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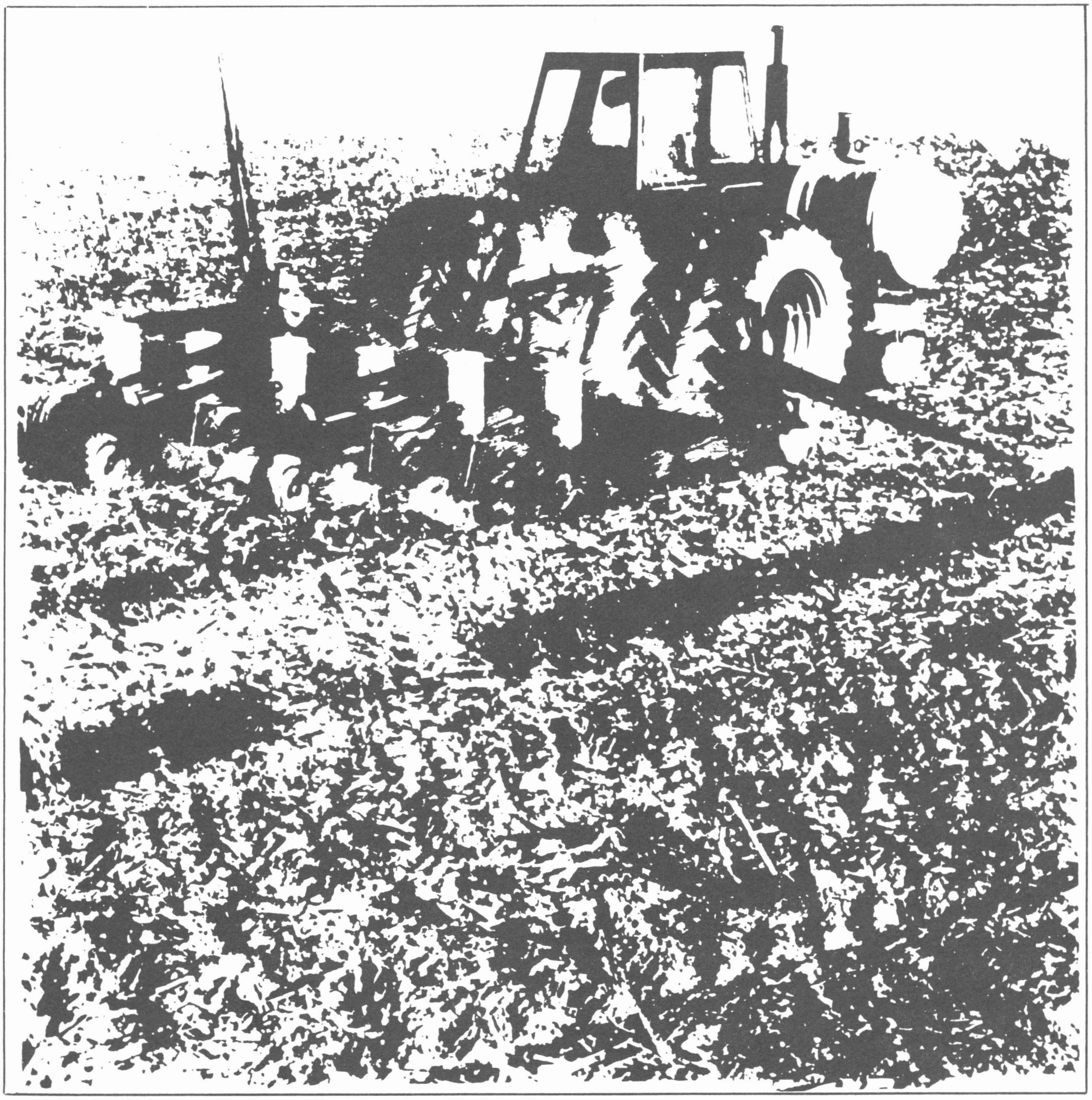
College Station

Conservation Tillage In Texas



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CONSERVATION TILLAGE IN TEXAS

B. L. Harris and A. E. Colburn, Editors

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FOREWORD

A concerted effort has been made to develop conservation tillage guidelines for all areas of Texas. These efforts were initiated and coordinated by Dr. B. L. Harris, Soil and Water Use Specialist, and Dr. A. E. Colburn, Agronomist-Soil Management, Texas Agricultural Extension Service. Included on the overall planning committee were Dr. E. Burnett, Director and Soil Scientist, Texas Agricultural Experiment Station and USDA-SEA-Agricultural Research, and Mr. C. L. Williams, Resource Conservationist, USDA-Soil Conservation Service. Numerous other individuals with several State and Federal agencies also have worked to develop these guidelines. In conjunction with these efforts several workshops were held. A statewide Conservation Tillage Workshop was held on the Texas A&M University Campus on January 25 and 26, 1979. Prior to the statewide workshop, five regional workshops were held to develop draft conservation tillage guidelines for the major cropping systems for five major regions covering the entire State. These draft guidelines served as the basis for discussions at the State workshop. A series of presentations on research findings and needs was also included.

Conservation tillage includes tillage systems that create as good an environment as possible for the growing crop, and that optimize conservation of soil and water resources, consistent with sound economic practices. Conservation tillage includes maximum or optimum retention of residues on the soil surface and use of herbicides to control weeds. Conservation tillage systems offer excellent control of wind and water erosion and maximum conservation of water resources. They also reduce labor, machine, and fuel requirements. Crop yields are generally as good as, and sometimes higher than those with the plow-based systems. There are disadvantages, however. Conservation tillage systems delay soil warming and drying, require more pesticides and nitrogen, limit fertilizer and pesticide placement options, and are sometimes restricted by climatic, weed, and soil conditions. Therefore, results from one area can be greatly different than those from another area. Also, the level of management required is higher with conservation tillage than with plow-based systems.

The development of successful conservation tillage systems is an "Art," as well as a "Science." The guidelines and experiences presented in this publication should serve as a valuable resource for fostering further trials in the search for new technology that will lead to optimum production of food and fiber with maximum conservation of our natural resources and environmental quality.

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POTENTIALS FOR CONSERVATION TILLAGE SYSTEMS IN TEXAS

B. L. Harris, E. Burnett, and C. L. Williams*

Technological advances in recent years have made possible many new tillage system alternatives for agricultural production. A primary development giving rise to these alternatives has been the development and refinement of chemicals for weed control. However, several other developments have paralleled the herbicide impacts.

Environmental concerns have provided impetus for critical evaluation of each step in agricultural production processes. Water and air quality management programs and regulations may restrict land use diversification potentials. The prospect of regulatory programs, which would limit alternative practices that farmers may select to carry out any given necessary operation, has raised some very serious questions for agricultural producers and others. Conservation tillage systems may provide renewed flexibility.

Economics has also forced evaluation of alternatives. Cost-price relationships dictate efficiency of operations.

Energy resource constraints have provided stimuli to consider more efficient means of producing food, feed, and fiber products. Availability as well as price of fuel has affected agricultural production operations.

In some parts of the United States, considerable research has been directed toward answering specific questions about conservation tillage systems. Such

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work will make possible a greater array of alternatives to agricultural producers for the selection of tillage practices. However, for most areas in Texas, there are limited research and experiences on which to base suggestions and recommendations regarding tillage system alternatives. However, more widespread recognition of potentials for conservation tillage is anticipated and a correspondingly, greater commitment of research and educational efforts will be directed toward providing answers to questions being asked about such systems.

In surveying potentials for tillage systems in Texas, major consideration must be given to the great diversities found in the State. Problems inherent to one section of the State may be entirely different from those of other areas. Tillage systems must be designed for a specific region with due considerations for cropping systems, rainfall, biomass production potentials (residue levels), soils, weeds, insects, disease control, equipment needs, economics, and hydrologic impacts. All of these factors will direct decision-making.

Recently, farmers have expressed more interest in learning about conservation tillage systems. Personnel with several agencies are actively involved in seeking responses to those farmer questions. Agronomists with the Soil Conservation Service annually estimate the extent of two types of conservation tillage systems in relationship to conventional tillage systems in Texas. Table 1 shows those estimates for the past five years and projections for 1979 (15).

Trends are for general reduction in acreage of no-tillage and minimum tillage in 1978 and 1979 following an all time high in 1977. These trends are counter to trends of "new starts" of minimum tillage for those same years (14). *"New starts" are measured annually and reported by SCS management* areas. Trends from those data show consistent increases in adoption of conservation tillage systems for most areas of the State.

Table 1. Extent of Conservation and Conventional Tillage Systems in Texas.

	No-Tillage	Minimum Tillage	Conventional Tillage	Total
	thousands of acres			
1974	109	1,101	22,290	23,500
1975	133	1,179	23,088	24,400
1976	209	2,121	23,740	26,071
1977	262	2,357	24,330	26,948
1978	147	1,501	21,789	23,436
1979	122	1,255	28,415	29,792

Conservation vs Conventional Tillage

Many considerations and questions at this time are directed toward comparison and contrast between so called "conventional tillage systems" and "conservation tillage systems". Conventional tillage systems are that collection of practices which are most commonly used by some of the better agricultural managers in a given area. Such practices include moldboard plowing, disking, cultivation, and other operations considered necessary to provide "clean tilled land". Frequently, conventional tillage systems result in excessively tilled lands as time, labor, and equipment efficiencies are sacrificed.

Conservation tillage is that combination of practices which are considered to be the minimum required tillage trips across the land that will generally provide for equal or greater economic advantage when compared to conventional tillage. This combination of practices will in some cases provide for accumulation of organic residues on the soil surface, combining of several operations into one, substitution of chemical weed control for mechanical weed control, substitution of chisel operations for moldboard plowing, use of sweeps instead of disking, and other such substitutions. Conservation tillage describes those practices which provide for conservation of soil, water, energy, labor, and/or time. Within this broad category, many conservation tillage methods are included such as: "minimum tillage", "no tillage", "stubble mulch", "zero tillage", "chisel plant", "slot plant", "chemical fallow", and others.

Research and experiences have provided the following comparisons and contrasts between conservation and conventional tillage:

- Conservation tillage operations are limited to those essential to produce a desired crop.
- In many cases, yield levels are equivalent for both tillage systems; however, an economic advantage may be gained with conservation tillage due to reduced input costs, even if actual yield levels are lower.
- Conservation tillage in some situations provides greater opportunity for multiple cropping.
- Conservation tillage systems generally save time, production costs, energy, soil, water, and labor, but may require greater inputs of chemicals (pesticides).
- Conservation tillage does not necessarily imply maintaining crop residues or mulch on the soil surface.
- In some cases, greater risks of crop failure are associated with conservation tillage systems (17).

- Different equipment may be required for conservation tillage systems, than for conventional systems, especially those conservation systems which involve retaining high levels of crop residues on the surface.
- Conservation tillage systems normally require a higher level of producer management than conventional systems.
- In most conservation tillage systems, weed control is a major problem.
- Control of insects and diseases and use of fertilizers may also present special problems for conservation tillage systems.
- Certain types of conservation practices may demand more plowing or bed shaping than might otherwise be practiced. Examples are: "basin tillage" and tillage necessary for wind erosion control.
- In many cases, and in both types of tillage systems, some tillage is necessary for disruption of soil compaction zones and surface crusts.

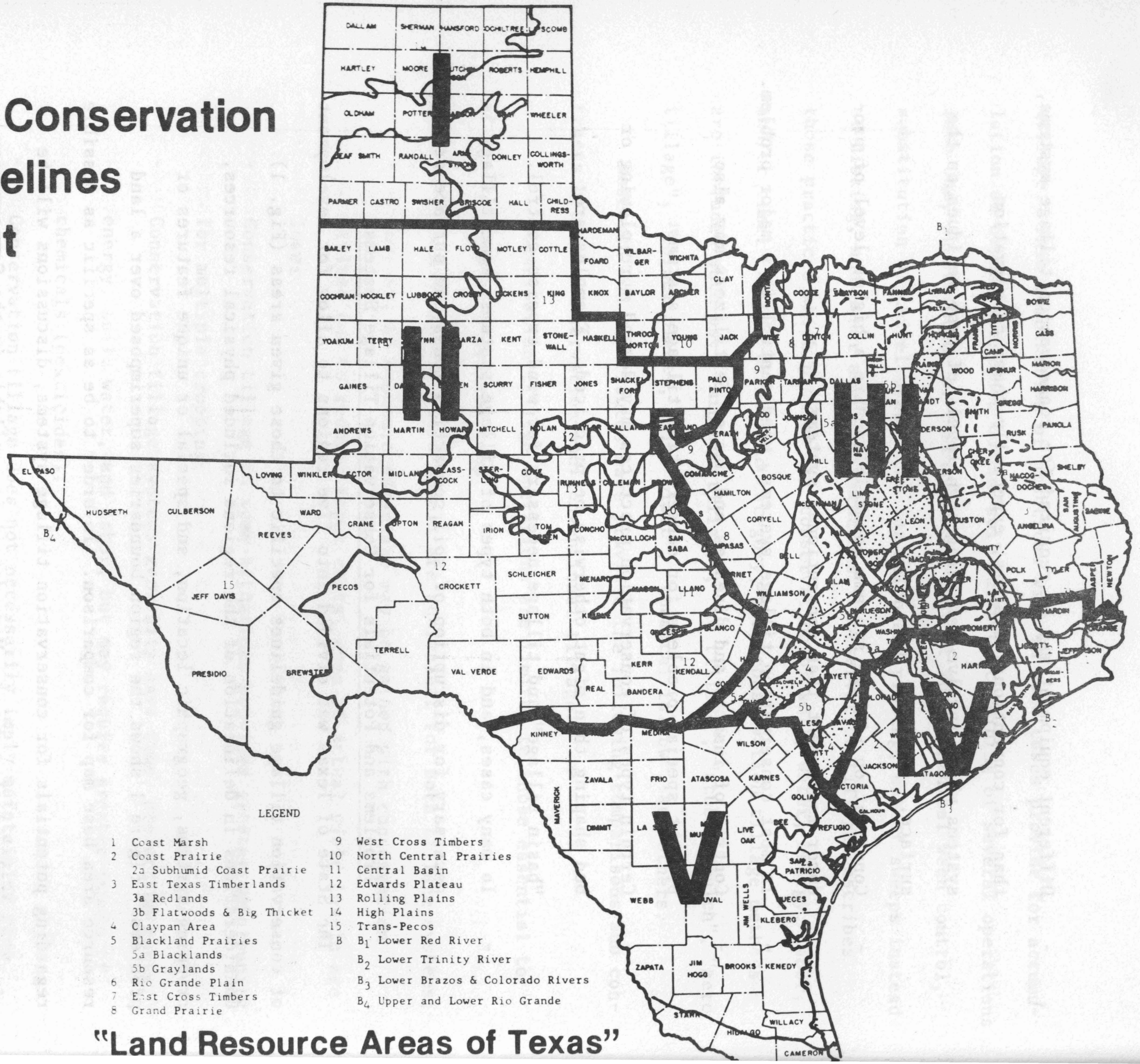
Problems and Potentials for Conservation Tillage Systems

The State of Texas was divided into five regions to allow for development of conservation tillage guidelines specific to those given areas (Fig. 1). Considerations in delineation of the regions included physical resources, cropping systems, geographic location, and special or unique features or problems. Figure 1 shows the region boundaries superimposed over a land resource area base map for comparison. In order to be as specific as possible regarding potentials for conservation tillage systems, discussions will be given for individual regions. More detail is available in the Conservation Tillage Guideline sections for each region, given later in this report.

Region I--Northwest Texas

This region of the State is unique in that a considerable amount of conservation tillage research has been done already. Those research studies have

Regions for Conservation Tillage Guidelines Development



LEGEND

1	Coast Marsh	9	West Cross Timbers
2	Coast Prairie	10	North Central Prairies
	2a Subhumid Coast Prairie	11	Central Basin
3	East Texas Timberlands	12	Edwards Plateau
	3a Redlands	13	Rolling Plains
	3b Flatwoods & Big Thicket	14	High Plains
4	Claypan Area	15	Trans-Pecos
5	Blackland Prairies	B	B_1 Lower Red River
	5a Blacklands		B_2 Lower Trinity River
	5b Graylands		B_3 Lower Brazos & Colorado Rivers
6	Rio Grande Plain		B_4 Upper and Lower Rio Grande
7	East Cross Timbers		
8	Grand Prairie		

"Land Resource Areas of Texas"

been underway for over twenty years. During that period, information has been amassed regarding alternative tillage and cropping systems appropriate for this region. References are provided of example published work (1, 2, 3, 4, 5, 9, 10, 12, 18, 19, 20, 22, 23, 24, 25).

Region I encompasses most of the major wheat producing counties in the High and Rolling Plains. Opportunities for development of conservation tillage systems which involve the maintenance of high levels of surface organic materials appear to be easier in systems which include wheat. However, with very high levels of residue production, wheat straw may become a problem, particularly if double cropping is to be practiced.

Several acceptable conservation tillage practices for various cropping systems are possible in this region (see Conservation Tillage Guideline sections). Specifics on yield relationships between various systems and other important aspects of the systems have been studied and information is available as indicated above.

This region does include some complications regarding the combination of irrigated and dryland production. Also wind erosion is a substantial problem throughout much of the region, particularly for sandy soils common in the western portion of the High Plains. In general, the quantity of residue produced by crops being grown is adequate to provide for wind erosion control where the residue is carefully managed, except on the very sandy soils. However, this situation may vary from year to year and with cropping systems. Producers must maintain flexibility to deal with specific situations that arise.

Where cattle are grazed on wheat or other crop residues, compaction and surface crusts will normally require tillage for amelioration. In addition to these necessary operations, research in the area has also demonstrated a distinct yield advantage for periodic deep plowing (11, 13).

Conventional tillage in this area, as with most areas, involves excess operations. In many cases, combinations of practices resulting in reduction of number of trips across the field can be accomplished with little change in types of tillage performed and without substantially affecting crop yields.

Under irrigation, multiple-cropping systems are possible in this area (5, 21). However, in most years rainfall is not adequate to allow for production of more than one crop per year under dryland conditions.

Soil Conservation Service records show a remarkable increase in conservation tillage "new starts" in the Amarillo Area, which is the western portion of Region I. "New starts" in that area increased from 36,351 acres in 1977 to over 102,000 acres in 1978 (14). Certainly, conservation tillage is becoming more popular in that area.

Region II--West Texas

A primary consideration in the development of conservation tillage systems for this region is that inadequate residues are produced in most years by most of the crops grown in the area to provide adequate protection against wind erosion. Amount of residue produced by cotton is very low. This area includes vast acreage of coarse and moderately coarse textured soils which are highly susceptible to wind erosion, particularly during the spring and early summer months. Inadequately protected soils during these periods of the year frequently result in substantial erosion, stand reduction, and crop injury or loss. Rainfall in most years in this region is not adequate to allow for a winter cover crop to be used to protect the soil without jeopardizing the yield potential of succeeding summer crops. Competition for the precious soil moisture must be carefully controlled to provide for economic crop production levels. Therefore, most of the conservation tillage systems and alternatives available to this region do not involve practices to promote retaining residues on the soil surface. Conservation tillage systems for this region will focus on eliminating unnecessary operations; substitution of sweep tillage for disk tillage, chemical for mechanical weed control, chiseling for plowing; and adoption of water conservation practices.

Deep plowing for wind erosion control is routinely practiced on many of the soils in this region, particularly those which are coarse textured. Many of the moderately coarse textured soils are also deep plowed once every three to five years with chisel operations being used in the interim years. Research at Big Spring has shown a distinct advantage in some years for plowing compared to chiseling; however, results have not been consistent (8). The apparent yield advantage due to plowing may be related to soil nutrient release.

This area has special problems regarding compaction and crusting. In many cases, traffic across the soil surface destroys the weak structural units and results in a virtual single-grained condition at the end of each growing season. Reduction of trips across these soils would help maintain the fragile structural units and reduce soil compaction. Tillage is required for disruption of restrictive layers.

Ample opportunity exists to reduce the number of trips across the field. There is a general tendency to keep the land "cleaner" or to kill more weeds than required for economical crop production levels. This practice involves unnecessary tillage operations. The opportunity also exists to combine two or more necessary operations into one trip across the land.

Practices designed to increase water infiltration and storage in the soils must be practiced since rainfall is limited. Even where irrigation water is available, limited quantities are present and must be stretched to provide for adequate supplementation of natural rainfall to give acceptable crop production levels. For dryland as well as irrigated crop production, basin tillage techniques have been recently revived. This technique involves construction of small, relatively closely-spaced dams across furrows to trap as much rainfall as possible.

Soil Conservation Service reports for this region show that "new starts" in the Lubbock Area dropped from 143,000 acres in 1977 to 89,000 acres in 1978. The Big Spring and San Angelo Areas showed little change during the same period, but registered small increases (14).

Region III--Central and East Texas

Cropland production in this area is primarily based on cotton-grain sorghum systems on upland soils of the central Blackland Prairies Land Resource Area and on alluvial soils in the same general area of the State. There are increasing amounts of small grains produced in the northern portion of the Blackland Prairies. Soybean production is important in the northeastern part of the State. Peanut production is centered on the sandy soils in the western portion of this region.

Johnsongrass is a major problem weed for this region, particularly in cropping systems involving grain sorghum. However, other weeds also present substantial problems. Conservation tillage systems for this region must allow for adequate weed control. This will be a difficult task with existing technology.

Water erosion is a major limitation for many soils in this region. The Blackland Prairies has some of the most severe erosion occurring in the State. Fine textured soils on 2-8% slopes produce considerable runoff during extended wet periods. Many soils in Region III with sandy surfaces and clayey textured subsoils are also highly erodible. Tillage system alternatives must include special considerations for water erosion hazards.

At the present time, no good system exists for the type of conservation tillage system which will result in retaining maximum levels of residue on the soil surface for cotton and grain sorghum rotation systems. Much of the cotton production area is dependent upon use of herbicides which require incorporation. Present methods for incorporation involve disking or some similar practice. Consequently, destruction of surface residues occurs during or before herbicide incorporation.

Research at Temple has resulted in the development of a wide-bed, narrow-row grain sorghum production system which permits reduction in number of cultivations and allows for removal of excess water during a wet spring. This system will permit a fixed traffic pattern, thereby reducing the area of a field compacted by tractor traffic. This system results in a yield increase over conventional wide rows. A producer can switch to this system with minimum additional equipment expenses (6).

Some producers in the Blacklands have developed systems in which corn and grain sorghum are planted flat or without beds and cotton is planted on low beds. Advantages of these practices include less energy requirement, less residue destruction, and less moisture loss. Herbicides are used to substitute for tillage as possible. Double-disk opener planters are used to plant through the heavier than normal surface residues. However, on flat slopes in wet years some drainage problems can develop.

