			---Bushels/Acre---					
Conventional	200	46	83	142	121	123	77	135	112
Zero-tillage	200	46	83	154	94	142	76	123	114
Zero-tillage	200	0	0	142	71	117	54	117	96
Chisel-plow	200	46	83	--	--	146	91	124	120
(L.S.D. 5%)				10	44	16	14	12	10

Source: (7) Fink and Wesley, 1974.

were reduced on the zero-till system because rainwater concentrated in the no-till slits flooding the young corn plants. With conventional tillage, the soil was able to absorb the excess moisture and reduce plant damage. The reduced tillage system, i.e., chisel-plow, produced very favorable corn yields on the Clinton silt loam soil and had the highest three-year average yield of all tillage systems.

A similar study investigated fertilizer movement and accumulation with depth in the soil from no-till and conventional tillage systems. Results of phosphorus and potassium fertilizer movement (Table 17) show a greater accumulation of phosphorus and potassium fertilizer in the top inch of soil with zero-tillage than conventional tillage three years after application. However, sufficient fertilizer was utilized by the corn plants to insure maximum yields. Even so, with the fertilizer nutrients remaining that near the soil surface, some could be lost if excessive runoff occurs even though they are not water soluble.

Table 17. Soil P and K levels after two and three-year applications in Illinois (Ipava Silt Loam)

Depth in soil profile	Phosphorus			Potassium		
	Zero-till: No P	Zero-till: P added	Conv. P added	Zero-till: No K	Zero-till: K added	Conv. K added
Cm	ppm					
0-2.5	42	75	43	120	235	130
2.5-5.0	34	45	40	115	168	120
5.0-7.5	27	31	69	105	192	170
7.5-15.0	30	26	70	145	175	160

Source: (7) Fink and Wesley, 1974.

The Influence of Tillage Systems on Runoff and Soil Erosion in Illinois

A suitable quantity of plant residue left on the soil surface will reduce soil erosion and conserve soil moisture for crop production. The mechanics of each tillage system determine the amount of residue left on the soil surface. One study evaluated the effect of tillage operations and time on the quantity of residue on the surface of a Flanagan silt loam soil (14).

Quantities of corn residue left on the soil surface with time are listed in Table 18 for each of the tillage systems. The residue remaining after harvest of the corn crop was 2.76 tons per acre. Fall tillage that included plowing completely buried all residue leaving no surface cover. With tillage delayed until spring, all surface residue remained over winter. Fall tillage that did not include chopping the stalks left the next largest amount of residue. The tillage system that provided the most soil surface protection for the longest period of time was fall tilled with a coulter plus twisted chisel plow and the stalks not chopped.

The benefit of surface mulch in reducing soil loss from erosion is shown in Table 19. While the amount of precipitation was not shown, runoff and soil loss was measured from the same tillage systems and included a zero-till system. Soil loss from conventional tillage fall plowed was 8.3 tons per acre while soil loss from the zero-till was 1.1 tons per acre. Soil loss from the reduced tillage systems was 1.9 and 1.7 tons per acre. Altering the tillage system to leave as much plant residue on the soil surface as possible significantly reduced soil loss from this soil with a 5 percent slope.

Table 18. Effect of tillage operations and time on the quantity of residue on the surface of a Flanagan Silt Loam soil, fall 1971 - spring 1972

Tillage system	Corn residue on soil surface					
	Nov. 3	Nov. 11	April 19	May 3	June 12	June 16
	Tons/Acre					
Fall chop, plow	2.76	0	0	0	0	0
Fall disk + twisted chisel	2.76	2.28	2.18	1.31	1.51	1.43
Fall coulter + twisted chisel	2.76	2.19	1.43	1.09	1.67	2.08
Fall chop + chisel	2.76	0.78	0.49	0.86	0.96	0.79
Spring chop, disk, plow	2.76	2.76	2.73	0.00	0.00	0.00
Spring chop + disk	2.76	2.76	2.73	0.98	1.63	1.68
Effect due to	Complete stalk cover	Fall tillage	Decomposition over winter	Spring tillage & planting	Application of NH^3	Cultivation

Source: (14) Unpublished data, Dept. of Agric. Eng. and Agronomy, Univ. of Ill.