As with other regions, opportunities exist to reduce the number of trips across the field by combining operations and reducing excessive and unnecessary practices or operations.

Records of Soil Conservation Service agronomists show some interest and increasing adoption by farmers of conservation tillage practices in the southern portion of the Blackland Prairies, but decreasing trends of adoption in recent years for other parts of this region (14).

Region IV--Southeast Texas

Cropping systems in this region involve rice, cotton, corn, grain sorghum, and soybeans. Soils of this region are unique in that most have very little if any erosion hazards. Only those soils adjacent to drainage ways have slopes steep enough to present water erosion hazards. Inadequate drainage is more of a problem than erosion. Wind erosion is not considered a hazard in any part of this region. Therefore, conservation tillage systems for this region will involve primarily reduction in the number of trips across fields and substitution of operations to minimize undesirable soil structure deterioration.

Another unique situation in this region is that development of a zone of compaction in some soils used for rice production is beneficial since such a pan promotes better water use efficiency. This is particularly true on the coarser textured soils. However, soil structure deterioration under rice production leads to problems for soybeans and other crops grown in rotation with rice. Special operations and tillage practices must be designed to correct permeability and infiltration problems caused by rice production and harvesting operations.

Red rice control is a major weed consideration for this region. Research indicates that minimizing tillage is beneficial in controlling red rice problems (16). Maintaining the red rice seed close to the soil surface allows more flexibility in control than if the seeds are mixed with the soil.

Potential also exists in this region for multiple cropping, and ratoon cropping of rice is commonly practiced.

Potentials for conservation tillage in this region for cotton-grain sorghum, cotton-corn, soybeans and related cropping systems are very good. In general, elimination of excessive operations would provide many benefits and savings. Also, alternatives available for residue management are more flexible in this region when compared to other areas of the State.

Many soils of this region readily form plow pans and other compaction zones which must be disrupted to allow water entry and movement in the soil for cropping systems other than those including rice. However, moldboard plowing is not required to achieve these goals; chiseling substitutes well.

Soil Conservation Service records suggest that interest is high in conservation tillage systems in the Victoria Area and records show consistent increases in adoption of such practices (14). However, the major rice production areas have not widely used such systems.

Region V--South Texas

In general, soils of this region are not highly susceptible to either wind or water erosion. This is with the exception of some soils in Frio, LaSalle, and Atascosa Counties. Water availability is a major limiting production factor throughout the region. Therefore, practices designed to promote water use efficiency are desirable. Johnsongrass is a major problem throughout the region. Tillage systems for this region must include provisions for control of johnsongrass and other special weeds. Many crops grown in this area require the use of herbicides which must be incorporated, resulting in destruction of residues.

Soils of this region generally have low organic matter levels and weak structures. Soil physical problems are common. Pans form readily in some soils. Drainage may also be a problem on some soils. Tillage to correct these problems may be necessary.

Salinity is also a problem in some soils and may require special tillage practices for control.

In general, conservation tillage systems developed for this region will involve a reduction in the number of trips across the fields and special practices designed to promote water conservation. A good potential exists to develop such systems. Research in the area has shown that grain sorghum can be grown under no-tillage and minimum tillage systems with little yield reduction (7).

Soil Conservation Service records (14) indicate that conservation tillage systems are not in wide usage in the Uvalde and Harlingen Areas. However, interest in such systems is strong and rapidly increasing in the Alice Area.

Special Problems for Conservation Tillage System Adoption

In general, conservation tillage systems will involve leaving more weeds in the fields than is true for conventional tillage. Such a situation will require changes in some long-held beliefs. For example, throughout most agricultural production areas in Texas there is a direct relationship assumed between weed infestation and level of management--the cleaner the field, the better the farmer. Consequently, this observable feature has become a commonly used technique of evaluating a farmer's managerial skills. This attitude will have to change.

To many farmers, keeping their fields free of weeds is a matter of personal pride. Therefore, many additional operations are performed which are not economical nor required for high levels of crop production. These attitudes and philosophies also will hamper adoption of conservation tillage systems, since such systems will often result in "trash farming" and perhaps increased weed populations.

Some landlords and bankers make specific demands regarding control of weeds and other farming operations. Those demands may hamper adoption of conservation tillage systems.

Tradition dictates selection of many tillage operations for some producers. Such operations may or may not serve a useful function. However, the "it worked for my dad and his dad before him, it'll work for me" attitude will prevent some producers from adopting the newer systems.

Summary and Conclusions

Realistically, farmers will not be interested in conservation tillage systems if the result is a financial loss. Systems proposed must provide either an economic advantage or an alternative for use of land not otherwise possible.

Strict no-tillage systems will have very limited application at this time in Texas. Only in a few cropping systems, primarily those including small grains, in a few areas of the State in some years, can such a system be used. However, minimum and reduced tillage have applicability throughout most of the State in most years.

Efforts to keep organic materials on the soil surface will be hampered in some cropping systems by the need to incorporate herbicides. Such herbicides are widely used with crops like cotton, soybeans, and corn. Routine and emergency tillage for wind erosion control where inadequate residues are produced will also destroy surface organic mulches. However, for some cropping systems, maintaining residues on the surface is possible and highly beneficial.

All areas of the State provide opportunities for systems which are more efficient than those presently used. Elimination or combination of operations will result in fewer trips across the land. Such systems will be readily adoptable and acceptable.

In general, potential for adoption of conservation tillage systems is good. However, social stigmas and special problems in some areas will require careful practice selections and extensive educational programs before widespread adoption will occur.

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SOIL-PLANT-WATER RELATIONSHIPS IN CONSERVATION TILLAGE SYSTEMS[1]

P. W. Unger, C. J. Gerard, and C. W. Wendt[2]

Conservation tillage systems, which emphasize the maintenance of crop residues on the surface, have received considerable attention in recent years because of their potential for conserving soil and water; reducing labor, machinery, and energy requirements; and increasing crop yields. In this report, we discuss the effects of these systems on soil and water conservation, soil properties, and crop yields. Most of the data are from studies in Texas, but data from other regions are used to illustrate the potential of conservation tillage for controlling erosion.

Results and Discussion

Effect on Soil and Water Conservation and Crop Yields

Maintenance of surface residues was first emphasized with the introduction of stubble mulch or subsurface tillage for wind erosion control in the late 1930's and early 1940's. When sufficient residues were present, stubble mulch tillage effectively controlled wind erosion and this practice is now widely used throughout the drier portion of the Great Plains.

Although stubble mulch tillage controlled wind erosion, it had variable effects on crop yields, depending on location in the Great Plains. In the

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[1] Contribution from Agricultural Research, Science and Education Administration, USDA, in cooperation with The Texas Agricultural Experiment Station, Texas A&M University.

[2] Soil Scientist, USDA Southwestern Great Plains Research Center, Bushland, Texas; and Professors, Texas Agricultural Experiment Station, Vernon and Lubbock, Texas, respectively.

drier western portion, yields generally were higher with stubble mulch tillage than with clean (one-way) tillage because slightly more water was stored in the soil. Results from a long-term study at Bushland, Texas, are typical of those for the western Great Plains (Table 1). At more humid locations, as in the eastern Great Plains where residue levels were higher and the need for storing extra soil water was not as great, yields generally were lower with stubble mulch tillage than with clean tillage (McCalla and Army, 1961). Contributing to the lower yields were more severe weed problems, tillage and planting problems due to large amounts of residue, lower plant populations, and possibly soil temperature and fertility problems. The last two problems were indicated by chlorosis during some parts of the growing season on plants grown with large amounts of surface residue.

Another form of conservation tillage, chemical fallow, was introduced in the 1950's after the development of herbicides. All crop residues were maintained on the surface for better wind erosion control, but results from early studies at Bushland were discouraging because soil water contents and crop yields usually were no better with chemical fallow than with stubble mulch tillage (Table 2). Also, the herbicides cost more than did tillage during a fallow period. Although not immediately recognized, a factor contributing to poor results with chemical fallow was the small amount of residues produced by dryland crops. For example, residue production by dryland winter wheat and grain sorghum at Bushland averages about 1,500 pounds per acre. As shown in Tables 3 and 4, water storage during fallow increased as surface residues increased at several Great Plains locations. The low residue levels are common on dryland areas where clean or stubble mulch tillage is used. The high residue levels are common where wheat is irrigated (Unger et al, 1971, 1973).

Table 1. Effect of cropping system and tillage method for winter wheat on soil water content at planting, water-storage efficiency, and grain yield (from Johnson and Davis, 1972).

Cropping system and tillage method	Available soil water at planting+	Water-storage efficiency‡	Grain yield
	in.	%	lb/A
Continuous wheat			
One-way	3.6	20	520
Stubble mulch	4.1	22	610
Wheat-fallow			
One-way	5.0	10	830
Stubble mulch	6.1	15	940
Delayed stubble mulch	5.7	13	920

+ Average for 1942 to 1969, determined to a 6-foot depth.

‡ Average for 1958 to 1969.

* For this treatment, tillage after wheat harvest was delayed until weed growth started the following spring.

Table 2. Effect of cropping system and tillage method on water storage and crop yields (from Wiese et al, 1960, 1967).

Cropping System and tillage method	Year(s)					
	1957		1958		1963-64 Avg.	
	Water storage	Yield	Water storage	Yield	Water storage	Yield
	in.	lb/A	in.	lb/A	in.	lb/A
Wheat-fallow						
Sweep alone	2.01	460	7.20	1,460	--	--
Chemical + sweep	0.33	300	4.92	1,280	--	--
Chemical alone	0.00	380	4.08	1,310	--	--
LSD (0.05)	1.47	66	1.98	126	--	--
Continuous grain sorghum						
No-tillage (propazine)	--	--	--	--	4.1	2,290
Tillage	--	--	--	--	4.4	2,690
LSD (0.05)					N.S.+	N.S.
Grain sorghum in wheat-sorghum-fallow						
No-tillage	--	--	--	--	4.7	2,830
Tillage	--	--	--	--	4.4	2,870
LSD (0.05)					N.S.	N.S.

+ Not significant.

Table 3. Mulch rate effect on precipitation storage during fallow in Colorado, Montana, and Nebraska (from Greb et al, 1967).

Mulch rate	Range in precipitation stored
lb/A	%
0	16
1,500	19 - 26
3,000	22 - 30
6,000	28 - 33
10,000	34

Table 4. Mulch rate effect on average precipitation storage during fallow and grain sorghum yields at Bushland, Texas (from Unger, 1978).

Mulch rate	Precipitation storage		Sorghum yield
lb/A	in.	%	lb/A
0	2.8	22.6	1,590
890	3.9	31.1	2,150
1,780	3.9	31.4	2,320
3,570	4.6	36.5	2,660
7,140	5.5	43.7	3,280
10,700	5.8	46.2	3,560

Precipitation: Fallow--12.5 inches; Growing season--9.8 inches.

In 1968, chemical fallow studies with irrigated crops were started at Bushland. An irrigated wheat crop in 1968 yielded about 10,000 pounds of residues per acre. After harvest, disk and sweep tillage and herbicides were used for managing residues and controlling weeds and volunteer wheat until grain sorghum planting the next spring. Effects of the treatments on surface residues, weed control, and water storage during fallow are shown in Table 5. Disk and sweep tillage greatly reduced surface residues and resulted in an average of 20% of the precipitation being stored as soil water during fallow.

Precipitation storage was increased to 39% where weeds were controlled with herbicides.

Grain sorghum yields were not obtained for the foregoing study, but were obtained in later studies. Water-storage efficiencies from wheat harvest to grain sorghum establishment were 26 and 52% for disk tillage and chemical fallow, respectively, for 8.1 inches of precipitation and 3.0 inches of pre-plant irrigation. Subsequent grain yields were 3,900 and 5,270 pounds per acre with 6.0 inches of seasonal irrigation for the disk tillage and chemical fallow treatments, respectively. With 12.0 inches of irrigation, the respective yields were 5,440 and 6,010 pounds per acre. Chemical fallow with 6.0 inches of irrigation resulted in only 170 pounds per acre less grain than disk tillage with 12.0 inches of irrigation, which showed that chemical fallow resulted in more efficient use of irrigation water than disk tillage. Where water for irrigation is limited, the chemical fallow system, therefore, has potential for more effective water use than disk tillage. Where adequate water for irrigation is available, the response to chemical fallow was adequate to justify applying 12 inches of water. Growing season precipitation was 8.1 inches. The yield increase with chemical fallow resulted from the higher water content at planting and possibly from greater water infiltration and lower evaporation during the growing season (Unger and Phillips, 1973).

In a 2-year rotation of irrigated winter wheat and dryland grain sorghum, Unger and Wiese (1979) used no-tillage, sweep, and disk tillage for wheat residue management and weed control from wheat harvest until sorghum planting. Precipitation stored as soil water, sorghum grain yields, water-use efficiency, and net returns for the sorghum crops, based on March, 1978, production expenses and grain prices, were highest with no-tillage, intermediate with sweep tillage, and lowest with disk tillage (Table 6). All plots were uniformly plowed after sorghum harvest and immediately planted to winter wheat.

Table 5. Effect of tillage method on surface residues, weed control, and precipitation storage during fallow between wheat harvest and sorghum planting at Bushland, Texas, 1968-69 (from Unger et al, 1971).

Tillage method	Surface residues--lb/A July	Oct.	May	Weed control in May--%	Precip. storage in.	%
Tandem disk	3,900	200	<200	76	3.1	22
Tandem disk + sweep	3,900	1,800	1,000	52	2.0	15
Sweep	8,000	3,800	3,200	44	3.4	24
Sweep + herbicide	8,000	6,000	4,000	100	5.6	39
Herbicide	10,000	6,400	4,100	100	5.6	39

Fallow period precipitation was 14.2 inches.

At Bushland, irrigation water infiltration was greater where continuous grain sorghum was planted without tillage in residues from previous crops than where the residues were incorporated by rototilling. Infiltration totaled 12.7 and 10.5 inches for the no-tillage and tillage treatments, respectively, from 14.3 inches of irrigation water applied from June 3 to August 31, 1971. Although total dry matter yields with no-tillage were higher than with the tillage treatment, grain yields were lower with no-tillage because of excessive volunteer sorghum growth (Allen et al, 1975).

Table 6. Effect of tillage method on average precipitation storage, sorghum grain yields, water-use efficiency, and net returns for the sorghum crop in an irrigated wheat-dryland grain sorghum cropping system at Bushland, Texas (from Unger and Wiese, 1979).

Factor	Tillage method No-tillage	Sweep	Disk
Precipitation storage--%	35.2	22.7	15.2
Grain yield--lb/A	2,810	2,230	1,750
Water-use efficiency--lb/A-in.	76.9	67.1	57.5
Net returns for sorghum--$[+]	50.23	26.04	12.52

Precipitation: Fallow--13.7; Growing season--10.4.

[+] Based on March, 1978, expenses and grain prices.

In a subsequent continuous grain sorghum study, volunteer sorghum was controlled in the spring with a rolling cultivator or a sweep-rodweeder for bed-splitting and mulch-subsoiling treatments, respectively. The mulch-subsoiler, with sweeps attached to undercut the old furrows, increased irrigation water infiltration by 10% and grain yield by 8% as compared to clean tillage (disking) and chiseling. Yields with the bed-splitting treatment were equal to those with the clean tillage treatment (Allen et al, 1979). The limited tillage treatments, bed-splitting and mulch-subsoiling, greatly reduced time and energy needs.

Evaporation after precipitation or irrigation results in major losses of soil water. In studies at Lubbock, Texas, evaporation was lowest from no-tillage and minimum-tillage (shredding and disking) plots followed by that from chiseled (shred, disk, chisel) and moldboard plowed (shred, disk, chisel, moldboard plow) plots. Water was adequate for seed germination without spring rains in no- and minimum-tillage plots, but not on moldboard plowed and chiseled plots. More water from spring rains was stored with no-tillage, minimum-tillage, and chiseling than with moldboard plowing. Cotton yields were higher with no-tillage and chiseling than with moldboard plowing, but sorghum yields were higher with chiseling, moldboard plowing, and disking than with no-tillage (Wendt, 1973).

Results from a few studies suggest that continuous no-tillage is not a practical or economical cropping system in Texas. Although water infiltration and soil water contents generally were higher and production costs generally were lower with no-tillage than with conventional tillage, crop yields declined after the first or second year of no-tillage (Allen et al, 1975; Unger 1977; V. M. Harris, Economics of Minimum Tillage, Perry Foundation Report). When plots were plowed after 3 years of no-tillage (Unger, 1977) or when no-tillage was alternated with limited tillage (Allen et al, 1976), yields with no-tillage generally were higher than with other tillage methods. Yield decreases with continued no-tillage usually were associated with increasing weed and volunteer plant control problems, planting problems, low plant populations, and poor seedling vigor.

Effect on Soil Properties

The foregoing examples and discussions have emphasized plant and soil water relationships. Another important factor in crop production is the influence of tillage on plant rooting depth, soil water relations, and soil physical condition.

If plant rooting is restricted by dense subsurface layers, plants must receive water frequently for high yields (Gerard and Clark, 1978a, 1978b; Gerard et al, 1977). Where plants are dependent on infrequent rainfall, the restricting layers can severely reduce crop yields, even though soil beneath the layers may contain plant available water.

Data on the effect of increased surface residues and reduced tillage and tractor traffic on the development or alleviation of dense soil layers are limited. Koshi and Fryrear (1973) showed that the application of cotton burs at rates of 5 tons per acre or more and confinement of tractor traffic to the same path each year decreased soil bulk density and increased soil hydraulic conductivity, air porosity, total porosity, and organic matter content. The study was conducted on a loam soil at Big Spring, Texas. Maintenance of surface residues and root systems of previous crops, as with no-tillage, should also enhance water infiltration, decrease evaporation, and decrease soil compaction. This should result in deeper plant rooting because of higher soil water contents and the associated lower soil strengths. At some south-eastern U. S. locations, crops have rooted deeper and yielded more following grasses on soils with compacted subsurface layers where reduced tillage rather than conventional tillage was used (Reicosky et al, 1977).

Unger (unpublished data, USDA Southwestern Great Plains Research Center, Bushland, Texas) measured some physical conditions of Pullman clay loam (Torrerti Paleustoll) after 4 years on plots where wheat was grown with and without irrigation in alternate years. No-tillage, disk, and sweep treatments were used for residue management and weed and volunteer wheat control. The differences in soil physical conditions due to tillage method were slight. Soil bulk densities to a 2-foot depth in plots irrigated for the crop before sampling were 0.04 and 0.05 g/cm^3 higher in no-tillage than in disk and sweep plots, respectively. Soil penetration resistance tended to be lowest with no-tillage, even though soil water contents to the depth of penetration measurement were similar. On dryland plots, soil organic matter content was significantly lower on disk than on no-tillage and sweep plots. The no-tillage soil tended to have more fine (<0.04 in.) and fewer large (>0.16 in.) water stable aggregates on the dryland plots, but there were no significant differences on irrigated plots. On dryland and irrigated plots, no-tillage resulted in more fine (<0.03 in.) and fewer large (>0.25 in.) dry aggregates than disk or sweep tillage. Although more fine aggregates suggested that the no-tillage soil was more subject to wind erosion, the soil was protected by the surface residues.

Effect on Erosion

The benefits of surface residues for controlling wind and water erosion are widely recognized, but soil loss data from Texas are limited. Unger (1969) found low and no significant differences in losses from Pullman soil when he used a wind tunnel on fallowed areas and areas cropped to winter wheat. Clean and stubble mulch tillage methods were used on the different areas. Soil losses were low because of residue on the surface and the stability of soil aggregates. Residue amounts needed to protect different soils against erosion are given in Table 7.

Table 7. Approximate amounts of flattened wheat residue needed to hold erosion to about 5 tons per acre per year (from Unger et al, 1977).

Soil	Protection from erosion Wind	 Water
	lb/A	
Silts	925	1,450
Clay and silty clay	1,600	1,850
Loamy fine sand	2,125	900

Considerable data have been published from outside of Texas concerning soil losses by water erosion. We show the results of two studies in Tables 8 and 9. Data in Table 8 were for a storm that had an expected recurrence frequency of over 100 years. The rain fell in 7 hours. Rainfall was identical and slopes were similar for clean-tilled watersheds having sloping or contour rows. However, runoff and soil loss from the contoured watershed were only 52 and 14%, respectively, of that from the watershed with sloping rows. No-tillage with contour rows resulted in 57 and 0.1% runoff and soil loss, respectively, as compared with that from the sloping-row watershed, even though the no-tillage watershed was much steeper (Harrold and Edwards, 1972).

Data in Table 9 show the influence of tillage practice and slope steepness on precipitation runoff and soil loss from a tropical location in Nigeria. The authors (Rockwood and Lal, 1974) considered sure and cheap control of erosion to be the greatest advantage of minimum tillage for tropical soils. Although soils and conditions in Texas are different from those in Ohio and Nigeria, the foregoing examples show the potential of conservation tillage for controlling soil erosion by water.

Table 8. Effects of tillage on runoff and soil loss from corn watersheds at Coshocton, Ohio (from Harrold and Edwards, 1972).

Tillage	Slope	Rain	Runoff	Soil loss
	%	in.	in.	lb/A
Plowed, clean tilled, sloping rows	6.6	5.50	4.40	45,300
Plowed, clean tilled, contour rows	5.8	5.50	2.30	6,430
No-tillage, contour rows	20.7	5.07	2.50	63

Table 9. Effect of tillage and slope on runoff and soil loss from bare fallow, plowed, and no-tillage areas on a tropical soil in Nigeria (from Rockwood and Lal, 1974).

	Bare fallow		Plowed		No-tillage	
Slope	Runoff	Soil loss	Runoff	Soil loss	Runoff	Soil los
%	%	lb/A	%	lb/A	%	lb/A
1	18.8	200	8.3	40	1.2	0
5	20.2	3,600	8.8	2,100	1.8	0
10	17.5	12,400	9.2	390+	2.1	0
15	21.5	15,900	13.3	3,900	2.2	0

Precipitation was 1.7 inches.

+ Probably an error in original publication.

Conclusions

1. Crop residues, when present in adequate amounts and maintained on the soil surface, can effectively control erosion and conserve water. Where residues are limited, tillage is an important erosion control practice.
2. In the drier regions of Texas, water conserved by conservation tillage systems generally increases crop yields.
3. Data are too limited to warrant conclusions concerning effects of conservation tillage on properties of Texas soils.
4. Continuous no-tillage crop production is not practical or economical in Texas at the present time.

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ENERGY CONSIDERATIONS IN CONSERVATION TILLAGE SYSTEMS[1]

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Conservation tillage systems were originally developed for conserving soil and water resources; however, these systems can also reduce fuel energy requirements and related expenses. To view energy considerations for tillage in a better perspective, it is helpful to consider the energy requirements of the entire U. S. food supply system.

Our food system uses about 16.5% of the nation's energy, but agricultural production uses only about 3% of the total (CAST, 1977). Table 1 provides a breakdown of the total energy use for the U. S. food system. It takes 3 times more energy to process, package, refrigerate, and transport food from the farm gate to the consumer than it does to produce it, and energy used for home food preparation is 1.7 times greater than for food production. Fuel energy for food production is divided into off-farm and on-farm use. Off-farm fuel is used to manufacture products for farming, such as natural gas for manufacturing nitrogen fertilizers, coal for steel production, and petroleum for pesticides, plastics, and machinery manufacture. On-farm fuel is used for tillage, planting, cultivation, pest control, irrigation, and harvesting.

Although the energy used for tillage is only a small part of that used in the complete food system, it is a major component of on-farm fuel use. To

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some extent, expenses for fuel, labor, machinery, and maintenance are related to the amount of tillage performed to manage a cropping system. We discuss here conservation tillage systems and their effects on energy use in Texas and at other representative locations. Tillage energy requirements reported are from field measurements or are estimates based on reported field operations and use of agricultural machinery management data (ASAE, 1978). Energy use is reported in diesel equivalents (gal/A). Where herbicides are used, the equivalent fuel energy for their manufacture and application is included in the tillage energy requirements unless otherwise noted.

Table 1. Energy use in the U. S. food system.

Function	Energy used (%)
Production	18
Processing	33
Transportation	3
Wholesale and retail trade	16
Household preparation	30

Dry Farming Tillage Systems and Energy

Stubble-mulch tillage, common to the western part of the Great Plains, usually involves tilling only as necessary to control weeds and wind erosion. Results of 27 years of research at Bushland, Texas, show that stubble-mulch tillage of wheat residue in the wheat-fallow portion of the study produced 13% greater yields than one-way tillage (Johnson and Davis, 1972). Fuel requirement for one-way tillage averaged about the same as for sweeps (Table 2). However, production efficiency was higher with sweeps because of the higher yields.

Draft requirements of the sweep and one-way plow were compared at Alliance, Nebraska (Dickerson et al, 1967). The one-way required more power in weed-free stubble, and sweeps required more in weedy stubble. At Archer, Wyoming, the energy requirements of bare fallow (one-way followed by sweeps and rodweeders) were compared with those of stubble-mulch tillage (sweep and rodweeders) for growing wheat (Fornstrom and Becker, 1977). Both tillage treatments required about the same energy. For discussion purposes, the power and energy requirements of sweeps and one-ways are assumed to be about equal. One operation of the one-way will bury from 30 to 70% of the residue, depending on tillage depth, whereas sweeps cover only 10 to 15% (Fenster, 1973).

Table 2. Yield and estimated fuel requirements for dryland wheat at Bushland, Texas (Johnson and Davis, 1972).

Tillage	Yield[1/]	Diesel Fuel
	lb/A	gal/A
Continuous wheat		
One-way	520	3.4
Sweep	610	3.4
Wheat-fallow[2/]		
One-way	830	6.4
Sweep	940	6.4

[1/] 27-year average 1943-1969.

[2/] Wheat-fallow represents one crop in 2 years with a 15-month intervening fallow period.

Wiese et al (1967) compared chemical weed control with sweep tillage in a wheat-sorghum-fallow system at Bushland, Texas in 1963-64. Chemical fallow replaced three fallow-season sweep operations and one sorghum cultivation for a net energy savings of about 1.5 gal/A of diesel. Sorghum grain yields and fallow-season soil water storage were equal for both treatments. Farther north on the Plains at North Platte, Nebraska, where the fallow-season evaporation potential is less, a herbicide treatment increased soil water storage and reduced fuel requirements as compared with stubble-mulch tillage (sweep) for fallow-season weed control (Smika and Wicks, 1968). The wheat-sorghum-fallow sequences consisted of 2 crops in 3 years with about 11 months of fallow between crops. Table 3 shows estimated energy use, soil water storage, and grain yields. Herbicide treatments reduced fuel use by 2.5 gal/A (27%) and increased soil water storage by 1.5 inches (20%) over sweep tillage. Succeeding wheat and sorghum yields were greater following fallow-season weed control with herbicides.

Table 3. Fallow-season soil water storage, energy requirements, and grain yield with sweep tillage and herbicide weed control, North Platte, Nebraska (Smika and Wicks, 1968).

Tillage	Number operations	Soil water stored	Energy[1/]	Yield Wheat	Yield Sorghum
		inches	gal/A	lb/A	lb/A
Sweep	8.5	7.3	5.5	3,110	3,640
Herbicide	6.0	8.8	3.0	3,240	4,470

[1/] Estimated

A combination of tillage and herbicides can reduce energy requirements. On a fine-textured soil at Hays, Kansas, dryland grain sorghum yields were increased when herbicides and limited tillage were used for fallow-season weed and volunteer sorghum control (Phillips, 1969). In the wheat-sorghum-fallow rotation, an application of atrazine followed by sweep tillage immediately after wheat harvest and one sweep operation just before seeding the sorghum, produced 60% higher 4-year average sorghum grain yields (3,370 vs. 2,050 lb/A) than the clean till check. Herbicide treatment alone did not significantly increase yield or control grassy weeds. The combination tillage-herbicide treatment required an estimated 0.55 gal/A (10%) less energy than clean tillage and had a much higher production efficiency because of increased yield.

In central and east Texas, johnsongrass [Sorghum halepense (L.) Pers] can be a problem with summer crops. Recommendations for medium johnsongrass infestations on cotton land include the incorporation of a preplant herbicide. (See section on Conservation Tillage Guidelines.) This increases the estimated tillage energy requirements by about 3 gal/A over the 5 to 7 gal/A for low johnsongrass infestations.

No-till seeding through a killed sod cover increased corn yields in Kentucky (Hill and Blevins, 1973) and Virginia (Shanholtz and Lillard, 1969). The sod cover reduced surface evaporation during the first 40 days until the crop canopy developed, which permitted more rapid early growth. Yields increased from 6,550 to 7,050 lb/A in Kentucky and from 4,480 to 5,770 lb/A in Virginia. Estimated energy requirements to prepare the seedbed and plant corn at both locations were 5.5 gal/A for clean tillage and 2.5 gal/A for no-till.

In Mississippi, Edwards (1971) found that limited tillage (cultivating furrow middles between crop rows) reduced energy requirements for seedbed preparation by 50% on a sandy loam and by 80% on a clay soil as compared with conventional disking and listing. Seed cotton yield was not significantly affected by limited tillage on either soil (Table 4).

At Florence, South Carolina (unpublished data, C. W. Doty, 1978), tractor fuel input was measured for primary tillage and planting operations with six different tillage systems for corn production on a Norfolk sandy loam. Limited tillage (chiseling 16 inches deep in 40-inch spaced rows and planting) used only about 40% as much energy (2.4 gal/A) as did conventional tillage (two diskings + harrow). A primary tillage treatment (chiseling 16 inches deep on 12-inch spacing) used 85% more energy than did conventional tillage.

Table 4. Energy used for seedbed preparation and yield of seed cotton in Mississippi (Edwards, 1971).

Tillage method	Tillage energy[1/]	Seed cotton yield
Marietta Sandy Loam	gal/A	lb/A
Disk-list	0.90	2,490
Cultivate middles	0.45	2,480
Houston Clay		
Disk twice-list	3.20	2,030
Cultivate middles	0.65	2,160

[1/] Tillage energy does not include stalk cutting, fertilizer application, herbicide application, or seeding. The energy requirements were originally reported in h.p. hr/A. We converted these values to the diesel equivalent.

Irrigated Tillage Systems and Energy

Irrigated cropping usually requires extra tillage if water is applied in furrows. For sprinkler irrigation, tillage energy requirements are similar to those in humid areas without irrigation. If irrigation water is supplied from deep wells, energy for pumping can overshadow that for tillage. This is discussed later in the section on pump irrigation.

Herbicide control of fallow-season weeds and volunteer wheat was compared with clean tillage on irrigated wheat residue at Bushland, Texas, (Unger et al, 1971). During the fallow period between wheat harvest in June and sorghum seeding the following spring, 2.5 inches more water was stored and about half as much tillage energy was used with herbicide control. The 2.5 inches of additional stored water nearly equalled that normally stored with a preplant irrigation and greatly reduced the need for an irrigation before seeding sorghum or corn. The fuel savings for one irrigation amounted to about 13 gal/A or 20% of the 65-gal/A average fuel use for seasonal irrigation of sorghum at Bushland.

In a follow-up study with a wheat-sorghum-fallow sequence (two crops in 3 years) under limited irrigation at Bushland, no-till herbicide control of fallow-season weeds and volunteer wheat was compared with clean tillage (Musick et al., 1977). During the approximate 11-month fallow period between wheat harvest and sorghum seeding the following spring, an average 1.7 inches more soil water was stored with no-till (Table 5); and as a result, no emergence irrigation was needed. No-till increased sorghum grain yield by 15% and reduced estimated tillage energy from 7.5 to 2.4 gal/A.

Annually cropped, furrow-irrigated grain sorghum was studied under various tillage treatments (disk-chisel, disk, bed-split, and bed-mulch) at Bushland (Allen, et al, 1979). Tillage effects on yield, irrigation water use, and fuel requirements are shown in Table 6. In the bed-mulch treatment, old stalks stood undisturbed until spring and a sweep-rodweeder was used to undercut the beds and clean the furrows before seeding the new crop. In the bed-split treatment, new beds were formed over the old furrows. The reduced tillage treatments, bed-splitting and mulching, required only about half as much fuel as the two clean-tilled disk treatments and increased yield by 8 and 16%, respectively. Irrigation water-use efficiency with bed-mulching and with bed-splitting was 8% greater than with disking. The results of no-till seeding grain sorghum double-cropped after winter wheat harvest at Bushland are also shown in Table 6. No-till required only about one-third as much fuel and one-fifth as much time as did clean tillage, and increased average grain yield by 12% (Allen et al, 1975).

In the Mesilla Valley of New Mexico, energy for limited tillage was compared with moldboard plowing and rototilling for irrigated cotton

(Abernathy, 1970). The moldboard plowing treatments were very energy-intensive and included 2 to 4 diskings after plowing 8 to 10 inches deep (Table 7). Moldboard plowing and disking used about 4 times more energy than did limited tillage (chiseling 12-14 inches deep) and 2.7 times more than rotary tillage. Four-year average cotton yields were significantly higher (15%) with moldboard plowing than with limited or rotary tillage.

Table 5. Fallow-season soil water storage after irrigated wheat, estimated fuel requirements, and grain sorghum yield with no-till herbicide and disk weed control at Bushland, Texas (Musick et al, 1977).

Tillage	Soil water stored	Fallow efficiency[1/]	Sorghum yield	Energy
	inches	%	lb/A	gal/A
No-till	4.5	35	5,150	2.4
Clean-till	2.8	21	4,480	7.5

[1/] Percent of fallow-season precipitation stored.

Table 6. Yield and measured fuel requirements for annual and double-cropped grain sorghum with various tillage methods, Bushland, Texas.

Tillage method	Grain yield	Energy
	lb/A	gal/A
Annual cropped (1975-76)		
Disk-chisel	5,670	7.3
Disk	5,280	6.1
Bed-split	5,710	3.4
Bed-mulch	6,120	2.5
Double cropped after winter wheat (1968-73)		
Clean-till	4,530	5.4
No-till	5,080	1.5

Table 7. Effect of tillage method on irrigated cotton yield and tillage energy use in the Mesilla Valley of New Mexico (Abernathy, 1970, with some recalculations).

Tillage method	Yield	Energy
	lb/A	gal/A
Minimum tillage	2,640	2.7
Moldboard-plow	3,020	11.0
Rotary tillage	2,600	4.1

Pump Irrigation

With irrigated cropping systems, especially where water is pumped from deep aquifers, tillage may account for only 3 to 10% of the energy used to produce the crop. Approximately 80% of the water to irrigate 25 million acres in the Great Plains is supplied from wells (Great Plains Agricultural Council, 1976). Table 8 illustrates the equivalent energy required to produce and harvest surface-irrigated and dryland grain sorghum on the Southern High Plains at Bushland, Texas. Energy requirements are about 16 times greater for irrigation than for dryland, but only 4 times more sorghum grain is produced. With dryland sorghum, about 250 lb. of grain are produced per gallon of diesel fuel used, but only about 65 lb/gal are produced with irrigation. In this case, irrigated sorghum production is only 25% as energy-efficient as dryland. About 20% of the energy used in irrigated production is for fertilizer and about 65% is for pumping water. If a sprinkler system is used to apply an equal quantity of water, total energy requirements are increased by 30 to 45% to pressurize the sprinkler system. However, with sprinkler irrigation less water may be applied. Irrigation pumping depths and related energy demands vary considerably within local areas as well as between regions.

Table 8. Energy equivalents for surface-irrigated and dryland grain sorghum systems with various tillage, Bushland, Texas[1/].

	Irrigated		Dryland	
Operation	Disk chisel	Bed mulch	Wheat-sorghum-fallow	Continuous sorghum
			Energy (gal/A)	
Till & seed	7.3	2.5	4.4	3.0
Fertilizer[2/]	21.0	21.0		
Herbicide	1.1	1.1	0.5	0.5
Irrigation[3/]	64.1	64.1		
Harvest	1.2	1.2	0.7	0.7
Transport[4/]	0.8	0.8	0.2	0.1
TOTAL	95.5	90.7	5.8	4.3
			lb/gal	
Grain production per gal of fuel	65.5	68.9	260.0	255.0

[1/] Assumed yields:
6,250 lb/A irrigated
1,500 lb/A dryland sorghum phase (Wheat-sorghum-fallow).

[2/] 150 lb/A N as NH_3 - 0.14 gal/A N equivalent for NH_3 (Miles, 1975).

[3/] 20 acre-inches, 250-ft. pump lift, 75% pump efficiency, 95% gear head efficiency.

[4/] 5,600-lb. load, 10-mi. round trip to market.

Energy Inputs to Cropping Systems

Previous discussion has shown that the energy perspective is limited unless tillage energy is considered with the complete cropping system. Some of these other necessary energy inputs are fuel, fertilizer, pesticides, harvesting, and drying.

Fuel

For every unit of petroleum-based fuel used in the United States, an additional 20% is required in exploration, refining, and delivery of the product. In agricultural production, the cost of lubricants amounts to about 15% of the fuel cost (Clark and Johnson, 1975). Among internal combustion engines, diesel power is the most efficient and most tractors and harvesters are diesel-powered. *A gallon of diesel fuel will do the work of 1.4 gal of* gasoline or 1.65 gal of LP gas.

Fertilizer

Fertilizers accounted for an estimated 33% of the total energy input for crop production in the United States in 1974 (USDA, 1976). About one-third of our crop yields result from the use of nitrogen fertilizer. In considering manure as fertilizer source, the collectible manure in the United States is estimated to be able to supply only about 18% of the cropland (CAST, 1977).

The total energy consumption of fertilizer in the U. S. agricultural system is about 585 X 10^{15} joules or about 0.7% of the total United States energy consumption (Davis and Blouin, 1977). Of this total, about 88% is for production, 1% is to transport raw materials, and 11% is for transportation, storage, handling, and application of the finished product. About 95% of the ammonia is produced from natural gas. About 37,900 ft^3 of natural gas are used to produce a ton of ammonia.

Pesticides

About 5% of the energy in agriculture is used for production of pesticides (USDA, 1976). Pesticide energy use averages only about 15% as much energy as is used to produce fertilizer in the United States. According to one estimate, about 40% of the U. S. food and fiber production would be lost without the use of pesticides (CAST, 1977). Table 9 shows some energy inputs to manufacture common pesticides.

Table 9. Energy inputs for pesticide manufacture (Jones, 1974 with some recalculations).

Pesticide	Energy input
	gal diesel/ lb A.I.
Insecticides	0.31
DDT, 2,4-D	0.31
MCPA	0.41
Diuron	0.84
Atrazine	0.60
Trifluralin	0.47
Paraquat	1.44

Green and McCulloch (1976) determined the energy required to produce and apply some common herbicides in England as a percentage of the energy required for mechanical cultivation. These were 28% for MCPA, 41% for trifluralin, 48% for atrazine, and 121% for diuron.

Harvesting and Drying

Examples of harvest energy requirements for sorghum were shown in Table 8. After harvest, drying of corn for safe storage with heated air can consume 15 to 20% of the total fuel energy input, much more than do threshing and hauling. About 1,250 BTU's of energy are required to remove a pound of water from grain (Lane et al, 1973). Heated-air drying is about 50% efficient, so in practice, 2,500 BTU's are required to evaporate a pound of water from grain. This amount of energy can be released by burning 0.03 gal of LPG or about 0.024 gal of No. 2 fuel oil in an indirect-fired burner. For example, to dry corn from 25 to 15.5% moisture, assuming a 7,300 lb/A yield, would require 27.7 gal of LP gas per acre. In the process, 110 gal of water would be removed by evaporation. An energy-conserving grain-drying method is to partially dry with heated air (discontinue heat-air drying at about 21% moisture) then finish with unheated air (Teter, 1973). This could reduce drying energy requirements by about one-half. Further energy savings could be made where corn could be field-dried to about 22% moisture, then harvested and further dried with unheated air.

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ECONOMICS OF CONSERVATION TILLAGE SYSTEMS

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Profitability and risk are important factors influencing the adoption of conservation tillage systems. Unfortunately, because of large differences in climates and soils in Texas, blanket statements regarding profitability and riskiness of conservation tillage systems cannot be made. This report presents estimates of the profitability of conservation tillage for two situations: (1) furrow irrigated winter wheat at Bushland; and (2) dryland grain sorghum in the Rio Grande Valley. Crop yields used in developing budgets for wheat at Bushland were obtained by Allen, Musick, and Wiese in a three year experiment while crop yields for sorghum in the Valley were obtained from experiments conducted by the Perry Foundation.

Three crop budgets were developed for each tillage system in each area. One budget was for the average crop yield obtained over the length of the tillage experiment. A second budget was developed for the yield obtained in the "best" year of the experiment, while a third budget was developed for yield obtained in the "worst" crop year of the experiment. The first crop budget--that for average yield--indicates profitability averaged overtime (i.e., weather) while the other budgets indicate the relative risk involved in the different tillage systems. Farmers who are neither gamblers or risk averters should select the tillage system with the greatest average return. However, farmers who desire

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"safety first" in the sense of maximizing returns in the worst year should select the tillage system that gives the highest net returns (or lowest net cost) in the worst year.

Irrigated Winter Wheat at Bushland

Tillage systems considered in the Bushland experiments were conventional tillage, limited tillage, and no tillage. Table 1 indicates the major tillage operations used for each system.

Experiments were conducted for both limited and adequate irrigation levels. An average of 4.3 irrigations of about 4 inches each were used for the experimental plots receiving adequate irrigation, while an average of 2.7 irrigations were used for the limited irrigation plots.

Table 2 shows the yields obtained for the three tillage systems under the two levels of irrigation. With adequate irrigation, no-till had the highest average yield (49.14 bu.) and conventional tillage resulted in the lowest average yield (44.83 bu.). However, in the worst year (1973/74) conventional tillage had the highest yield (33.70 bu.) and no-tillage had the lowest yield (31.17 bu.). In the best year, no-till had the highest yield (62.79 bu.) and conventional tillage the lowest yield (55.96 bu.). These experimental results suggest that in terms of yield, no-till is better on the average, but is more variable. That is, in the good weather years no-till is very good, but in the bad weather years, yield with the no-till system is very bad.

Now consider the profitability of the three tillage systems. Budgets for adequate irrigation for the various situations considered are given in Tables 3 through 5. Table 3 gives budgets based on yields averaged over the three years of the experiment. All inputs except tillage operations and herbicide use were held constant in the experiment. No-till has a $12.15 higher herbicide cost than the other two systems because of the need to use a contact herbicide (such as Paraquat) to control weeds. Preharvest labor and machinery cost items reflect the tillage operations shown in Table 1. Because of fewer field operations with the reduced tillage systems, fixed costs for machinery and tractors were also reduced. However, for a farmer who already has all machinery required for conventional tillage, fixed costs with reduced tillage will not be as low as Table 3 indicates.

Table 1. Tillage systems evaluated for furrow irrigated winter wheat at Bushlan Texas.

System	Operations
No-till	1. 2,4-D applied in early July 2. Contact herbicide in August 3. NH_3 furrow chiseled
Limited	1. 2,4-D in early June 2. Disk bed in August 3. NH_3 furrow chiseled 4. Sweep-rod weeder cultivation before seeding
Conventional	1. Tandem disk in early July 2. Chisel 3. Disk in August 4. Disk bed 5. NH_3 furrow chiseled 6. Sweep-rod weeder cultivation before seeding

Table 2. Furrow irrigated wheat yields (bu./ac.) at Bushland, Texas.

Tillage System		Adequate Irrigation	Limited Irrigation
3-year average (1971-72 through 1973-74)	No-till	49.14	43.20
	Limited	45.43	41.27
	Conventional	44.83	38.74
Worst year (1973-74)	No-till	31.17	25.68
	Limited	31.62	25.98
	Conventional	33.70	27.61
Best year (1972-73)	No-till	62.79	60.42
	Limited	57.00	57.30
	Conventional	55.96	54.04

Net returns for the three tillage systems are summarized in Table 6. Over the three year period, no-till had the highest net return ($41.73 versus $36.98 for limited tillage and $26.98 for conventional tillage). This ranking also held for the best crop year. However, in the worst year, no-till did not fare as well as the other systems. Net returns in this year were $7.32 lower with no-till as compared to limited-till, and $5.09 lower as compared to conventional tillage.

Results in Table 6 suggest that no-till of furrow irrigated winter wheat at Bushland would be a gamble. Limited tillage is much more attractive, and gives a higher average net return as well as a slightly higher return in the worst year relative to conventional tillage.

Table 3. Average year crop for furrow irrigated winter wheat at Bushland, Texas

Budget*	Tillage System		
	Conventional	Limited	No-till
Gross Receipts			
Wheat (@$3.00/bu.)	$134.69	$136.29	$147.42
Grazing	18.62	18.62	18.62
Variable Costs			
Herbicide	$ 3.50	$ 3.50	$ 15.65
Labor (Tractor & Mach.)	19.70	16.07	13.40
Machinery & Tractors	9.62	7.59	6.07
Harvest Costs			
Combine	$ 9.00	$ 9.00	$ 9.00
Custom Haul	4.48	4.54	4.91
Fixed Costs (Excl. Land)			
Machinery	$ 4.49	$ 3.41	$ 2.61
Tractors	6.35	4.83	3.68
Irrigation Machinery	11.88	11.88	11.88
Total Costs	$126.13	$117.93	$124.31
Net Returns	$ 26.98	$ 36.98	$ 41.73

*Budgets based on experimental data by Allen, Musick, and Wiese, and 1978 TAEX C Budgets.