Table 19. Conservation tillage reduces soil and water loss from a Catlin Silt Loam with a 5 percent slope

Tillage system	Runoff	Soil loss
	Inches	Tons/Acre
Fall plow, spring disk + harrow, plant	5.7	8.3
Fall disk + chisel, spring disk + sweep, plant	4.1	2.3
Fall coulter, chisel, spring field cultivate, plant	3.7	1.9
Fall chop, chisel, spring disk, plant	4.0	3.2
Zero-till (spring chop, plant)	5.1	1.1
Spring disk, plant	4.0	1.7

Source: (14) Illinois Agronomy Handbook, 1976.

Iowa

Corn Yields

Generally, results on Iowa soils have shown little effect on corn yields from using reduced tillage rather than conventional tillage in corn production. A 5-year study compared conventional tillage with reduced tillage (wheel-track) for 5 Iowa soils. (16).

Corn yields, shown in Table 20, indicate similar corn yields for the Galva, Marshall and Ida soils from conventional and reduced tillage systems. Conventional tillage produced slightly higher yields on the Grundy soil but lower yields on the Moody soil. Yields ranged from 8 bushels per acre in favor of the wheel-track system to 5 bushels per acre for conventional tillage.

Table 20. Corn grain yields as influenced by tillage systems and soil types in Iowa

Soil type	Year of test	Corn grain yields	
		Wheel-track	Conventional
		---Bushels/Acre---	
Moody silt loam	1956-1960	69	61
Galva silt loam	1957-1960	99	102
Marshall silt loam	1956-1960	96	95
Ida silt loam	1957-1960	103	103
Grundy silt loam	1957-1960	117	122

Source: (16) Larson, 1962.

Observations from this study indicate that when soil moisture limits growth and when reduced tillage decreases water losses due to runoff, corn yields may be greater from reduced tillage. Yields may be greater by using reduced rather than conventional tillage on soils susceptible to considerable packing during tillage or rainstorms (15, 16).

Corn yields produced by using different tillage systems on Iowa soils were compared with numerous soils in several other Corn Belt States (21). The systems included conventional, reduced and no-till systems. Reduced tillage and no-till systems provided yields similar to conventional tillage except for the Muskingum soil in Ohio (Table 21). For this soil, the no-till system produced superior corn yields to those obtained from conventional tillage.

Table 21. Corn yields from conventional tillage systems compared to other tillage systems for different soils in the Corn Belt States

	Ohio (1-3 years) 9 soils	Iowa Nicollet	Wisconsin Fayette	Iowa (4-6 years) 4 soils	Ohio (3 years) Muskingum
		----Bushels/Acre----			
Plow, disk, harrow	98	120	97	89	99
Mulch, sweep tillage		117		85	
Mulch returned after plowing		120			
Listing				86	
Wheel-track			87	88	
Mulch-cultivator tilled			95		
No-till	99				120

Source: (21) Moldenhauer and Amemiya, 1969.

Plow-plant and wheel-track planting methods have been used in some corn belt states but they have not been widely used in Iowa. Timing has been suggested as the primary reason for the limited use of these methods (5). The optimum time for plowing is some time ahead of planting and can either be in the fall or early spring. However, if plowing is done too early in the spring, the soil may dry out before planting which makes the clods hard to break down and results in a dry, cloddy seed zone. The main value of plow-plant and wheel-track systems has been to emphasize that the entire plowed area, row and inter-row need not be worked into a perfect seedbed (30).

Each variation of till planting influences the position and distribution of the plant residue remaining on the soil surface.

To test the influence of surface mulch on corn yields in Iowa, a study was initiated on a Grundy silty clay loam (21).

The presence of a surface mulch on this soil reduced corn yields (Table 22). Without a surface mulch, soil temperatures were higher, the corn plants grew faster and required less days to silking. Plowing the residue under, as with conventional tillage, produced the highest corn yields. Banding the mulch to simulate ridge planting produced the next best yields. Completely covering the soil surface with a mulch reduced corn yields by 17 bushels per acre.

Table 22. Corn grain yields as affected by mulch management on a Grundy Silty Clay Loam soil in Iowa

Mulch treatment	Soil temperature May 1 - June 17	Days to silking	Corn yields
	Degrees F	Days	Bushels/Acre
Straw plowed under + N	66	82	122
Straw on surface + N	63	88	105
Straw banded + N	63	84	112

Source: (21) Moldenhauer and Amemiya, 1969.