Table 4. Worst year (1973-74) budgets for furrow irrigated winter wheat at Bushland, Texas.

Budget*	Tillage System Conventional	 Limited	 No-till
Gross Receipts			
Wheat (@$3.00/bu.)	$101.10	$ 94.86	$ 93.51
Grazing	18.62	18.62	18.62
Variable Costs			
Herbicide	$ 3.50	$ 3.50	$ 15.65
Labor (Tractor & Mach.)	19.70	16.07	13.40
Machinery & Tractors	9.62	7.59	6.07
Other Variable Costs	57.11	57.11	57.11
Harvest Costs			
Combine	$ 9.00	$ 9.00	$ 9.00
Custom Haul	3.37	3.16	3.12
Fixed Costs (Excl. Land)			
Machinery	$ 4.49	$ 3.41	$ 2.61
Tractors	6.35	4.83	3.68
Irrigation Machinery	11.88	11.88	11.88
Total Costs	$125.02	$116.55	$122.52
Net Returns	$ -5.30	$ -3.07	$-10.39

*Budgets based on experimental data by Allen, Musick, and Wiese, and 1978 TAEX Crop Budgets.

Table 5. Best year (1972-73) budgets for furrow irrigated winter wheat at Bushland, Texas.

Budget*	Tillage System		
	Conventional	Limited	No-till
Gross Receipts			
Wheat (@$3.00/bu.)	$167.88	$171.00	$188.37
Grazing	18.62	18.62	18.62
Variable Costs			
Herbicide	$ 3.50	$ 3.50	$ 15.65
Labor (Tractor & Mach.)	19.70	16.07	13.40
Machinery & Tractors	9.62	7.59	6.07
Other Variable Costs	57.11	57.11	57.11
Harvest Costs			
Combine	$ 9.00	$ 9.00	$ 9.00
Custom Haul	5.60	5.70	6.28
Fixed Costs (Excl. Land)			
Machinery	$ 4.49	$ 3.41	$ 2.61
Tractors	6.35	4.83	3.68
Irrigation Machinery	11.88	11.88	11.88
Total Costs	$127.25	$119.09	$125.68
Net Returns	$ 59.25	$ 70.53	$ 81.31

*Budgets based on experimental data by Allen, Musick, and Wiese, and 1978 TAEX Budgets.

Table 6. Summary of net returns for furrow irrigated winter wheat at Bushland, Texas.

Tillage System	Net Returns ($/ac.)		
	Average for 3 years	Worst Year	Best Year
Conventional	$26.98	$-5.30	$59.25
Limited	36.98	-3.07	70.53
No-till	41.73	-10.39	81.31

Thus, limited tillage warrants serious consideration by risk averse as well as profit maximizing wheat producers in the Bushland area.

Dryland Grain Sorghum in the Rio Grande Valley

Table 7 lists the cultural practices undertaken for each of the three different tillage systems considered for production of grain sorghum in the Rio Grande Valley. Yield data obtained from field trials by the Perry Foundation is shown in Table 8. Conventional tillage showed the highest average yield at 2995 pounds per acre and the highest yield during the worst year. However, in the best year no-till was the highest yielding system. In this study the limited till option always had the poorest yield.

Tables 9 through 11 give example budgets for the different tillage systems using the average yield, worst year yield and best year yield data, respectively. Once again tillage machinery and labor costs decline as fewer field operations are required. Fixed costs for tractors and machinery also decline. Custom harvest was budgeted on a per hundredweight basis so that harvest costs were made a function of yield.

The net returns to land and management are shown in Table 12. The no-till system had the highest net returns for both the three year average and for the best year. For the worst year conventional tillage had the highest returns.

In spite of no-till's higher average returns the wide variation in return from year to year would make the system less attractive to risk averse farmers than conventional tillage which was much more consistent.

Table 7. Tillage systems evaluated for dryland grain sorghum for the Rio Grand
Valley.

System	Operations
No-till	1. Shred stalks 2. Apply fertilizer 3. Plant 4. Apply herbicide 5. Run middle (if necessary)
Limited	1. Roller cut stalks 2. Point out stalks 3. Re-bed 4. Fertilizer 5. Row disk or harrows (if necessary) 6. Plant 7. Apply herbicide
Conventional	1. Cut stalks 2. Point out stalks 3. Re-bed 4. Disk 5. Harrow 6. Fertilizer 7. Run middle 8. Plant 9. Apply herbicide 10. 3 cultivations

Table 8. Dryland grain sorghum yields (lbs./ac.) for Rio Grande Valley, 1974-7

Tillage System		Dryland Yield
Average for 3 years	No-till	2741
	Limited	2361
	Conventional	2995
Worst Year (1975)	No-till	1782
	Limited	1050
	Conventional	2600
Best Year (1974)	No-till	3921
	Limited	3192
	Conventional	3641

Table 9. Crop budgets for dryland grain sorghum in Rio Grande Valley under three different tillage systems using yields in average years.[a]

Budget	Tillage System Conventional	 Limited	 No-till
Gross Receipts			
Grain (@$3.90/cwt)	$116.81	$ 92.08	$106.90
Variable Costs			
Fertilizer 200 lb. 32-11-0	$ 13.50	$ 13.50	$13.50[b]
Herbicide & Application	6.63	6.63	23.38
Labor	11.40	6.04	3.48
Tractor & Machinery	14.38	8.69	5.01
Other Variable Costs	7.83	7.83	7.83
	$ 53.74	$ 42.69	$53.20
Harvest Costs			
Custom Combine (@$.30/cwt)	$ 8.99	$ 7.08	$ 8.22
Custom Haul (@$.17/cwt)	5.09	4.01	4.66
	$ 14.08	$ 11.09	$ 12.88
Fixed Costs (Excl. Land)			
Machinery	$ 6.56	$ 3.96	$ 2.28
Tractor	8.30	5.01	2.89
	$ 14.86	$ 8.97	$ 5.17
Total Costs	$ 82.68	$ 62.75	$ 71.25
Net Returns	$ 34.13	$ 29.33	$ 35.65

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[a] Budgets based on data from Perry Foundation and 1978 TAEX Crop Budgets.
[b] One year an added 100 lbs. of 32-0-0 was applied.

Table 10. Crop budgets for dryland grain sorghum in Rio Grande Valley under th
different tillage systems using yields in worst year.

Budget	Tillage System		
	Conventional	Limited	No-till
Gross Receipts			
Grain (@3.90/cwt)	$101.40	$ 40.95	$ 69.50
Variable Costs			
Fertilizer	$ 13.50	$ 13.50	$ 13.50
Herbicide	6.63	6.63	23.38
Labor	11.40	6.04	3.48
Tractor & Machinery	14.38	8.69	5.01
Other	7.83	7.83	7.83
Harvest Costs			
Custom Combine	$ 7.80	$ 3.15	$ 5.35
Custom Haul	4.42	1.79	3.03
Fixed Costs (Excl. Land)			
Machinery	$ 6.65	$ 3.96	$ 2.29
Tractor	8.30	5.01	2.89
Total Costs	$ 80.82	$ 56.60	$ 66.75
Net Returns	$ 20.58	$-15.65	$ 2.75

Table 11. Crop budgets for dryland grain sorghum in Rio Grande Valley under three different tillage systems using yields in the best year.

Budget	Tillage System		
	Conventional	Limited	No-till
Gross Receipts			
Grain	$142.00	$124.49	$152.92
Variable Costs			
Fertilizer	$ 13.50	$ 13.50	$ 13.50
Herbicide	6.63	6.63	23.38
Labor	11.40	6.04	3.48
Tractor & Machinery	14.38	9.69	5.01
Other	7.83	7.83	7.83
Harvest Costs			
Custom Combine	$ 10.92	$ 9.58	$ 11.76
Custom Haul	6.19	5.43	6.67
Fixed Costs			
Machinery	$ 6.56	$ 3.96	$ 2.28
Tractor	8.30	5.01	2.89
Total Costs	$ 85.71	$ 66.67	$ 76.80
Net Returns	$ 56.29	$ 57.82	$ 76.12

Table 12. Summary of net returns for dryland grain sorghum production in Rio Grande Valley.

Tillage System	Net Returns ($/ac.)		
	Average for 3 years	Worst Year	Best Year
Conventional	$34.13	$20.58	$56.29
Limited	29.33	-15.65	57.82
No-till	35.65	2.75	76.12

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DISEASE CONTROL IN CONSERVATION TILLAGE SYSTEMS

C. Wendell Horne*

Disease control in conservation tillage systems is a subject that raises more questions than answers. The first thing necessary is to obtain a contemporary definition of conservation tillage. According to my colleagues in Extension agronomy an accepted definition is: A system emphasizing a reduction in the number of primary and secondary tillage trips in an effort to conserve soil, fuel, time, and labor. Other objectives of the system are to leave crop residue on the surface and avoid soil compaction.

It is pleasing to me to see that disease control is being considered not only in this conference but in much of the newer research on the subject. Base on a literature review the disease control aspect of conservation tillage seems to have been somewhat overlooked in much of the earlier work. The nature of disease development may have been a contributor to this omission since new crop and new systems experience a grace period. Our experience indicated that a "honeymoon period" of three to five years exists before disease organisms reach a dangerous level at which time control alternatives must be utilized.

One of the major limiting factors of crop production has always been plant diseases. With the advent of intensive cultivation of a single species, plant diseases developed at alarming rates. Biblical records certainly indicate that early man was treated harshly by these biological agents that limited his

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The author wishes to express appreciation to Dr. Walter J. Walla and Dr. Rober Berry, both Plant Pathologists with The Texas Agricultural Extension Service for their comments on the subject and assistance with the preparation of this paper.

food supply. Since he failed to understand the nature of the problem he sought *relief through worship of certain gods.*

Today with our sophisticated technological developments we understand the general nature of disease development and occurrence. In many instances we can substantially reduce disease development to a point where production does not suffer and losses can be economically tolerated. In other instances we over compliment ourselves in being able to successfully deal with the problems.

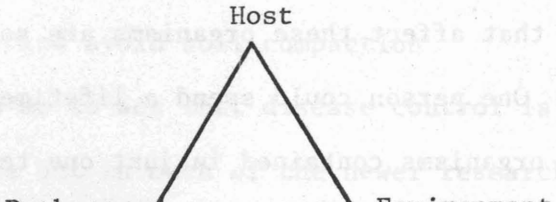
Soil borne diseases have traditionally been difficult to handle because we have a poor grasp of what occurs in soil so far as organism interrelationship is concerned. Variables that affect these organisms are so numerous that it boggles the imagination. One person could spend a lifetime studying the potential interrelationships of organisms contained in just one teaspoon of soil. Perhaps this is one of the reasons why we still consider ourselves at the mercy of the elements in nature.

When we till the soil we cultivate not only the favored crop species but also all of the organisms that develop in the rhizosphere. The health of crop plants depend on the presence of beneficial organisms and the absence of detrimental ones. Any practice used will have an influence on that balance.

Tillage is almost always associated with an attempt to deal with plant residues that reside on or near the soil surface. The type of tillage employed usually dictates whether decomposition of that residue proceeds at a rapid or slow pace. Rapid decomposition may serve my purposes for disease control while slow decomposition may be beneficial for the erosion control. Finding ourselves at cross-purposes is to be expected.

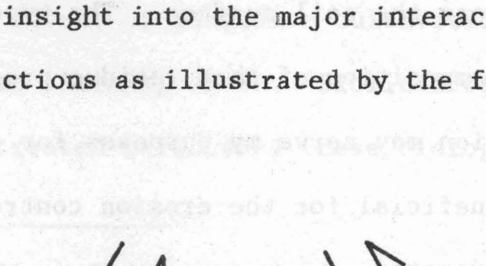
Living, dying, and dead plant material constitutes a major component of the soil environment and represents the primary source of organic matter available for decomposition. The process of generation and decomposition of organic matter is a dynamic one and the effects of these processes are continuous and transitory.

Crop residue and how it is handled may have a profound effect on disease development. In order to put this into proper perspective let us consider the requirements for disease development. Here we employ the diagram of the diseas triangle where a susceptible host, presence of a pathogen and a favorable envi ment must be present for disease development to occur.



In most crops it is necessary to manage crop residue so that it does not harbor and increase the population of pathogens or contribute an environment favorable for disease development. With some crops this requires that crop residue be completely buried or otherwise removed from the soil surface. In almost all cases it necessitates a look at what effect it is having on the soi microbial population.

Park gives us insight into the major interactions that occur in soil. He proposes six interactions as illustrated by the following diagram and the desc tions listed.



1. *Host → Soil Microbial Population - Growing plants have a profound* effect on soil microorganisms resulting from water and nutrient absorption and liberation of gaseous compounds and leachates into the soil. The greatest effect results when residues of the host are returned to the soil.
2. Host → Pathogen - Growing susceptible host plants generally results in an increase in population of a specific pathogen.
3. Soil Microbial Population → Host - Effects are many, ranging from absorption of nutrients by mycorrhizal fungi to conversion of nutrients into forms utilized by plants.
4. Pathogen → Host - The most usual effect of a pathogen on the susceptible host is that of pathogenesis.
5. Pathogen → Soil Microbial Population - The pathogen is usually less dominant in soil than many members of the saprophytic organism community and is most often influenced as opposed to influencing. There are exceptions, however, since some pathogens are excellent saprophytes.
6. Soil Microbial Population → Pathogen - Soil microbial populations are known to exert effects on the activities of soil borne pathogens mainly by increasing or decreasing their activity.

The use of cultural practices to reduce disease occurrence is almost always associated with reduction of inoculum potential. This takes many different turns depending on the crop grown, pathogens present, soil, and weather conditions. Since many if not most plant pathogens are carried over from season to season in the crop residue, disease control then becomes a matter of dealing with that aspect. In certain crops the need may be so drastic as to require deep burial with moldboard plows, burning or some other form of physical removal of crop residue.

Southern blight, a serious disease of peanuts caused by the fungus _Scleroti rolfsii_, is a case in point. If crop residue is left on the soil surface the fungus can be expected to develop in it and cause devastating losses. Without such residue it is incapable of initiating pathogenesis. Furthermore, overwinte ing sclerotia are killed if buried five or more inches deep. For this reason we advocate complete trash burial with a moldboard plow where peanuts are to be grown.

It has been shown through research that moldboarding is effective in reducing inoculum potential fungi which cause downy mildew and head smut of grain sorghum to the point where disease development is lowered by fifty percent. This practice is not advocated because both diseases can be handled by using resistant varieties.

The use of a moldboard plow or other type of deep tillage equipment has been shown to reduce the incidence of Phymatotrichum root rot. This procedure has more to do with being disruptive to live cycle of the fungus than burying it as is the case with other organisms.

Burning or thermosanitation is not presently advocated even though it accomplishes several objectives of disease control. Social and political pressu have been brought to bear that have reduced its suitability as an alternative. I might point out, however, that many accidental burnings do occur. Ironically, this is a practice that has a great deal of potential in conservation or minimu tillage.

Crop rotation is a practice that we have relied upon for years to reduce inoculum potential. It has served our purposes well and we advocate it continuously. With the exception of using resistant varieties crop rotation is probab the least expensive form of disease control.

Monocropping is more prevalent than most of us would like to admit and it does have some advantages if certain factors can be accommodated. Perhaps the major accommodation needed is that of limiting the inoculum potential of pathogenic organisms. One farmer in particular, that we have been working with in the Colorado River bottom, has been continuously growing corn on the same land for twelve years. His yields average about 100 bushels per acre and production has increased continuously over twelve years. He is an unusually astute producer who pays close attention to every detail. He has been able to limit disease development by utilizing resistant hybrids and has managed crop residue well.

Since conservation tillage is perceived by some to be minimum tillage the subject of disease potential has to be addressed. For the most part, new research projects have not run for a sufficient period of time to properly evaluate disease development. In a few cases, namely in Indiana and Virginia, certain corn diseases have increased under minimum tillage programs. It is reasonable to assume that those diseases harbored in crop residue will increase with the employment of minimum tillage.

Leaving crop residue on the soil surface is usually an objective of conservation tillage systems. While the practice may be rather neutral for many organisms it may strongly encourage those pathogens of a high competitive saprophytic nature. Diseases caused by these pathogens usually fall in the categories of damping-off or blights. Some of these organisms are highly aggressive and successfully compete with other members of the soil flora.

In order to be acceptable, conservation tillage must embody the practices that limit the buildup of disease causing organisms. Unfortunately, we do not have at our command all of the information that we need to make good decisions in this area. So far as knowledge of interactions of organisms in the soil is concerned we are in our infancy.

We, as plant pathologists, have for years used every possible alternative for disease control available to us. We have had to consider insect transmiss of disease organisms, weeds as alternate hosts of pathogens and the effects of cropping sequences on disease development. It has been necessary to keep our options open and I hope that this will be done in conservation tillage. It is unlikely, in my opinion, that a system will be developed that works in all situations. Disease occurrence alone is a sufficient reason for not stereotyp the system.

Even with several years of experience in dealing with soil borne problems I consider myself a beginning student. Furthermore, I choose to learn from tw teachers both of whom have much to teach. First, I have great respect for all of the scientists who do research in soil related matters. I can and do learn much from them. Secondly, I learn from farmers who successfully coax a living from the soil. If they are successful in this venture, I automatically assume that they must be doing something right. They independently discover what is *right for their farm and if they are thoughtful about the future they may have* lot to tell us about what is good conservation tillage.

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ANTICIPATED IMPACT OF CONSERVATION TILLAGE ON INSECT PEST PROBLEMS

John G. Thomas*

With any alteration of the environment we can anticipate a change in our pest problems in field crops. Some of these changes can be expected to elevate minor pests, or even nonpest species, to "major pest" status. On the other hand, certain economic pests of crops produced by conventional tillage systems will become less serious or perhaps economically unimportant.

Conservation (reduced) tillage is likely to most greatly influence the abundance of soil inhabiting insect species, species which depend on crop residue for overwintering (or oversummering), pests which depend on crop residue for food or habitat, and species which have alternate weed hosts which become more abundant as a result of conservation tillage practices.

Those factors directly related to conservation tillage having the greatest impact on pest species' survival, numbers and damage status will be factors directly affecting the pest's habitat. These primarily include availability of moisture, temperature and any alteration in the abundance of alternate host plant species (particularly weeds). The above reference to moisture and temperature relates directly to micro-habitat rather than macro-habitat. Many of the basic advantages of conservation tillage relate to altering soil moisture and temperature patterns. Altering moisture, temperature and alternate hosts has a direct bearing on pest survival, oviposition site/behavior, habitat adequacy, alternate host plant availability and species (plant and animal) mix

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as affected by the micro-environment. The latter characteristic relates to an alteration of environmental factors which favor either the host, pest or its natural enemies (beneficial species such as parasites, predators and pathogens)

The above general statements should not be interpreted to mean that pest problems will be increased in all situations. With numerous pest species, reduced tillage will result in conditions that favor natural mortality, beneficial species which attack the pest and/or reduce alternate hosts on which the pest depends. It is essential to understand each pest species and its biology, behavior and habitat requirements before projecting the impact conservation tillage may have on the abundance of a pest or its damage. It is equally important to recognize the impact that a change to conservation tillage may have on the abundance or condition of host plants. Any reduction of stress is likely to reduce the amount of damage, or yield loss, resulting from a particular pest. Therefore, increasing available moisture or influencing soil temperatures to provide a more favorable crop environment would be expected to reduce the damage caused by certain pests where these factors did not directly influence the insect species itself.

Considering five of Texas' major field crops, it is possible to predict some of the most obvious changes in pest abundance and damage as the result of adopting conservation tillage as opposed to conventional tillage. A discussion of the major insect/mite pest species of wheat, corn, sorghum, cotton and soybeans follows with reference to the anticipated change in pest status of the major pest species.

Wheat

The greenbug is the major insect pest of wheat. Adopting conservation tillage in this crop would not alter existing greenbug problems unless the availability of alternate host plants on which the greenbug depends for oversummering was significantly influenced. The principal weed host species are johnsongrass, western wheat grass or other grass-type crops. Changes in alternate host species availability would be expected to increase or reduce fall greenbug abundance. It should be kept in mind that sorghum also serves as an oversummering host; however, in most production areas johnsongrass or other grasses serve as an intermediate host in the migration of greenbug from sorghum to wheat; if the crops do not overlap. Conservation tillage would influence greenbug damage indirectly by influencing moisture stress. Increasing stress would contribute to increased damage and reducing stress would likely reduce damage. Other factors influencing the abundance of greenbugs in wheat would likely override these less significant factors.

The major soil pests of wheat would likely show the greatest response to conservation tillage. Any increase in moisture levels and reduction in temperature at germination could be expected to increase seedcorn maggot and seedcorn beetle population densities; and thus damage. An increase in soil moisture would also tend to increase wireworm adult egg laying; this is particularly true with an increase in surface soil moisture. Any environmental or seed quality factor contributing to more rapid germination would tend to reduce wireworm damage. Any increase in alternate hosts during the summer fallowing season or during the fall or early spring would contribute to an increase in adult egg laying activity.

White grubs are a sporadic problem in wheat. They also respond to soil temperature in moving up and down in the soil profile. In cooler soils they tend to be deeper and therefore would do less root feeding than in warmer soils. One of the major factors contributing to reduced white grub damage would be increased plant residue in the soil which provides an alternate food source for many species of white grubs. This tends to reduce the extent of root feeding and, therefore, damage. On the other hand, tillage exposes the larvae to weathe as well as predators (arthropods and birds) which would both tend to reduce white grub numbers. A reduction in tillage would favor the abundance of white grub species.

It would not be anticipated that armyworms would be greatly affected by conservation tillage. This assumes that the conservation tillage practices did not greatly alter other plant species in the area. Winter grain mite problems could be intensified if rotation were not followed. Winter grain mites oversummer in small grain fields and tillage is a major means of reducing the numbers. Rotation is by far the most effective means of cultural control.

Corn

The southwestern corn and sugarcane borers are major pest species of this crop. Stalk destruction, a crop management practice designed to kill overwintering larvae, is the key to effective borer control. Any tillage practices which results in reduced destruction of corn stalks and stubble during the winter and early spring (prior to planting the subsequent crop and while temperatures are still low) will significantly increase the corn borer problem. It is essential that conservation tillage practices in those areas of Texas where the corn borer is a problem, very cautiously take into account the resulting corn borer populations should stubble be left in the field.

A secondary pest of corn in many areas are spider mites. The impact of conservation tillage on these species will be directly related to a reduction i moisture stress of plants and the alteration of alternate hosts. Less moisture stress on corn will result in reduced damage by spider mites. Where conservatic tillage speeds crop maturity, spider mite damage should be reduced.

Corn earworm abundance and damage are not likely to be affected by conservation tillage. The earworm is very mobile and has an extensive host range.

Therefore, practices which only influence one of its hosts is not likely to significantly influence the overall density of corn earworm in an area. The greater impact is likely to be observed in the increased survival of overwintering pupae of this species. Reduced tillage would likely result in less exposure of the pupae to cold temperatures in the winter and predators which feed on the overwintering pupae.

Corn leaf aphid damage is not likely to be altered by conservation tillage as long as the abundance of alternate host plants is not significantly altered. We must keep in mind the role of corn leaf aphid in transmitting several viral diseases. If conservation tillage practices result in increased density of johnsongrass and other sources of virus inoculum, an increase in the indirect damage caused by corn leaf aphid as a virus transmitting vector can be expected.

Corn rootworms will not be significantly affected by conservation tillage. This statement is made assuming that rotation will continue to be followed in those areas where the western corn rootworm is an economic problem. Rootworm control depends extensively on rotating (western corn rootworm) or the use of chemicals (western, southern and northern species). Conservation tillage practices which preclude soil incorporation of insecticides for rootworm control will result in greater damage resulting from rootworms.

Sorghum

The major impact of conservation tillage on sorghum midge damage would be related to factors which contribute to early, uniform blooming. Reduced midge damage would result. Additionally, conservation tillage practices which increase winter survival of the midge larvae in sorghum spikelets must also be considered. This will vary dramatically according to the area of the State involved. Most midge overwintering occurs in late blooming alternate hosts or in sucker heads of sorghum or late planted sorghum. The midge overwinters as a last instar larvae in the spikelets of host plants. Tillage practices which contribute to a breakdown of these heads following harvest or during the winter will contribute to greater diapause larval death.

It is not anticipated that conservation tillage would significantly alter greenbug numbers or damage. Spider mite problems on sorghum would be influenced in the same manner and to the same extent as discussed previously under corn. Armyworm, fall and true, problems would not likely be altered by an adoption of conservation tillage practices in sorghum. The major soil pests of sorghum (wireworm, white grub, seed corn beetle and seed corn maggot) would be affected in the same manner as discussed above for corn.

Sod webworms and billbugs are not currently considered pests in Texas sorghum production. However, extensive adoption of conservation tillage practices may result in their becoming problems in certain areas of Texas.

Lesser cornstalk borer is known to be a sporadic economic pest of sorghum during droughty periods. Conservation tillage may well further reduce the importance of this species as a pest. The two factors influenced which contribute to its economic importance would be an increase in crop residue and soil moisture. This species does feed on plant residue; therefore, reducing its requirements on living host tissue. The reduced plant stress and increased soi moisture would also contribute to a reduction in recognizable damage by this species.

Cotton

Since the boll weevil is considered the major key pest of cotton on approximately 2 million acres of the State's production, the influence of conservation tillage on this species could be important. Fortunately, boll weevil numbers would not likely be influenced by conservation tillage practices. Although the weevil depends on plant residue for overwintering survival, it doe not typically overwinter in cotton fields and, therefore, would not be influenced by tillage practices. There is speculation, however, that boll weevil parasite survival might be increased by conservation tillage practices. This is highly speculative at this point and supporting documentation does not exist.

The impact of conservation tillage on cotton bollworm and tobacco budworm abundance would be minimal. The major influence would be recognized in the survival of overwintering pupae in the soil. Again, the tremendous number of Heliothis hosts and their mobility would likely tend to protect a species from any significant adverse impact of conservation tillage. Also, their wide distribution in an area would tend to minimize the greater survival in any given cotton field. This is assuming that the area is not in monoculture. In areas such as the Southern High Plains, where cotton is by far the predominant crop, the additional winter survival could significantly increase spring densities.

There is a significant potential for aggravating cotton fleahopper populations if alternate hosts (such as croton, goatweed, silverleaf nightshade, etc.) are increased in numbers in or surrounding cotton fields. Maintaining weed abundance at existing conventional tillage levels or below would dictate the impact on the cotton fleahopper.

Stalk destruction would be an important factor in preventing a significant increase in pink bollworm damage. The pink bollworm overwinters as larvae in cotton seed, often in the field. Shredding stalks at the time of completing harvest is a major means of control. This practice would have to be continued under conservation tillage to avoid a significant increase in pink bollworm survival and subsequent damage. In the southern areas of Texas, burying the residue to allow for crop residue deterioration must also be carefully weighed in adopting conservation tillage practices. Cold winter temperatures in the northern part of the State, coupled with good stalk shredding, will result in significant reduction in survival of diapausing larvae. This is not the case i the more tropical areas of the State.

Soybeans

The velvetbean caterpillar, green cloverworm, stink bugs and bollworm are the major insect pest species of soybeans in Texas. The abundance and damage o these species would not be greatly altered by the adoption of conservation tillage practices.

Since the velvetbean caterpillar does not overwinter in the State, the tillage practices followed during the post-harvest period would not alter pest densities or damage in the subsequent year. There could be a slight influence on green cloverworm in that they overwinter as pupae; although this would not b anticipated. Stink bug populations might be influenced by weed hosts. However a substitution of chemical for tillage weed control would dictate any change in pest status which was recognized. Also, stink bugs are extremely mobile and rely on many hosts for survival. Therefore, limited alteration of pest status could be anticipated.

Summary

In summary, we can state that any change in tillage practices which influe the habitat, host or enemies of a particular pest can be expected to alter its pest status. We would anticipate the greatest change in pest problems to occur in the soil inhabiting species or those species which depend on or inhabit crop residue.

The major changes which will occur will be directly due to altering soil moisture, micro environmental temperatures, crop and alternate hosts and the parasite/predator abundance.

WEED CONTROL IN CONSERVATION TILLAGE SYSTEMS

Dave Weaver*

Herbicides make conservation tillage possible in some areas in Texas. In fact, since herbicides came into common usage in the mid-sixties, the number of tillage operations performed on most farms has decreased. It is not always possible, however, to substitute a herbicide application for tillage or cultivation.

The same methods of weed control that are used in conventional tillage systems are also used in conservation tillage. These are 1) cultivation during the cropping season, 2) tillage between crop sequences, 3) herbicides, and 4) crop rotation. The difference in the two systems is the frequency of use of each method and the choice of tillage implements.

As mentioned earlier, there are some areas in the State where limited tillage has definite advantages and the availability of herbicides makes possible the utilization of these systems. Dr. Paul Unger, USDA Soil Scientist, Ron Allen and Jack Musick, USDA Agricultural Engineers, and Dr. Allen Wiese, Texas Agricultural Experiment Station Weed Scientist have conducted research on conservation tillage systems in the Panhandle area since the early 1960's. Their efforts have resulted in workable systems involving the high residue crops grown in that area.

No-tillage has not proven successful because of three problems: 1) volunteer sorghum must be controlled and because it often emerges in several flushes, tillage is more economical than repeated herbicide applications; 2) furrow irrigation demands firm beds and these must be rebuilt at least every

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other year; 3) soil conditions may restrict movement of irrigation water into the soil; therefore, deep tillage may be necessary.

In a continuous sorghum cropping sequence, an economical limited tillage system includes deep chiseling of anhydrous ammonia into furrows in late fall, control of weeds and rebuilding of beds with a rodweeder equipped with sweeps, and control of weeds just prior to planting with a rolling cultivator. The rodweeder with sweeps should be run in the spring prior to irrigation. When the sorghum is planted, Milogard, Igran, or Milogard mixed with Ramrod, Bexton, or Lorox can be used for preemergence weed and grass control. If desired, a postemergence application of atrazine in an oil-water emulsion may be substituted for the preemergence herbicide.

A short residual herbicide such as Igran must be used in a sorghum-wheat or sorghum-rye rotation in order to avoid injury to wheat following the sorghum crop. If broadleaved weeds such as pigweeds are the only problem, 2,4-D can be used postemergence.

A corn-wheat rotation demands that a short residual herbicide such as Lasso, Dual, or Bladex be used in the corn crop. Bladex should be used only on fine sandy loam or finer soils. Weeds that escape the preemergence herbicide can be controlled with directed applications of Lorox or Evik or by sweep tillage.

Weeds can be controlled with minimum tillage in a wheat-fallow-sorghum rotation. After wheat harvest, atrazine applied at 3 lb. (a.i.) per acre will prevent weeds during the fallow period. If broadleaved weeds are present at the time of wheat harvest, it will be necessary to add 2,4-D to the atrazine. If annual grasses exist prior to the application of atrazine, it will be necessary to sweep plow before applying the herbicide. Some years, the atrazine will carry over (persist) and give weed control in the sorghum crop. It may be necessary to apply Igran or Milogard at the time sorghum is planted.

Herbicides cannot be used for weed control during the fallow period in a sorghum-fallow-wheat rotation because residues carry over to damage the wheat. Wiese's research shows that the most practical system is to use a disk bedder after sorghum harvest, inject anhydrous ammonia deep between beds, and control weeds with a heavy-duty rodweeder until wheat is sown. Winter weeds in wheat can be controlled with 2,4-D.

These same rotations and limited tillage systems could possibly be used in some areas in Southwest Texas where irrigation water is available. Other areas of the State have large acreages of cotton. Cotton not only produces little residue, but weed control in this crop is achieved primarily with dinitroaniline herbicides which require mechanical incorporation. Even though sorghum-cotton rotations are quite common and the sorghum residue could be beneficial in the following cotton crop, it is almost impossible to incorporate a cotton herbicide with residue on the surface. Table 1 shows that cotton acreage treated with preplant incorporated herbicides has increased in recent years. These herbicides are necessary for grass control, particularly seedling johnsongrass; therefore, their use will probably continue to increase.

Table 1. Types of herbicides used in cotton in Texas since 1974.*

	Percent of Acreage Treated			
Herbicide	1974	1975	1976	1977
Preplant	56.0	58.0	63.2	66.9
Preemergence	17.0	16.4	15.4	15.3
Postemergence	15.4	13.9	15.6	13.5

*Data was taken from County Extension Agents Annual Reports.

Table 2 indicates the acreage incorporated with various implements. The disk is the most popular means of incorporating dinitroaniline herbicides in cotton. Although not included, field cultivators are used on a portion of the acreage.

Table 2. Methods used to incorporate preplant herbicides in Texas since 1974.*

	Percent of Acreage Treated			
	1974	1975	1976	1977
Disk	78.3	77.9	50.6	77.0
Rolling Cultivator	11.5	11.0	15.5	13.3
Power Tiller	1.3	1.0	4.4	0.6
After Planting Devices	8.9	10.0	29.5	9.0

*Data was obtained from County Extension Agents Annual Reports.

Preemergence herbicides can be used in minimum tillage systems. In fields not infested with johnsongrass, Texas panicum (Coloradograss) or other large seeded grasses, the preemergence herbicides can be and are used successfully.

Dr. John Morrison, USDA Agricultural Engineer at Temple, is beginning a research project to investigate the possibilities of incorporating cotton herbicides while leaving crop residues on the surface. An under-sweep application technique will be investigated in clay soils in 1979.

Destruction of stubble regrowth and volunteer sorghum after harvest is necessary whether conventional or conservation tillage is used. Paraquat or Roundup can be substituted for tillage but repeated applications may be require in the southern half of the State. Herbicides may have no economic advantage some years.

Paraquat has been classified by EPA as a restricted use pesticide. It is to be sold to and used only by certified applicators or persons under their direct supervision.

Limited tillage is not suggested in fields infested with perennial weeds such as bermudagrass, johnsongrass, or nutsedge. With the recent EPA registration of Roundup used in recirculating sprayers in cotton and soybeans, the control of rhizome johnsongrass may be possible in limited tillage situations in these crops. Wipe-on or rope-wick applicators are also being developed.

These new approaches for weed control above the crop canopy may hold some promise for use in conservation tillage systems.

Additional research is needed in many areas of the State to develop weed control methods for use in conservation tillage systems.

FERTILIZATION PRACTICES FOR CONSERVATION TILLAGE SYSTEMS

A. Edwin Colburn and John E. Matocha*

Conservation tillage crop production, as defined by Harris earlier today, has raised some questions concerning fertilization, as producers have converted from conventional tillage systems. In conventional tillage systems, many farmers have followed fertilizer programs that have combined plow-down and/or row placement of the major nutrients, nitrogen, phosphorus, and potassium. All these materials have been incorporated into the soil. In some conservation tillage systems, such as no-till systems, the opportunity for incorporation of fertilizer materials is limited; hence, questions have been raised as to the efficiency of use of surface applied nitrogen fertilizer materials, and the relatively immobile materials such as phosphorus, potassium, and lime. In some systems, adjustments must be made in fertilizer programs in order to convert from conventional tillage to conservation tillage systems.

However, in conventional tillage systems or in conservation tillage systems, fertilization is required for efficient crop production.

Substantial increases in efficiency of fertilizer use, especially nitrogen, could be achieved by application of proven technology. Soil tests are not used to the degree necessary to select optimum application rates. In most areas nutrients are not applied at the optimum time. Fertilizers may not be placed at the point where maximum benefit is achieved. However, optimum timing of application may require additional trips over the field and may reduce timeliness of other operations. Good fertilizer placement may require more energy and more equipment.

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Crop residue remaining on the soil surface usually decomposes at a slower rate than when incorporated into the soil. Also, infiltration of rainfall may be higher, resulting in less runoff. These factors may cause minor differences in fertilizer requirements for some conservation tillage systems compared to conventional tillage. Some reduced tillage systems may require somewhat higher fertilization rates. If an increased level of stored soil moisture in the soil profile occurs, the result may be higher yields. Higher crop yields require an increased supply of plant nutrients, thus more fertilizer would be required to reap the benefits of a conservation tillage system. Nutrient immobilization may be considerable in conservation tillage systems because of slow decomposition rates for crop residues left on or near the soil surface.

Fertility requirements of stubble mulch systems are quite similar to those of conventional tillage systems; however, reduced nitrogen availability has been associated with stubble mulch. Nitrate content of soil under stubble mulching, because of nitrogen "tie up" in the residue, is generally somewhat less than with conventional tillage. The decreased amount of nitrate associated with stubble mulching depends on quantity of residue, amount of residue incorporation, and weather conditions. This can be alleviated by applying nitrogen fertilizer. There appears to be little difference in phosphorus relationships between conventional tillage and stubble mulching systems.

Irregardless of the type of tillage system being considered, a sound fertilizer program should be based on a soil test. This inventory of the nutrient status of the soil provides a basis for fertilizer recommendations. Soil samples should represent approximately the upper six to eight inches of soil to determine fertilizer requirements.

A good soil fertility program should result in production of desirable levels of crop residues. These crop residues, if managed wisely, should contribute to improved soil physical properties, such as structure and tilth. Thus, over a period of years, improved soil physical properties may result in a reduction in tillage operations required for seedbed development.

Conservation tillage systems may result in decreased soil erosion. Soil nutrient levels are usually highest in the surface soil, which is most susceptible to erosion. Reduced soil erosion should help in maintaining soil fertility levels.

Nitrogen

Some researchers have advised an increase of ten to thirty-five percent in nitrogen fertilization rates for some conservation tillage systems to meet the demands of the growing crop of increased microbiological activity related to decay of crop residues.

Some conservation tillage systems may utilize broadcast surface applications of nitrogen, some may result in incorporation of fertilizers during tillage, and others may utilize chiseling of fertilizer materials into the soil. A number of nitrogen materials including ammonium nitrate, ammonium sulfate, urea, urea-ammonium nitrate solutions, or anhydrous ammonia may be used. Both the method of application and the form of nitrogen may affect the efficiency of applied fertilizer nitrogen.

Certain considerations must be made when considering nitrogen applications for some conservation tillage systems in which nitrogen is broadcast on the surface. Care should be taken to use sources of nitrogen that are not highly susceptible to volatilization losses. Nitrogen, in the nitrate form, moves readily through the soil with movement of soil water. In those conservation tillage systems which result in greater infiltration rates of water, nitrogen may leach slightly deeper in the soil profile than in a conventionally tilled crop.

As indicated, some reports suggest increased nitrogen rates because of increased yields and increased nitrogen immobilization due to microbial activity. These precautions are related to soil type and tillage system and probably are more important in no-tillage operations.

If soil and temperature will allow, some farmers may want to apply some nitrogen prior to planting. However, this practice may not be advisable on extremely sandy soils that have potential for considerable leaching of nitrogen, or if soil temperatures are high enough that excessive nitrification of materials may occur. However, if conditions favor such a practice, it may conserve time and relieve some labor pressures at planting.

Nitrogen fertilizers may be applied in several different forms including liquid materials, dry materials, or gaseous materials. A farmer's choice of materials will depend on several factors, including availability of materials, application equipment, and cost of materials.

Dry sources of nitrogen including ammonium nitrate, ammonium sulfate, and urea, should perform comparably in conservation tillage systems to their level of effectiveness in conventional tillage systems. If the tillage system offers an opportunity for incorporating the dry fertilizer into the soil, efficiency of the applied nitrogen should be increased. Considerable amounts of nitrogen may be volatilized from nitrogen fertilizers if left on the soil surface, particularly with calcareous soils and during warm seasons of the year.

Liquid nitrogen sources contain about half of the nitrogen in the urea form. These materials are dribbled or sprayed onto the soil surface, or may be chiseled into the soil. Application may occur preplant or as a side dressing. Volatilization losses in surface applied nitrogen may be increased if applied to crop residues on the surface. Nitrogen on crop residues is not utilized by the crop until it is incorporated.

Liquid nitrogen is sometimes used as a carrier for some herbicides. Maximum response to applied nitrogen fertilizer is usually obtained when the material is incorporated into the root zone of the plant. This method of application may not be the most effective method for applying herbicides. Often, best results from some herbicides are obtained from spraying directly on the soil surface. Herbicide-nitrogen solution mixtures should be used only when there is a potential to obtain acceptable responses from both the fertilizer and herbicide.

Anhydrous ammonia may be used successfully in conservation tillage systems. It usually is the cheapest form of nitrogen available. It may be used in a preplant operation, applied at planting, or side-dressed after the crop is growing. This material may be applied using a chisel, knife applicator or with a sweep applicator, dependent on soil conditions and amount of residue present.

The relatively new "cold flow" system for anhydrous ammonia may offer some advantages in conservation tillage programs. With this system, the anhydrous ammonia is applied as a liquid. It may be applied in a tillage operation such as disking. It does not require as deep placement as conventional ammonia application, thus less energy is required for application.

Phosphorus

Phosphorus is considered to be an immobile plant nutrient. Movement from its point of application in a soil is very slow. Many soils, because of the tendency of phosphorus to attach itself to clay particles, have a high phosphorus-fixing capacity. This adsorbed phosphorus is slowly available for crop usage. Consequently, some phosphorus should be applied near the seed so that plant roots may have access to the phosphorus during the early growth of the plants. If a soil test indicates that large amounts of phosphorus are needed, it generally is recommended that the phosphorus fertilizer be incorporated into a soil before initiation of a conservation tillage program.

Some conservation tillage systems, such as no-till plantings, may include surface applications either in a band or broadcast. Some research from the midwest and the mid-Atlantic states have indicated that these surface applications were equal in plant use efficiency to band applications of phosphorus near the seed or broadcast applications that have been plowed down. However, these data were obtained under much more favorable rainfall regimes than occur over most of the cropping areas in Texas. In the more arid Southwest, particularly on calcareous soils, it would seem that surface applications of phosphorus would not be as efficient as phosphorus incorporated in the soil.

Most surface-applied phosphorus, if not incorporated by tillage, may be found in the upper one to two inches of soil long after application. Plant roots must be active in this zone to utilize this phosphorus. However, during much of the cropping period, many Texas soils are too dry near the surface to support active rooting growth there. Additionally, any cultivation operation for post-emergence weed control would damage or prune those roots feeding on the surface-applied fertilizer.

Conservation tillage systems which may utilize double cropping, such as seeding wheat into grain sorghum or soybeans into newly harvested wheat stubble, may require adjustments of phosphorus fertilizer applications. In double cropping systems, it is often advantageous to apply sufficient phosphorus fertilizer to the first crop in the sequence to meet the needs of the first crop and the following crop. For example, some farmers apply phosphorus fertilizer for both the wheat crop and the double-cropped soybean crop prior to planting the wheat crop. Many farmers have found this to be an effective practice.

Few Texas farmers own equipment that applies dry fertilizer in a band. The convenience of bulk fertilizers and more rapid application have caused many farmers to apply phosphorus prior to planting.

The use of liquid fertilizer in Texas has increased rapidly in recent years. Many farmers feel that it offers an effective way to apply fertilizer materials, especially phosphorus, in a band application. Also, low rates can be applied in the row as a starter fertilizer. Because phosphorus is immobile in mineral soils and also tends to give a good starter effect, it is best placed near the seed for most efficient plant usage.

If the soil test indicates that the phosphorus level is low to medium, it is preferable to place the phosphorus fertilizer below the seed with a coulter or chisel. If the soil test indicates that the phosphorus application rate should be less than thirty pounds of phosphorus per acre, then the straight phosphorus fertilizer may be placed directly with the seeds.

Potassium

Many Texas soils are very high in potassium. Most of these soils have not been shown to respond to potassium fertilization; hence, much of the crop acreage in Texas is not fertilized with potassium. However, some soils do have a need for potassium fertilization. Irregardless of the type of tillage system, that potassium need must be met.

Potassium is intermediate in mobility to nitrogen and phosphorus. It moves downward through the soil at a faster rate than phosphorus, but slower than nitrogen fertilizers. Because of this characteristic, potassium fertilizer may be broadcast on the surface, banded, or plowed down. Some research has shown that incorporation of potassium into the soil is more effective than surface application.

If double cropping is to be practiced, soil levels of potassium should be closely monitored. Double cropping may accelerate the rate of nutrient removal and deplete soil potassium to the extent that increased potassium fertilization may be required to produce acceptable yields.

If more than sixty pounds of potassium per acre are needed, fertilizers containing potassium should be uniformly broadcast before or immediately after planting. Band applications beside or under the row should not exceed sixty pounds of potash per acre. If mixed fertilizers containing both nitrogen and potassium are applied in bands at planting beside the row, the total of nitrogen plus potash should not exceed eighty pounds per acre and should be at least three inches from the seed. High rates of nitrogen and potash should not be placed in bands directly under the row since salt injury may occur if the salt moves upward.