Organic residue effects on corn yields were also tested on a Marshall silty loam soil (23). As the quantity of surface residue increased, corn yields decreased on this soil even though additional nitrogen was supplied (Table 23). The kind of organic residue had a limited effect on yields except for the corn stalk residue. Corn yields from all rates of corn stalk residue for the 1963 to 1966

Table 23. Corn grain yield effects of organic residue application on a Marshall Silty Clay Loam soil in Iowa

Residue treatment	Quantity of residue	Nitrogen added each year	Corn yield 1955-1960	Corn yield 1963-1966
	Tons/Acre	Pounds/Acre	Bushels/Acre	
None	0	180	81	113
Alfalfa	1	180	84	115
"	2	180	83	113
"	4	180	85	111
"	8	180	83	109
Cornstalks	1	200	85	111
"	2	220	84	108
"	4	260	85	107
"	8	340	86	102
Oat straw	4	260	85	110
Bromegrass	4	260	84	110

Source: (23) Morachan, Moldenhauer and Larson, 1972.

period were consistently lower than yields from other residue materials. The quantity or kind of residue applied during the 1955 to 1960 period had little effect on corn yields. Because yields for the 1963 to 1966 period were substantially reduced with increasing quantities of surface mulch, particularly corn stalks, a no-till system would be yield reducing on this soil. Instead, in those situations in which such quantities of plant residue were present, a form of reduced tillage should be used to partially bury some of the residue. This would minimize yield reductions but maintain the surface protection benefits which the residue provides.

The Influence of Tillage Systems on Runoff and Soil Erosion in Iowa

Plant residue that remains on the soil surface as a mulch prevents erosion of the soil surface. This point has been adequately demonstrated many times. However, the interrelationship of such physical features as slope, quantity of residue, i.e., tillage systems and rainfall intensity are still under investigation. Two of these variables, slope and tillage systems, were tested on a Marshall silty clay loam soil (22).

Runoff and soil loss from the Marshall soil with simulated rainfall are shown in Table 24. The three tillage systems, conventional, till-plant and ridge-plant, were used on each slope. The conventional tillage system was responsible for the greatest amount of soil loss on all slopes with till-plant next and ridge-plant the least. Observations made during the simulated rainfall showed that runoff came directly down the crop row on the till-plant system and

Table 24. Runoff and soil loss as affected by slope and tillage systems with simulated rainfall on a Marshall Silty Clay Loam soil in Iowa (1968)

Tillage system	3.4% slope		6.9% slope		9.0% slope	
	Runoff	Soil loss	Runoff	Soil loss	Runoff	Soil loss
	Inches	Tons/Acre	Inches	Tons/Acre	Inches	Tons/Acre
Conventional	5.8	20.1	--	--	5.2	36.7
Till-plant	4.8	11.3	6.0	28.0	4.8	25.0
Ridge-plant	6.4	6.8	6.1	8.0	6.0	5.9

Source: (22) Moldenhauer, Lovely, Swanson and Currence, 1971.

down the furrow on the ridge-plant system. This probably accounts for the high soil loss with the till-plant system as compared with the ridge-plant system. Additional observations indicated that soil loss for the conventional and till-plant systems was generally highest for the first storm. With conventional tillage, soil loss decreased with each succeeding storm. With till-plant, soil loss was about the same for the second and third simulated rainstorms. Soil loss with the ridge system was substantially lower than that with the other systems but tended to increase with each successive storm.

Slope had no effect on soil or water losses under the ridge system. This would indicate that with the ridge system for short runs on slopes up to 9 percent, the expected soil and water losses would be similar to those obtained with a 3.4 percent slope. The trend to greater runoff with the ridge-plant system indicates that mulches on untilled soil reduce soil loss but do not increase infiltration as in the case of tilled soil (22).

Simulated rainfall was also used in another study to compare the relative erodibility of three Iowa soils (25). The soils were Monona silt loam, Marshall silt loam and Sharpsburg silt loam.

Results of this study have shown that soil loss rates from the Monona soil were lower than those from the Marshall and Sharpsburg soils. As runoff began, soil loss rates increased rapidly on all three soils to an initial peak rate, and then decreased gradually to a fairly constant rate. Soil loss peaked at 3.1 tons per acre per hour on the Monona soil and gradually decreased to a constant rate of 2.5 tons. The Marshall and Sharpsburg soils reached slightly higher peak rates of 5 tons per acre per hour and then decreased to a fairly constant soil loss of 3.3 tons.

The infiltration rates on all three soils gradually decreased to a final constant rate. The infiltration rate of the Monona soil decreased more gradually than the other two soils and became constant at a higher final rate of 0.40 inches per hour after 45 minutes. The Marshall and Sharpsburg soil had almost identical infiltration curves but dropped rapidly to an equilibrium rate of 0.18 inches per hour after only 30 minutes. After repeated simulated runs after drying, total soil loss on the Monona soil was 3.57 tons per acre per hour compared to 5.39 tons per acre per hour for the Sharpsburg soil.