Lime

The need for lime should be based on a soil test. If a soil test indicates that lime is needed, it is generally recommended that the lime be worked into the soil. This reasoning is based on experience that surface-applied lime moves slowly into the soil profile. Thus, if liming is being undertaken to reduce soil acidity and improve crop growth, the lime should be incorporated into the soil. Most Texas soils that are cropped do not require liming. However, some east and southeast Texas soils require periodic lime applications to adjust soil pH levels.

In conservation tillage systems where no-till planting is to be practiced, or in those soils where soil pH is low, continued surface application of nitrogen materials may result in development of extreme acid conditions in the surface three inches of the soil. This problem should be corrected, since this is where seeds germinate and initiate growth. Any abnormal pH level may result in accumulation of elements toxic to plant growth and poor plant performance.

The surface soil is where herbicides react and are in greatest concentration. Low soil pH can reduce the effectiveness of residual type herbicides.

Low soil surface pH can potentially reduce crop yields by contributing to the reduction of plant population, poor weed control, and less efficient nutrient uptake.

Summary

Most conservation tillage systems are relatively new, thus many aspects of these systems are not fully understood. Researchers have indicated the need for additional research on effective fertilizer programs for conservation tillage systems. Especially needed are research on fertilizer rates and application techniques for most efficient usage.

Some conservation tillage systems, which feature large amounts of crop residue remaining on the soil surface during the year, may require a twenty to thirty percent increase in nitrogen fertilizer levels. Nitrogen fertilizers may be applied and incorporated during tillage operations, chiseled in preplant or post-emergence as a side-dressing. Phosphorus and potassium fertilizers may perform most efficiently if banded or incorporated by tillage, rather than applied to the surface. In dry areas or in dry seasons, response to phosphorus and potassium fertilization may be limited if the nutrients are surface applied and concentrated at shallow depths. Lime, if needed, may also be plowed down.

Fertilizer application, in many instances, may be combined with some tillage operation for increased efficiency.

EQUIPMENT FOR CONSERVATION TILLAGE SYSTEMS

J. E. Morrison, L. H. Wilkes, and E. B. Hudspeth*

Conservation tillage can be many things to many people. In general, it is tillage in which soil, water, and energy are conserved while enhancing agricultural production. The particular conservation tillage system used for a given crop or set of conditions may be quite different from that for another crop or set of conditions. At the current state of the art, conservation tillage procedures, unfortunately, have not been developed for everybody, everywhere, and for all conditions.

Machine systems are necessary components of conservation tillage systems. Individual tillage system machines can range from small, simple spinning-disk seeders to large, complex folding cultivators. Although any given field machine may normally be associated only with conventional tillage farming, when it is used in a different manner or in a different sequence of operations, it may become an effective component of a conservation-tillage-machine system. Conventional machines may be specifically modified for use as components in conservation tillage systems, or new machines may be specially designed for such use.

The use of conventional or moderately modified machines for new agricultural procedures such as conservation tillage offers many advantages. When farmers have conventional machines that can be used in conservation tillage,

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either with or without modifications, the education, management changes, and capital investments associated with converting an agricultural enterprise from conventional tillage to conservation tillage can be minimized.

Some conservation tillage systems may require one or two specialized field machines to perform the prescribed activities in that system. We recognize that there will be differences between the conservation tillage systems used by any one farmer for different crops and conditions, and by different farmers with different resources and needs. We also recognize that some anticipated conservation tillage activities cannot be accomplished with machines that are commercially available in 1979 and that systems for use in such activities cannot be recommended at this time. We anticipate that some inventors, researchers, and others may design novel devices or use multiple operations to accomplish conservation goals and that the knowledge so gained will contribute to the development of new tillage machines.

Machine Requirements

Components of machine systems for conservation tillage must minimize fuel requirements, soil-compacting traffic, and soil and water loss. Together, as a system, they must be economically feasible and enhance crop productivity.

A minimum use of farm machinery will not necessarily provide the most economical conservation tillage system. As an example, when land is seeded by aerial broadcast, energy use, soil compaction, and capital investment have been minimized, but such a seeding method will be acceptable only if the subsequent crop production is adequate to provide a profitable return.

High-energy tillage-machine operations may be required by particular combinations of soils and crops. One such operation is the deep chiseling of dense soils. Even this high-energy operation may be conducted in the spirit of conservation tillage. It may be possible to chisel only under proposed crop rows or between adjacent rows rather than to chisel the entire field. Such a restricted deep-chiseling operation may be combined with the application of anhydrous ammonia, other fertilizers, or pesticides, thus minimizing the energy expended for the necessary activities.

According to Trouse (1978) the degree of soil compaction caused by machine traffic in fields depends upon previous compaction, soil structure, soil moisture, and soil type. Dr. Trouse emphasized that the first pass of a tractor or machine wheel over the soil causes the greatest soil compaction. He also point out that the use of wide tires and dual tractor wheels compacts a high percenta of the entire field area. For soil conditions susceptible to traffic compactio he suggested that traffic by all tractors and implements be confined to specifi lanes and that appropriate cropping practices be used between these lanes. Suc practices have been used by Parish et al (1973) in Arkansas and by Fulgham et a (1973) in Mississippi.

Surface residues have been used effectively to minimize soil and water los from cropped fields (McGregor et al, 1975; Wischmeier, 1973; Siemens and Oschwa 1974; Singer and Blackard, 1978; Unger and Phillips, 1973). For areas without adequate surface residue, conservation tillage systems will require tillage to retard wind erosion and moisture evaporation and to control weeds.

To many persons, "conservation tillage" embodies the maximum use of surfac residues to conserve soil and water. Farmers who use conventional tillage practices have found that surface residues from previous crops have been a grea hindrance in their attempts to prepare a seedbed that would be adequate for their planting machines and for crop germination and emergence. We now recogni that much conventional tillage is conducted to allow the use of conventional planting and cultivating machines that may not operate satisfactorily in surfac residue. The maintenance and management of surface residue is one of the great challenges in conservation tillage operations. A challenge is also presented to the farm equipment manufacturing industry to provide cultivating and planting implements for conservation tillage operations in surface residue.

Available Machines

Ways must be found to use presently available tillage machinery in conservation tillage, incorporating modifications as necessary, until specialized machine-system components are commercially available. Such usage can be facilitated by the adoption of standard terminology for tillage equipment to eliminate the terminology confusion within the manufacturing industry and among sales personnel and developers of technical literature for tillage equipment. This terminology problem has been addressed by members of the Power and Machinery Division of the American Society of Agricultural Engineers under the direction of Mr. Roy Brandt, Winamac Steel Products Division, McIntosh Corporation. The first five sections of their report are given below. (The full report will be available from ASAE, St. Joseph, MI 49085, complete with definitions and illustrations for each subgroup of tillage implements.)

Terminology and Definitions for Agricultural Tillage Equipment

1. Purpose:

The purpose is to provide uniform terminology and definitions for tillage equipment designed primarily for use in the production of food and fiber.

It does not include equipment designed for earth movement and transport.

Dimensions, spacings, depths of operations, widths or velocities may be used as a part of the machine descriptions. These in no way should be considered as performance specifications for any type of design or publication.

2. Types of Tillage:

2.1 Primary Tillage: Primary tillage cuts and shatters soil and may bury trash by inversion, mix it into the tilled layer, or leave it basicall undisturbed. Primary tillage is a more aggressive, relatively deeper operation, and usually leaves the surface rough.

Primary Tillage Implements

- Plows
  - Moldboard
  - Chisel
  - Wide-Sweep
  - Disk
- Bedders
- Moldboard Listers
- Disk Bedders
- Sub Soilers
- Disk Harrows
  - Offset Disk
  - Heavy Tandem Disk
- Rotary Tillers

2.2 Secondary Tillage: Tillage that works the soil to a shallower depth than primary tillage, provides additional pulverization, levels and firms the soil, closes air pockets and kills weeds. It might be the final tillage preparation prior to planting or might be followed by further tillage.

Secondary Tillage Implements

- Harrows
  - Disk
  - Spring, Spike or Tine Tooth

Cultivators

Field or Field Conditioners

Rod Weeders

Roller Harrow

Rotary Tillers

2.3 Seed Bed Tillage: Some soils and seed beds require precision controls for seed placement. This type of tillage produces conditions for various degree of control in placement of seeds.

Seed Bed Tillage Implements

Harrows - Spike, Tine or Roller

Bed Shapers

Rotary Tillers

Rotary Hoes

2.4 Cultivating Tillage: Shallow tillage whose principal purpose is to aid the planted crop by either loosening the soil or by mechanical eradication of undesired vegetation.

Cultivating Equipment

Row Crop Cultivators

Rotary Hoes

Rotary Tillers - Strip Type - Power Driven

3. Types of Machine Classifications:

3.1 Pull

3.1.1 Wheel Mounted

3.1.2 Drag

3.2 Semi-Mounted (semi-integral)

3.3 Rear Mounted (3 point hitch)

3.4 Front Mounted

3.5 Center Mounted

All tillage tools are not produced in all classifications.

4. Types of Machine Constructions:

    4.1 Rigid Frame

    4.2 Single Wing

    4.3 Dual Wing

    4.4 Multiple Wing

    4.5 Hinged Frames

Wing styles may have a mechanical, hydraulic or no folding assistance.

5. Tillage Machines with Distinctive Design Features:

    5.1 Disk Harrows

        5.1.1 Single

        5.1.2 Tandem

            In Line

            Front Offset

            Front & Rear (double) Offset

        5.1.3 Offset

        5.1.4 One Way (Disk Tiller)

    5.2 Moldboard Plows

        5.2.1 One Way

        5.2.2 Two Way (Turn Over)

    5.3 Chisel Plows

        5.3.1 Conventional

        5.3.2 Combination

    5.4 Disk Plows

        5.4.1 One Way

        5.4.2 Two Way (Turn Over)

- 5.5 Sub-Soilers
  - 5.5.1 In Line
  - 5.5.2 "V"
- 5.6 Bedders
  - 5.6.1 Lister Bedder
  - 5.6.2 Disk Bedder
  - 5.6.3 Sub-Soil
- 5.7 Cultivators
  - 5.7.1 Field Cultivators
  - 5.7.2 Row Crop Cultivators
    - Rotary - Ground Driven
    - Rotary - Power Driven
    - Shank Tine
- 5.8 Harrows
  - 5.8.1 Spike Tooth
  - 5.8.2 Spring Tooth
  - 5.8.3 Power Tooth
  - 5.8.4 Coil Tooth
  - 5.8.5 Tine Tooth
- 5.9 Powered Tillers
- 5.10 Rod Weeders
- 5.11 Rotary Hoes
- 5.12 Roller Harrow
- 5.13 Packer

Predictions for Conservation Tillage Systems

We predict that the following practices will be included in future conservation tillage systems:

1. Incorporating herbicides and fertilizers into the subsurface with minimum disturbance of surface residue.
2. Using deep chiseling only under proposed rows; sweep-plowing will be regarded as an unnecessary energy expense.
3. Using deep fertilizer placement under proposed rows in conjunction with deep chiseling.
4. Planting fields without preparing bedded rows when surface residue is adequate.
5. Using narrow rows for sorghum and cotton to increase soil shading and plant populations.

In addition, we predict that conservation tillage planters will be commercially available for many crops, such as cereals, sorghum, cotton, corn, and soybeans, and that they will be designed to operate in residue, with minimu soil disturbance.

Successful Conservation Tillage

Farmers who plan to adopt the use of conservation tillage practices must follow recommended procedures if they wish to be successful in the endeavor. Recommendations followed only half-way can lead to disaster. Following are examples of actions that must be avoided.

1. Trying to use a nonadapted machine to avoid investment in a new machine.
2. Using fertilization procedures that are not recommended.
3. Trying to perform such operations as tilling or seeding when the condition of the soil is unsuitable for either the operations or for the necessary traffic in performing the operations.

4. Inadequately managing surface residue, with the result that the soil can erode and form gullies.

Shortened Name Proposed

We may become weary of using the long name, "conservation tillage," for the system discussed herein. Adoption of the shortened name, "Con-Till," is proposed in sympathy for readers, speakers, and listeners of the future.

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TILLAGE FOR WIND EROSION CONTROL

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History of Wind Erosion in Texas

Wind erosion was a hazard to the sandy soils of West Texas long before the region was put into cultivation. The geomorphology of the area illustrates that wind erosion has been a part of West Texas climatic history for a long time. Newspapers in the Eastern United States mentioned "dark days" in the East in October 21, 1716; October 19, 1762; May 19, 1780; October 16, 1785; and July 3, 1814. The reduction in visibility may have been caused by forest fires, blowing dust or volcanic ash. The lack of climatic data and observations in the Great Plains in the 1700's prevents us from establishing definite links between these "dark days" and wind erosion, but a similar occurence was reported in January, 1965, in Ohio when a 3-day dust storm in West Texas deposited a layer of red dust in Ohio.

Extent of Wind Erosion Problems in Texas

Since 1953 the Soil Conservation Service has been reporting the land damaged by wind erosion in each blow season. The major problem area is in the sandy land region of the Texas Panhandle. Of the 4.8 million acres damaged in 1971 in the entire Great Plains, more than 2.78 million acres were in Texas (Table 1). On the average, about 35% of the land damaged by wind in the United States is in Texas. The 5-state area of Texas, New Mexico, Oklahoma, Kansas, and Colorado which was the heart of the "Dust Bowl" in the 1930's, remains the center of activity for annual wind erosion.

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Table 1. Total land damaged annually by wind erosion in the Great Plains and in Texas.

Blow Season	Great Plains	Texas	% in Texas
	-------Million Acres-------		
1954-55	15.8	1.92	12
56	9.8	2.72	28
57	10.5	1.76	17
58	4.0	1.18	30
59	3.3	1.08	33
60	2.6	1.09	42
61	2.3	0.33	14
62	1.5	0.47	31
63	3.1	0.39	13
64	4.4	0.69	16
65	4.0	2.05	51
66	1.1	0.62	56
67	2.5	0.88	35
68	1.2	0.31	26
69	0.9	0.49	54
70	1.9	0.58	31
71	4.8	2.78	58
72	2.2	1.15	52
73	1.8	1.02	57
74	3.8	2.05	54
75	5.5	1.40	25
76	6.2	1.6	26
77	8.0	2.1	26
78	2.8	1.4	50

Social Factors Influencing Conservation Tillage

Most farmers today are from several generations of farmers. Farming techn are handed down from father to son. With the advent of large tractors and herbicides, the farmer's dream of clean, weed-free fields became a reality. As conservationists developed the trash farming concept, many farmers were and still are reluctant to adopt the practice because of the negative connotation of being a "Trashy Farmer". Farmer pride and peer group pressure are real factors that must be considered in promoting conservation tillage practices. With conservation tillage, crop residues are maintained on the soil surface;

and the number of tillage operations is reduced. The presence of 10 weeds in an 160-acre field, for example, may not justify the expense of cultivating the entire field if the farmer uses a herbicide to control weeds the next year. Habits and tradition are difficult to change. With data on the influences of each tillage operation on production cost, crop yields, soil water evaporation, and erosion control, the farmer will be in a better position to decide if and when he should till the soil.

Wind Erosion Control

Basic Factors Responsible for Wind Erosion

For wind erosion to be a problem 3 basic conditions must be present:

1. an erodible soil,
2. wind velocities above the threshold velocity of the soil, and
3. a bare or nearly bare soil.

Man can have limited influence on soil texture as it relates to soil erodibility unless severe erosion is allowed to occur each year. As severe erosion continues, the soil texture becomes sandier; and the soil becomes more erodible until a "desert pavement" is formed or until only individual coarse sand grains are present. He can temporarily modify soil erodibility with various tillage methods. Although with present technology man does not exercise any controlled influence on atmospheric wind velocities, he may alter wind velocities adjacent to the soil surface with barriers or surface residues. In agriculture areas, man can influence and, in most cases, control the presence, type, and amount of vegetative cover on the soil surface.

The wind erosion equation (Woodruff and Siddoway, 1965) is:

$$E = F\ (I'\ K'\ C'\ L'\ V)$$

where E = Potential annual soil loss in Tons/A/yr.

I' = Soil erodibility index.

K' = Soil Ridge roughness factor.

C' = Climatic factor

L' = Field length along prevailing wind erosion direction.

V = Equivalent quantity of vegetative cover.

Of the 5 factors identified, man can reduce and, in some cases, control wind erosion by modifying three--field length, soil roughness, and vegetative cover. With present technology he cannot change the climatic factor, but he can modify the soil erodibility index within limits determined by the texture of the soil.

Crop Barriers, Shelterbelts, Strip Cropping

Because of the highly variable wind direction in West Texas, strip cropping shelterbelts, and crop barriers to reduce field length have not proven satisfact Crop barriers or strips are used in Central Texas in the peanut production area. Any object or system that slows the wind speed and traps drifting sand is subjected to soil aggradation until the erosion resistant element is covered.

As the wind encounters an unprotected erodible soil, it starts picking up eroding soil until the wind stream becomes saturated. After the wind stream is saturated, any additional field length does not increase soil erosion. Reducing field length to less than 1000 feet does not reduce erosion loss by even 50% unless the soil erodibility I' is less than 160. For the highly erodible soils of West Texas, (I' of 160 or greater) field length would have to be less than 40 feet before erosion losses are reduced as much as 50% (Figure 1).

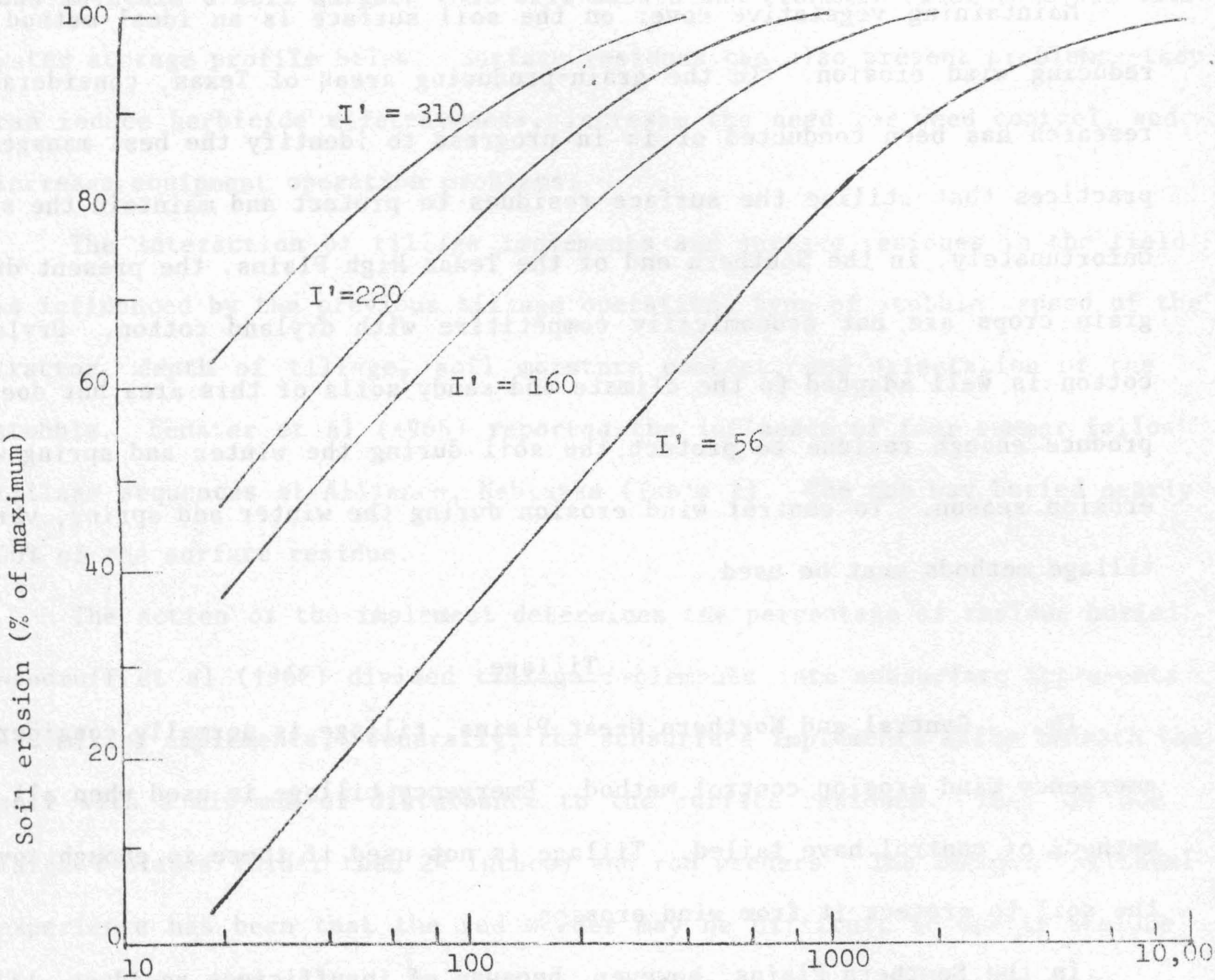

Figure 1. Influence of field length on maximum soil erosion rate for a climatic factor C' of 100, a soil ridge roughness factor K' of 1, a vegetative factor V of 0, and four soil erodibility indexes I' (Woodruff and Siddoway, 1965).

Crop barriers or strip cropping, when used alone, must be on less than 50-foot intervals to greatly reduce wind erosion. The highly variable wind direction in the winter and spring months further reduces the effectiveness of barriers or crop strips.

Surface Residues

Maintaining vegetative cover on the soil surface is an ideal method of reducing wind erosion. In the grain-producing areas of Texas, considerable research has been conducted or is in progress to identify the best management practices that utilize the surface residues to protect and maintain the soil. Unfortunately, in the Southern end of the Texas High Plains, the present drylan grain crops are not economically competitive with dryland cotton. Dryland cotton is well adapted to the climate and sandy soils of this area but does not produce enough residue to protect the soil during the winter and spring wind erosion season. To control wind erosion during the winter and spring, various tillage methods must be used.

Tillage

In Central and Northern Great Plains, tillage is normally considered a emergency wind erosion control method. Emergency tillage is used when all othe methods of control have failed. Tillage is not used if there is enough cover o the soil to protect it from wind erosion.

In the Southern Plains, however, because of insufficient residues, tillage is used to reduce the susceptibility of the soil to wind erosive forces each year. To be most effective, the bare soil must be tilled before erosion begins.

Influence of Tillage Operations

Every time a soil is tilled, many factors are changed. The factors of primary interest are the effects on crop residue reduction, surface roughness, soil cloddiness, and soil erodibility.

Residue Reduction

Every tillage operation influences the orientation and quantity of residue remaining on the soil surface. In the dryland crop production area of West Texas, residues can be multibeneficial if they are retained on the soil surface. Surface residues protect the soil from wind erosion, absorb rain drop impact, and maintain a soil surface that will absorb and transmit water into the soil water storage profile below. Surface residues can also present problems--they can reduce herbicide effectiveness, increase the need for weed control, and increase equipment operation problems.

The interaction of tillage implements and surface residues in the field is influenced by the previous tillage operation, type of stubble, speed of the tractor, depth of tillage, soil moisture content, and orientation of the stubble. Fenster et al (1965) reported the influence of four summer fallow tillage sequences at Alliance, Nebraska (Table 2). The one way buried nearly 50% of the surface residue.

The action of the implement determines the percentage of residue buried. Woodruff et al (1966) divided tillage implements into subsurface implements and mixing implements. Generally, the subsurface implements slide beneath the soil with a minimum of disturbance to the surface residues. They include large V-blades (wider than 24 inches) and rod weeders. The authors' personal experience has been that the rod weeder may be difficult to use if residue rates exceed 1500 lbs/A. The rod weeder effectively controls weeds, but as the rotating rod gets close to the soil surface, it may not shed the residue, causing the residue to drag. The rod weeder is used in the summer fallow winter wheat region of the Central Great Plains to control late season weeds and firm the soil before wheat planting.

Table 2. Percentage of 3600 lbs/A of wheat residue conserved with four summer fallow tillage sequences at Alliance, Nebraska.[1]

Tillage Sequence [2]				Pretillage residue remaining after each operation in the sequenc				
Operation				Operation				
1	2	3	4	0	1	2	3	4
						%		
OW	8-V	32-V	RW	100	55	51	53	42
8-V	32-V	RW	RW	100	76	66	61	57
C	32-V	RW	RW	100	67	61	63	59
OW	OW	32-V	RW	100	55	39	43	37

[1] From Fenster, et al., 1965.

[2] OW is one-way, 8-V is 8-ft V-sweep, 32-V is 32 inches sweeps, RW is rod weeder, C is 2-inch wide chisels.

Soil Roughness

Soil roughness can be measured in the field using an equivalent ridge height-spacing of 1 to 4 if the soil is in a ridged pattern. To compute "ridge roughness equivalent", (Zingg and Woodruff, 1951) the factor

$$K_r = \frac{\text{Standard ratio (1:4)} \times \text{ridge height}}{\text{Field measured ratio (1:x)}}$$

is used. For example, 3-inch-high ridges spaced 18 inches apart will give a K_r of 2. This is then converted to a soil ridge roughness factor K' from Figure 2. If there is no symmetrical ridge-furrow pattern, the equivalent soil roughness is 0 and the K' for those tillage implements is 1. Soil ridge roughness equival (K) can be determined from the pressure drop down a wind tunnel. The larger the ridges, the greater the pressure drop, and the greater the drag of the wind on the soil surface (Figure 2). Essentially, as the soil roughness increases to 3-inch high ridges, more of the wind's energy is being transferred to the soil surface and less is available for soil detachment and transport. If the ridge height exceeds 5 inches, the wind force on the windward side of the soil ridge may overcome the benefits of the additional roughness, and erosion increases (Figure 3). If the ridged soil surface is eroding, the roughness will drop until the soil is smooth except for minor ripples similar to miniature sand dunes.

The roughness generated by various tillage implements depends primarily on the type of implement, operating depth and speed, soil moisture content, and soil texture. Listing produces the largest ridges but not necessarily the most erosion-resistant soil surface (Table 3). Listing 6 to 8-inches deep is necessary in many years if the field has started to erode and there is 1 to 2 inches of loose sand on the surface. Listing on 40-inch centers normally buries most of the loose sand, but listing on 20-inch centers to produce 3 to 4-inch high ridges may not bury the loose sand. Unless the loose sand is covered, the soil will continue to erode whenever the wind exceeds 20 - 25 mph.

Soil Cloddiness

As tillage implements pass through the soil, they modify the surface roughness; but they also change the size and distribution of clods on the soil surface. The formation of clods resistance to breakdown by weathering is essential to control wind erosion. On sandy soils, clods are generally not resistant to weathering. Those clods larger than 0.84 mm are considered non-erodible by wind. In results from Nebraska, variation in percent of clods or aggregates greater than 0.84 mm was 54-79% due to tillage, which reduces the soil erodibility I' from 29T/A/yr to 2 T/A/yr (Dickerson et al 1967).

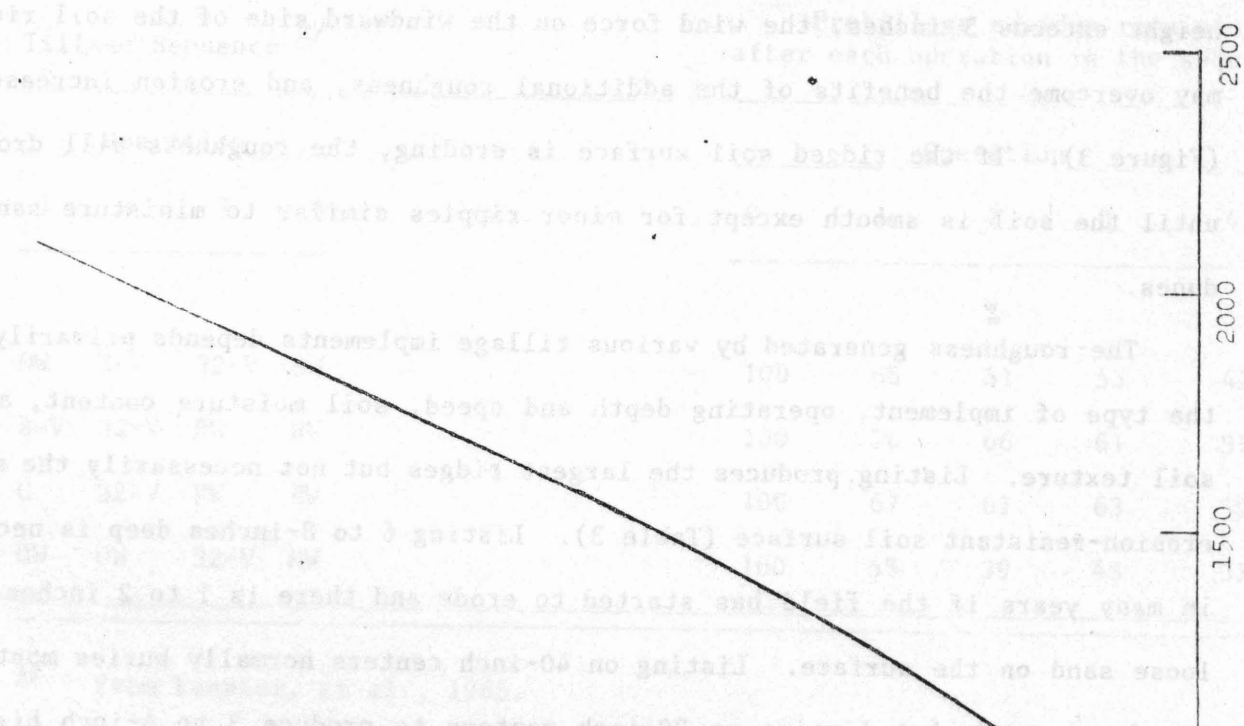

Figure 2. Relation between soil ridge heights and drag of 30 mph wind on soil surface. From Zingg and Woodruff, 1951.

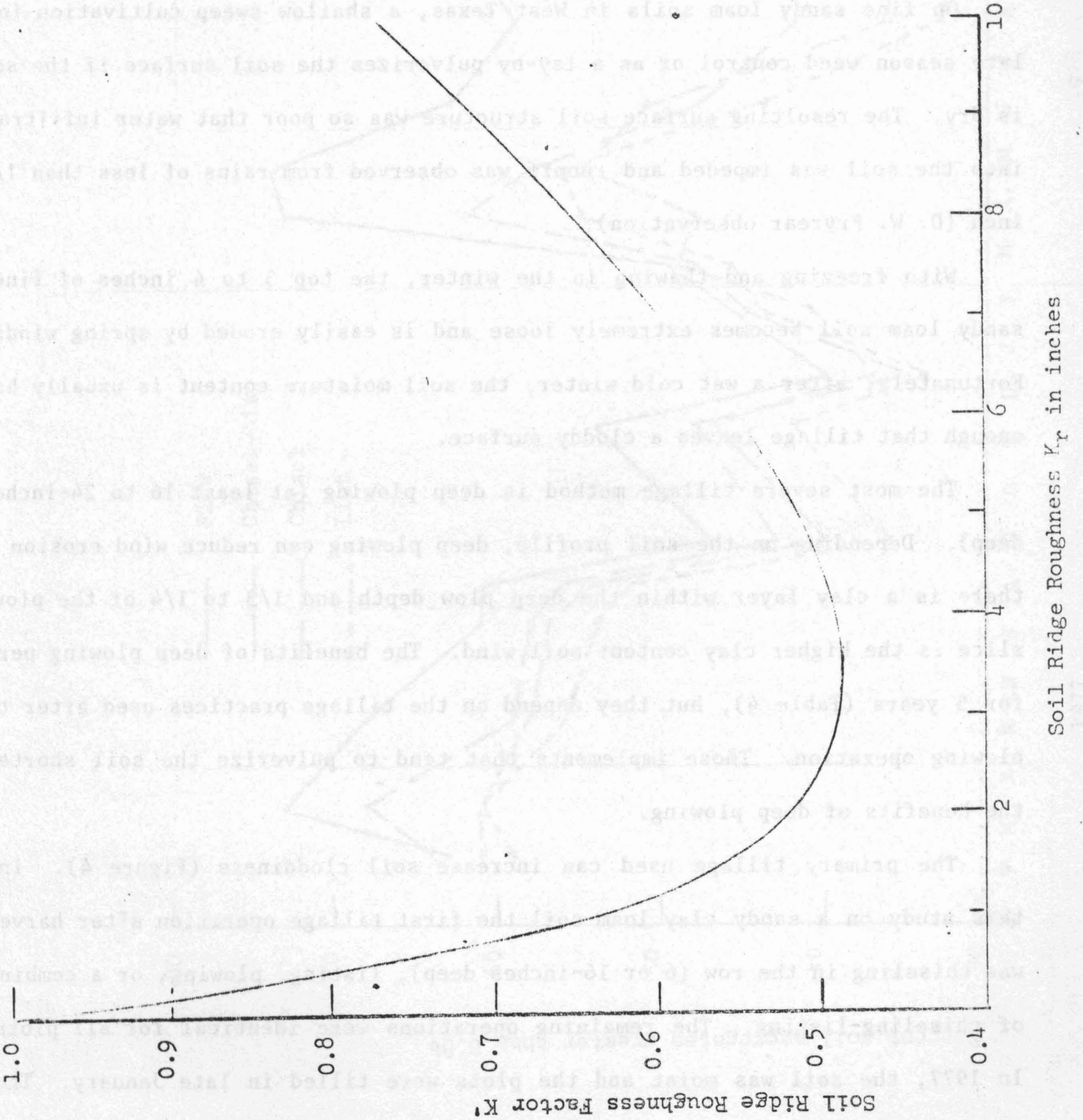

Figure 3. Relation between soil ridge roughness and soil ridge roughness factor. Armbrust, et. al. 1964

The subsurface implements usually produced a larger percent of clods than the mixing type implements (Table 3). Tilling a dry or wet silty clay loam soil produced more clods than tilling at an intermediate soil moisture content (Lyles and Woodruff 1962).

On fine sandy loam soils in West Texas, a shallow sweep cultivation for late season weed control or as a lay-by pulverizes the soil surface if the soil is dry. The resulting surface soil structure was so poor that water infiltratio into the soil was impeded and runoff was observed from rains of less than 1/2 inch (D. W. Fryrear observation).

With freezing and thawing in the winter, the top 3 to 4 inches of fine sandy loam soil becomes extremely loose and is easily eroded by spring winds. Fortunately, after a wet cold winter, the soil moisture content is usually high enough that tillage leaves a cloddy surface.

The most severe tillage method is deep plowing (at least 16 to 24-inches deep). Depending on the soil profile, deep plowing can reduce wind erosion if there is a clay layer within the deep plow depth and 1/3 to 1/4 of the plow slice is the higher clay content soil wind. The benefits of deep plowing persis for 5 years (Table 4), but they depend on the tillage practices used after the plowing operation. Those implements that tend to pulverize the soil shorten the benefits of deep plowing.

The primary tillage used can increase soil cloddiness (Figure 4). In this study on a sandy clay loam soil the first tillage operation after harvest was chiseling in the row (6 or 16-inches deep), listing, plowing, or a combinati of chiseling-listing. The remaining operations were identical for all plots. In 1977, the soil was moist and the plots were tilled in late January. The differences in soil cloddiness between the treatment was small except for the plowing. The differences during the year were small, but plowing left more clods than the other treatments. The fall and winter of 1977-78 was very dry,

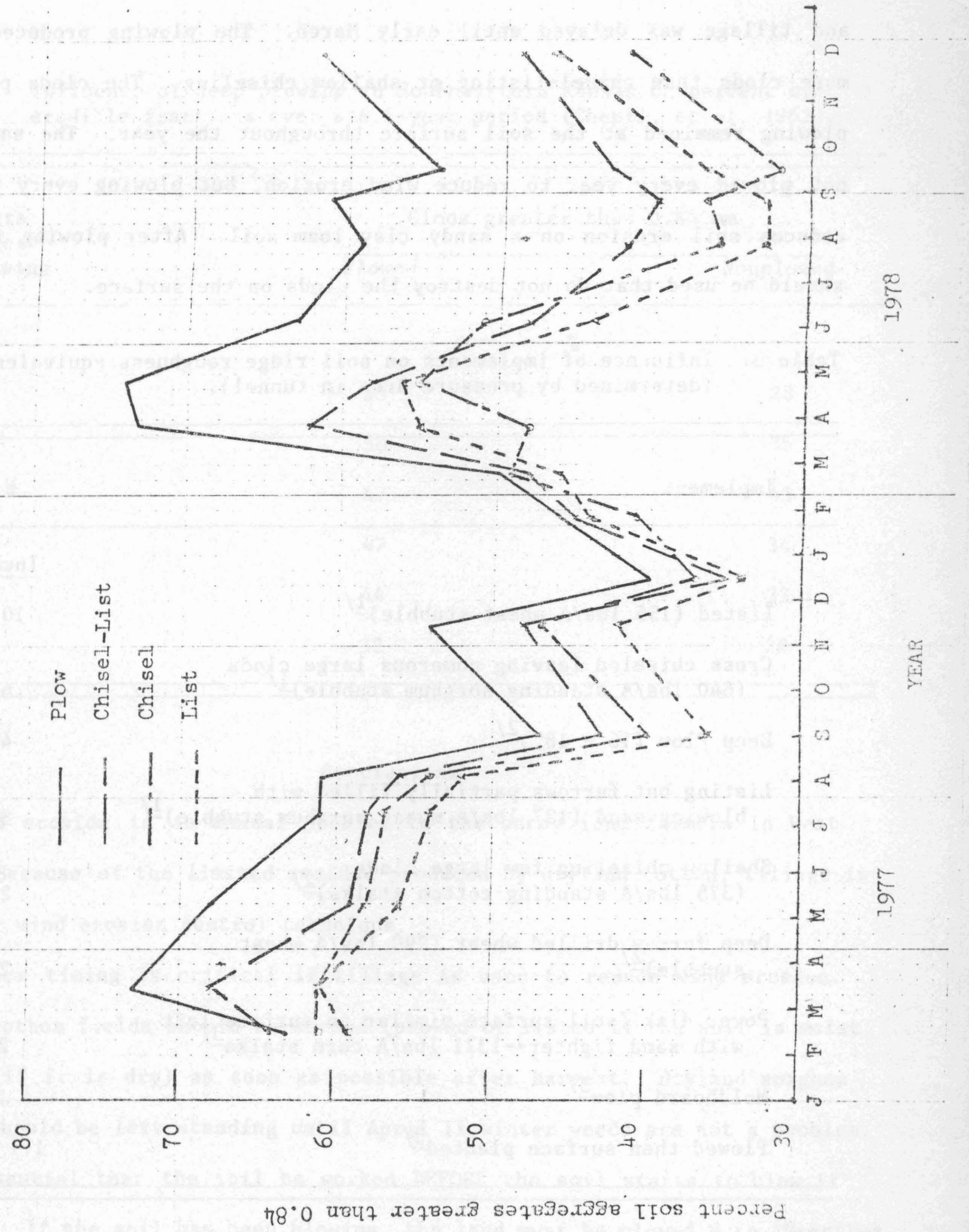

Figure 4. Influence of primary tillage on soil aggregation throughout 1977 and 1978 (*D. W. Fryrear, unpublished data*).

and tillage was delayed until early March. The plowing produced 10-20% more clods than chisel-listing or shallow chiseling. The clods produced by plowing remained at the soil surface throughout the year. The same land is not plowed every year to reduce wind erosion, but plowing every third year reduces soil erosion on a sandy clay loam soil. After plowing implements should be used that do not destroy the clods on the surface.

Table 3. Influence of implements on soil ridge roughness equivalent (K) (determined by pressure drop in tunnel).

Implement	K
	Inches
Listed (155 lbs/A wheat stubble)[1/]	10.1
Cross chiseled leaving numerous large clods (640 lbs/A standing sorghum stubble)[1/]	4.6
Deep Plow (16 - 18")[2/]	4.0
Listing but furrows partially filled with blowing sand (127 lbs/A wheat sorghum stubble)[1/]	3.8
Shallow chiseling few large clods (375 lbs/A standing cotton stalks)[2/]	2.7
Deep furrow drilled wheat (790 lbs/A wheat stubble)[2/]	2.6
Power disk (soil surface similar to surface left with sand fighter--1371 lbs/A corn stalks[3/]	2.2
Moldboard plow[3/]	1.6
Plowed then surface planted[3/]	1.1 to 1.5

[1/] Zingg, et al, 1953.
[2/] Chepil, et al, 1955.
[3/] Woodruff, et al, 1968.

Table 4. Influence of deep plowing in Southwestern Kansas on percent of erodible fractions over a 6.5-year period (Chepil, et al, 1962).

Years after plowing	Clods greater than 0.84 mm	
	Plowed	Nonplowed
	--------------------%--------------------	
0.5	55	28
1.5	50	35
2.5	47	43
3.5	47	34
4.5	44	33
6.5	32	28

Conclusions

Wind erosion is an annual problem to the sandy land farmers in West Texas. Because of the limited residue produced by dryland cotton, tillage is the major wind erosion control technique.

Proper timing is critical if tillage is used to reduce wind erosion. Dryland cotton fields should be worked (plowed or listed if the soil is moist, chiseled if it is dry) as soon as possible after harvest. Dryland sorghum stubble should be left standing until April if winter weeds are not a problem. It is essential that the soil be worked BEFORE the soil starts to blow if possible. If the soil has been blowing, the land must be plowed 8 to 10-inches deep or listed on 40-inch centers.

If the soil has not been blowing, chiseling on 20-inch centers reduces the hazard if large clods are brought to the soil surface. If the soil has been blowing, plowing or listing is the only effective tillage method. An ideal surface has ridges 4 to 5-inches high on 20-inch centers, but this may not control wind erosion as effectively as 8 to 10-inch lister ridges on 40-inch centers unless all loose sand on the soil surface is buried.

Moldboard plowing on Amarillo soil (8 to 10-inches deep) increases surface aggregation about 10%, and the increased aggregates will persist for 12 months. Plowing every third year reduces soil erodibility, buries loose sand on the soil surface, and breaks up any dense layers within the plow depth.

Deep plowing 16 to 24-inches deep reduces the wind erosion hazard if 1/3 to 1/4 of the plow slice contains subsurface clay. The additional surface cloddiness resulting from deep plowing persists about 5 years, depending on rainfall received and management practices followed.

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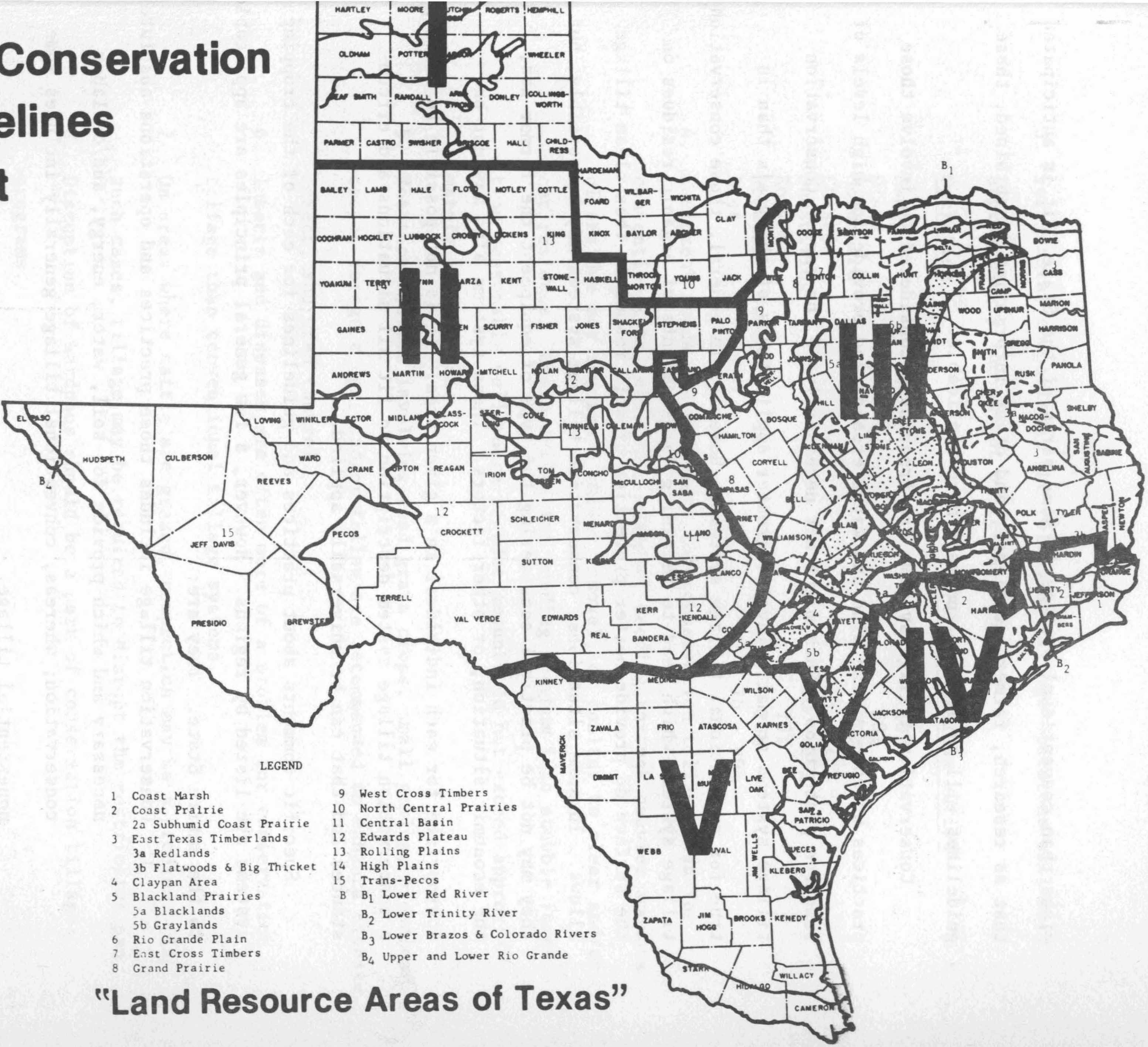
INTRODUCTION TO CONSERVATION TILLAGE GUIDELINES

Texas was divided into five regions--Northwest Texas, West Texas, Central and East Texas, Southeast Texas, and South Texas (Figure 1) for purposes of facilitating development of conservation tillage system guidelines. The rationale for placement of regional boundaries included considerations of such factors as cropping systems, soils, geographic locations, and climate. A brief description of each of these and other factors is given for each of the regions preliminary to the guidelines for that region.