The effect of surface sealing appeared to be a major cause in the erodibility of all three soils. Higher soil losses on the Marshall and Sharpsburg soils were associated with lower infiltration rates than those for the Monona soil. Overall, the Monona soil appears to have slightly less relative erodibility than the Marshall and Sharpsburg soils (25). The physical delineations as made for these three soil comparisons are useful in grouping similar soils with relatively equal erosion potential.

Table A-1. Corn yields resulting from different tillage systems on Wooster Silt Loam soil (average of 6 years) in Ohio

Tillage system	Tillage operation			Soil cover	Corn grain yield previous crop	
	Plowed 1/	Disked 2/	Cultivation 3/		Sod	Corn
				Percent	Bushels/Acre	
1	X	X	X	0	96	90
2	X	X	-	0	87	81
3	-	X	X	0	107	94
4	-	-	X	40	111	97
5	-	X	-	75	115	107
6	-	X	-	50	100	84
7	-	X	-	25	85	79
8	-	-	-	100	125	110
9	-	-	-	75	111	98
10	-	-	-	50	97	86
11	-	-	-	0	--	58

1/ Spring, moldboard 8-inch depth. (LSD = 4 bu/ac.)
2/ One to three times over with tandem disk.
3/ Twice between emergence and plant growth to a height of 24 inches.

Source: (30) Triplett, Van Doren and Johnson, 1970.

Table A-2. Influence of plowing, disking, cultivation, previous crop, and surface residue on corn yields from a Wooster Silt Loam in Ohio (1962-63)

Tillage system	+ Residue After sod	+ Residue After corn	- Residue After sod	- Residue After corn
Conventional	---------Bushels/Acre-----------			
Plow + disk + cultivation	96	91	95	96
Reduced tillage				
Plow + disk ----	90	88	83	88
Plow ---- + cultivation	104	94	105	94
Plow ---- ----	103	92	96	88
---- disk + cultivation	117	106	111	97
---- disk ----	101	90	81	78
---- ---- cultivation	112	105	104	85
No-Till				
---- ---- ----	122	95	106	71

LSD (5%) = 7 bushels

Source: (32) Van Doren, 1965.

Table A-3. Effect of crop residue on corn yields from conventional tillage and no-till on a Wooster Silt Loam in Ohio

Tillage system	Year 1962	Year 1963	Year 1964	3-year average
	---------Bushels/Acre---------			
Conventional tillage	64	90	100	84
No-till, residue removed	66	82	70	71
No-till, normal residue	77	93	104	91
No-till, double residue	89	104	107	100

Source: (31) Triplett, Van Doren and Schmidt, 1968.

Table A-4. Evaluation of tillage systems on a Brookston Silty Clay Loam soil in Southwestern Ohio

Tillage system (no cultivation)	Corn grain yield
	Bushels/Acre
Fall plow - disk - plant	137
Spring plow - disk - plant	139
Rotary till - plant	129
Disk - plant	123
Field cultivator - plant	121
No-till	122

Source: (3) Baxter, Triplett and Bone, 1971.

Table A-5. Corn yields from different tillage systems on Hoytville Silty Clay Loam soil (average 3 years) in Ohio

Time of operation	Tillage		Corn grain yields previous crop	
	Plowed[1/]	Disked[2/]	Sod	Corn
			Bushels/Acre	
Fall	X	X	119	115
Fall	X	-	113	110
Spring	X	X	95	91
Spring	X	-	83	79
Fall spray	-	X	113	--
Fall spray	-	-	112	--
Spring spray	-	X	98	103
Spring spray	-	-	95	100

1/ Moldboard plowed 8 inches deep.
2/ One to three times over with tandem disk.

Source: (30) Triplett, Van Doren and Johnson, 1970 (LSD = 7 bu/ac)

Table A-6. Fertilization of conventional tilled and no-till corn on a Canfield Silt Loam soil in Ohio

Year	Tillage					
	Plow			No-Till		
	N-60 lbs.	N-120 lbs.	N-240 lbs.	N-60 lbs.	N-120 lbs.	N-240 lbs.
	Bushels per acre					
1962	62	68	69	80	79	79
1963	76	75	76	91	96	96
1964	61	61	59	68	76	78
1965	55	62	59	64	71	78
1966	43	40	42	60	61	64
1967	64	61	64	65	75	73
Mean	60	61	61	71	76	78

Source: (27) Triplett and Van Doren, 1969.

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