The guidelines were basically developed through extensive conversations and discussions with personnel of agencies from throughout the State including the Texas Agricultural Experiment Station, USDA-Science and Education Administration-Agricultural Research, USDA-Soil Conservation Service, Texas Tech University, West Texas State University, Texas State Soil and Water Conservation Board, Texas Agricultural Extension Service, and several other agencies and universities. Farmers were also involved in developing these guidelines. The guidelines were drafted at workshops in each of the five regions and reviewed and revised at a State workshop.

These guidelines represent a compilation of the best thinking and opinions of individuals knowledgeable of crop production, soil fertility, weed control, soil conservation economics, equipment design, water use, soil management, and disease and insect control. Many of these guidelines are not research proven and have not been field tested. They provide flexibility for farmer adaptation to meet individual situations. Each farmer will of necessity add or delete certain practices depending on production economics, weed, disease and insect control demands, specific cropping systems, soil conditions, equipment available weather, and other factors. Conservation tillage systems may involve higher

Regions for Conservation Tillage Guidelines Development



LEGEND

1 Coast Marsh
2 Coast Prairie
2a Subhumid Coast Prairie
3 East Texas Timberlands
3a Redlands
3b Flatwoods & Big Thicket
4 Claypan Area
5 Blackland Prairies
5a Blacklands
5b Graylands
6 Rio Grande Plain
7 East Cross Timbers
8 Grand Prairie
9 West Cross Timbers
10 North Central Prairies
11 Central Basin
12 Edwards Plateau
13 Rolling Plains
14 High Plains
15 Trans-Pecos
B B_1 Lower Red River
B_2 Lower Trinity River
B_3 Lower Brazos & Colorado Rivers
B_4 Upper and Lower Rio Grande

"Land Resource Areas of Texas"

risks than conventional systems in some parts of the State. It is anticipated that as research, farmer experience, and other information is obtained, these guidelines will be revised and made more applicable.

Conservation tillage systems are frequently considered to involve those practices which minimize wind and water erosion and provide for high levels of resource protection. Such might not necessarily be the case. Conservation tillage systems normally involve greater applications of chemicals than is true for conventional tillage systems. However, in general, those conservation tillage systems which lead to retaining large amounts of organic residues on the surface do provide better protection of soil resources than clean tillage allows. In some situations, conservation tillage systems may be possible, but they may not be practical considering the type of equipment the farmer has, the economic situation, or other factors. These systems also may not be appropriate for each individual in a given area. It is not possible to develop a conservation tillage system description to fit all situations and circumstances and that can be universally applied.

Specific comments about practices and guidelines for each of the cropping systems are listed by regions. However, a few general principles are applicabl to the entire State. They are:

1. Conservation tillage includes those practices and operations absolute necessary and which provide for soil, water, energy, and/or labor conservation; whereas, conventional tillage generally includes some nonessential tillage.
2. For conservation tillage systems, herbicide applications are substituted for mechanical weed control, number of tillage practices and other operations is reduced, chiseling is substituted for moldboard plowing, and disking is replaced by sweep plowing.

3. For general comparison, the following tillage operatons will bury approximately the amount of residue shown:

Operation	Percent Residue Buried
Sweep	10%
Disks	50%
Moldboard	90%
Chisel	15 - 20%
Subsoiling	20 - 25%
Rodweed	10%
Rodweed - Sweep	20%
List	70 - 90%

4. Equipment needs are different for conservation tillage than for conventional tillage. For example, seeding through heavier amounts of residue may require a chisel, shovel, or coulter to clear and/or cut residues. Grain drills for seeding sorghum into stubble function reasonably well where residue amounts do not exceed approximately 5000 pounds.

5. Rotation systems involving feed grain crops, small grains, broadleaf crops, forage crops, and/or fallow are recommended to enhance disease, insect, and weed control.

6. Insects and diseases are often more of a problem for conservation tillage than conventional tillage systems.

7. On areas where cattle are grazed, compaction may be a problem. In such cases, tillage may be required to disrupt the restrictive pan.

8. Disruption of hardpans should be a part of conservation tillage programs.

9. Conservation tillage may enhance wildlife habitat.

10. Under certain situations where residue is inadequate and soil is susceptible to wind erosion, emergency tillage may be necessary to provide adequate surface roughness to control wind erosion.

11. Conservation tillage requires a higher level of management than conventional systems. It is suggested that the procedure be tried on a small area before committing an entire farm to any tillage system.
12. Twice as much flat-lying (shredded) grain sorghum residue is required to provide the same wind erosion control as that of standing stubble.
13. For all cropping systems where appropriate, terraces and contour farming should be practiced.
14. Johnsongrass is a major obstacle to any conservation tillage system in the State, and weed control is generally more difficult in these systems.
15. Equipment changes are normally necessary for conservation tillage systems; therefore, compatibility of equipment with the projected cropping system is an important consideration.
16. In many cases, farmers could tolerate more weeds during fallow periods. However, areas of heavy weed infestations may require more mechanical or chemical control practices than those suggested in the guidelines.
17. Energy costs and availability dictate acceptance of conservation tillage practices.

Terminology concerning farm implements and operations used in following sections in some cases may not be consistent with standard terminology but is intended to provide adequate description for user understanding.

CONSERVATION TILLAGE GUIDELINES FOR NORTHWEST TEXAS

Characteristics of Region I

Region I consists of the northern portions of three Land Resource Areas: High Plains, Rolling Plains, and North Central Prairies (Figure 1, page 117). This region comprises approximately 20 million acres of which approximately 8 million acres is cropland. The northern High Plains, with about 60 percent of the area cropped, is more intensively cropped than either the northern Rolling Plains or the upper North Central Prairies. Each of these latter areas has approximately one-fourth of the land cropped with most of the remainder in range.

Topography of the northern High Plains is typically that of a broad level plains lacking in prominent hills and valleys. Scattered playa lakes occur over its entirety. The eastern and western edges are characterized by escarpments, broken with short canyons which form the upper reaches of streams such as the Canadian and Red Rivers. Elevations of the northern High Plains range from 3200 feet above sea level in Briscoe County to slightly over 4300 feet in the northwest portion of Dallam County.

The northern Rolling Plains has a nearly level to rolling topography. The area is broken by numerous entrenched streams including the Canadian, Red, Pease, and Wichita Rivers. Elevations range from approximately 1000 feet in Wichita County to over 3000 feet in Oldham County.

The upper North Central Prairies consists of undulating prairies and nearly level valleys interspersed with rapidly drained sandstone and shale ridges and hills. The area is bisected by the Little Wichita, Trinity, and Brazos Rivers and their tributaries. Elevation of this area ranges from approximately 900 feet in Clay County to 1100 feet in Young County.

Climate

Climatic factors such as rainfall and temperature determine the range of crops that may be grown successfully in an area. Rainfall, both in terms of total rainfall and seasonal distribution, drastically affects the choice of cropping systems. Temperature affects crop production primarily through the length of the growing season. Average annual rainfall in the northern High Plains ranges from 14 to 21 inches, 18 to 30 inches in the northern Rolling Plains, and 25 to 32 inches in the upper North Central Prairies.

Average date of the last killing frost in the spring in the northern High Plains ranges from April 15 to May 1, while the average date of the first killing frost in the fall ranges from October 20 to November 1. Average length of the annual frost free period is 170 to 200 days.

In the northern Rolling Plains, the average date of the last killing frost in the spring ranges from April 1 to April 15, while the average date of the first killing frost in the fall occurs between October 20 and November 10. This results in an average length of frost free period ranging from 185 to 220 days.

The last killing frost in the upper North Central Prairies in the spring is between March 25 and April 1, and the first killing frost in the fall between November 10 and November 12. Range of the frost free period is 220 to 230 days.

Wind is another important climatic factor in this region. Wind velocities are greatest from January through mid-July with peak velocities occurring generally in March and early April. Wind speeds in excess of 50 miles per hour are not uncommon for brief periods during these months. Serious wind erosion and blowing dust from unprotected soils is a problem during these months, particularly from sandy soils on the High Plains and Rolling Plains.

Desiccating winds or "hot, dry winds" (defined by the National Weather Service as the "simultaneous occurrence of relative humidity less than 30 percent, wind speed of 15 miles per hour or greater, and temperature equal to or greater than 75 degrees Fahrenheit") occur throughout much of the growing season but are most common in June, July, and August. Occurrence of these plant injurious winds is 4 to 5 times more common in the western portion of this region than in the eastern portion.

Soils

Soils of the northern High Plains are fertile, deep, dark brown, neutral to calcareous clay loams and fine sandy loams, with clay loams predominating. Subsoils are dark brown to reddish in color, clay to sandy clay loam in texture, and alkaline in reaction. The soils are locally divided into either "hardlands" or "mixed lands." The clay and clay loam hardlands in the thermic temperature zone are dominantly Pullman soils with associated Olton and Mansker soils. Their mesic equivalents are Sherm, Gruver, and Sunray soils. The loamy mixed lands of the northern High Plains include Dallam soils along with associated Dalhart and Dumas soils.

Soils of the northern Rolling Plains are variable. Cropland soils are moderately deep to deep with loamy surface layers and clayey subsoils overlying redbeds, calcareous loamy materials, or layers of gypsum. Major cropland soils include Mansker, Berda, and Woodward. Other important northern Rolling Plains soils include the Miles, Springer, and Tillman series. These deep productive soils are widely cultivated.

Cultivated soils of the North Central Prairies are predominantly moderately deep to deep with loamy surface textures and clayey subsoils. Major soils include the Truce and Waurika series. These soils are brown slightly acid soils over red or gray neutral to alkaline clays.

Soil Management and Conservation Considerations

Management and conservation of croplands of this region are at least as variable and complex as the soils. Soils on the High Plains tend to occur on mostly level to nearly level slopes so that water erosion is not as severe a problem as on the more rolling topography of the Rolling Plains and North Central Prairies. However, wind storms are more frequent on the High Plains and therefore, wind erosion is much more of a problem there than for other sections of the region. Cover crops, proper residue management, and emergency tillage operations are requirements in protecting the land, particularly the medium and sandy textured soils in the western High Plains portion of this region. Similar practices are required for other portions of the region, especially the Rolling Plains.

Throughout almost all of the region, soils of medium and heavier textures tend to form tillage or compaction pans. These pans are caused mostly by relatively weak soil structure, low organic matter content, and improper tillage. Frequently, emergency tillage operations for wind erosion control or other trips across the land are made when the soil is too wet, thus hastening pan development. These compaction pans periodically must be broken up to allow for root growth and air and water penetration into the subsoils.

Much of the precipitation in this region occurs as high intensity rainstorms. Topography of the region is sloping. Most slopes are 1 to 5 percent with a large portion of the cropland being on slopes of 3 to 5 percent. These conditions, occurring mostly in the Rolling Plains and North Central Prairies, create potentially severe water erosion. For cropland protection, terraces are built in combination with grassed waterways or other suitable outfall conveyance practices to transmit water from upslope areas to foot slope or receiving water positions to minimize soil erosion and sediment transport. In combination with the terrace systems, contour farming is also required for row crop production.

Since inadequate precipitation is a major production limiting factor, many water conservation practices are currently being employed. Among those practices experiencing increasing interest is the recently revived basin tillage technique. This involves building small water blockage dams in row furrows at relatively short intervals. The small row sections trap water and permit greater infiltration into the soil, thus increasing available soil water. Also in combination with terrace systems designed to control erosion, land levelling is practiced to decrease slopes between terraces. Commonly, ends of parallel bench terraces are blocked so that water is retained between the terraces, thereby increasing available soil water.

Crusting is also a problem on soils in this region, particularly as it affects seedling emergence. Weak surface structures combined with high intensity rainstorms commonly necessitate a cultivation operation to break surface crusts and permit seedlings to emerge.

In 1976, the Research Committee of the Association of Texas Soil and Water Conservation Districts with assistance from several interested state and federal agency personnel developed a listing and prioritization of the conservation problems which they recognized in their individual districts. Following is a partial listing of those problems by land resource area as the District personnel identified them:

A. Northern High Plains

Weed Control

Wind Erosion

Soil Moisture Conservation

- Efficient Usage of Irrigation Water
- Water Erosion
- Inefficient Tillage Systems
- Soil Compaction

B. Northern Rolling Plains

- Water Erosion
- Weed Control
- Soil Moisture Conservation
- Wind Erosion
- Inefficient Tillage Systems
- Soil Compaction
- Salinity (locally)

C. Upper North Central Prairies

- Soil Moisture Conservation
- Water Erosion
- Weed Control
- Soil Compaction
- Wind Erosion
- Inefficient Tillage Systems

Conservation Tillage System Guidelines

Following are selected examples of possible conservation tillage systems for Region I, Northwest Texas.

Northwest Texas Conservation Tillage System No. 1.

Cropping System: Continuous Grain Sorghum (Dryland)

Crop	Month	Tillage System Alternatives	
		High Plains	Rolling Plains
Grain Sorghum	Oct.-Nov.		Sweep Plow (uproot plants)
	Dec.-Apr.	Sweep Tillage (as needed for weed control)	
	Mar.-May		Sweep Tillage (as required during spring for weed control)
	Apr. or June		Plant
	May	Plant	
	Sept.-Nov.		Harvest
	Oct.	Harvest	

In the High Plains, sorghum stubble is normally grazed. Post-plant weed control may be accomplished either by herbicides or cultivation. In the Rolling Plains, chisel plowing may be substituted for one sweep tillage operation. Dependent on soil moisture, in the eastern part of the region planting should be done in early April or late June.

Northwest Texas Conservation Tillage System No. 2.

Cropping System: Continuous Grain Sorghum (Irrigated)

Crop	Month	Tillage System Alternatives	
		System 1	System 2
Grain Sorghum	Nov.-Feb.	List	
	Dec.-Feb.		Chisel-Fertilize (in furrow)
	Mar.-Apr.	Chisel-Fertilize (in furrow)	
	Mar.-Apr.	Tillage (as required for weed control)	
	Apr.-May		Sweep-rodweed (as needed)
	May	Plant	Plant
	June	Herbicide	Herbicide
	Oct.	Harvest	Harvest

These systems are adapted to both furrow or sprinkler irrigation. Grain sorghum in system 1 may be seeded with a conventional planter or a drill and can be cultivated after planting if required. Research has shown that grain yields in this system equal those where clean tillage is practiced.

System 2 involves planting in standing stalks or shredded stalks after fertilization. A single row rather than double row per bed is recommended. A drill with disk opener has been used successfully in this system. These systems are not recommended where johnsongrass or other perennial weeds are a problem. There is also some potential for increased insect or disease problems, particularly in dry years. Corn could be substituted for sorghum.

Northwest Texas Conservation Tillage System No. 3.

Cropping System: Corn or Grain Sorghum-Soybeans (Irrigated)

Crop	Month	Tillage System Alternatives	
Corn or Grain Sorghum	Nov.	List	
	Dec.-Feb.		Chisel-Fertilize (in furrow)
	Mar.-Apr.	Chisel-Fertilize (in furrow)	
	Mar.-Apr.	Tillage (for weed control)	
	Apr.-May		Sweep-rodweed (1 or 2 as required)
	May	Plant	Plant
	June	Herbicide	Herbicide
	Oct.	Harvest	Harvest
Soybeans	Jan.	Tillage (for weed control)	
	Mar.-Apr.	Sweep-rodweed	
	May	Plant	
	Oct.	Harvest	

Cultivation or short-residual herbicides are necessary for post-plant weed control in corn or soybeans. Weed control in grain sorghum may utilize either cultivation or herbicides.

Northwest Texas Conservation Tillage System No. 4.

Cropping System: Continuous Corn (Irrigated)

Crop	Month	Tillage System Alternatives	
Corn	Nov.-Feb.	Shred or Graze	
	Nov.-Feb.		Sweep Plow (crown upheaval)
	Dec.-Jan.	Sweep Plow (Crown upheaval)	
	Dec.-Feb.		Chisel-Fertilize (in furrow)
	Mar.-Apr.	List	
	Mar.-Apr.	Chisel-Fertilize (in furrow)	
	Mar.-Apr.	Tillage (for weed control)	
	Apr.-May		Sweep-rodweed (1 or 2 as required)
	Apr.	Plant	Plant
	May	Herbicide	Herbicide
	Oct.	Harvest	Harvest

Southwestern corn borer may be a problem in corn. Old plant crowns should be ripped out by sweeps and a drag before February to help control the borer. Normally, corn stalks will be grazed which may necessitate chiseling or subsoili

Northwest Texas Conservation Tillage System No. 5.

Cropping System: Continuous Wheat (Dryland)

Crop	Month	Tillage System Alternatives
Wheat	June-Sept.	Sweep Tillage (as needed)
	Sept.	Drill
	June	Harvest

Chiseling (every few years to disrupt compacted zones) may be required after harvest if the area has been grazed. Disking may be required after harvest in years when heavy residues occur. Sweep tillage as needed for weed control. Annual winter grasses may be more of a problem in continuous winter wheat production under some conservation tillage systems.

Northwest Texas Conservation Tillage System No. 6.

Cropping System: Continuous Wheat (Irrigated)

Crop	Month	Tillage System Alternatives	
		Furrow	Sprinkler
Wheat	June-July	Offset Disk	
	July		Offset Disk
	Aug.	Chisel-Fertilizer	Chisel-Fertilize
	Aug.	List	Tillage (for weed control)
	Aug.	Rodweed or Rolling Cultivator	Drill
	Sept.	Drill	
	June	Harvest	Harvest

"No till" planting in continuous irrigated wheat is not practical because of heavy residues, weed control, and wheat streak mosiac. Root rot may become a problem after 3-4 years and require rotation of crops. Tillage for weed control on sprinkler irrigated land may be done with rodweeder, spring-tooth harrow, or sweep cultivator.

Annual winter grasses may be more of a problem in continuous winter wheat under some conservation tillage systems.

Northwest Texas Conservation Tillage System No. 7.

Cropping System: Dryland Wheat-Fallow-Dryland Grain Sorghum

Crop	Month	Tillage System Alternatives
Fallow after Sorghum	Winter	Chisel (if necessary)
	May	Sweep Tillage
	Summer	Sweep Tillage (as often as required to control weeds)
Wheat	Sept.	Drill
	June	Harvest
Fallow after Wheat	June	Chisel (if necessary to disrupt compacted soil)
	Summer	Sweep Tillage (during summer to control weeds and volunteer wheat, as required)
Sorghum	June	Plant
	Nov.	Harvest

This system is used in the High Plains, where rainfall is lower than in the Rolling Plains. The system features an eleven month fallow period between crops. If broadleaf weeds are predominant, either 2,4-D or other herbicides may be substituted for sweep tillage. A June application of herbicide, applied after wheat harvest, may substitute for sweep tillage and is in many instances less expensive.

Northwest Texas Conservation Tillage System No. 8.

Cropping System: Wheat-Fallow

Crop	Month	Tillage System Alternatives
Wheat	Aug.-Sept.	Drill
	June	Harvest
Fallow	Summer	Chisel (if necessary to disrupt compacted soil)
	Fall, Spring, & Summer	Sweep Tillage (as necessary for weed control)

This system features one crop in two years. It is used only in the drier western part of the High Plains.

Northwest Texas Conservation Tillage System No. 9.

Cropping System: Silage Corn-Wheat (Irrigated)

Crop	Month	Tillage System Alternatives	
		Furrow Irrigation	Sprinkler Irrigation
Silage Corn	June-July	Herbicide	Herbicide
	Dec.-Feb.	Fertilize	Fertilize
	Apr.	Plant	Plant
	May	Furrow Opener	
	Sept.	Harvest	Harvest
Wheat	Sept.	Sweep-rodweed	Disk
	Sept.	Fertilize	Fertilize
	Sept.	Drill	Drill
	June	Harvest	Harvest

Use a sweep-rodweeder or disk to knock out corn plant crowns to aid in control of Southwestern corn borer. Herbicide may be applied for weed control following wheat harvest in June or early July.

Northwest Texas Conservation Tillage System No. 10.

Cropping System: Irrigated Wheat-Fallow-Dryland Sorghum

Crop	Month	Tillage System Alternatives
Irrigated Wheat	Spring & Summer	Sweep Plow
	Aug.	List
	Aug.	Fertilize
	Sept.	Plant
	June	Harvest
	June	Herbicide
Fallow	July-Apr.	Sweep Tillage (if needed for weed control)
Grain Sorghum	May	Plant
	May	Herbicide
	Oct.	Harvest

Residue from irrigated wheat is managed to store additional moisture for the grain sorghum crop. Herbicide (atrazine) should be used for weed control during the period between wheat harvest and grain sorghum planting. Grain sorghum is planted into wheat stubble.

Other Conservation Tillage Systems for Northwest Texas.

Various Other Conservation Tillage and Cropping System Possibilities

Crop Month Tillage System Alternatives

System

1. Irrigated wheat - harvest late June - first year.
   Fallow - herbicides for weed and volunteer wheat control; sweep tillage or chisel if wheat was grazed.
   Grain sorghum - no-tillage - plant in May - dryland or limited irrigation - second year.
   Forage sorghum or silage corn - plant April or May - irrigated - third year.
   Irrigated wheat - plant early September - third year.

2. Irrigated wheat - harvest late June - first year.
   Fallow - herbicides - sweep tillage or chisel if wheat was grazed.
   Sunflowers - no-tillage - dryland or limited irrigation - plant April-June - second year.
   Grain sorghum or corn for grain - irrigated - plant April or May - third year.
   Forage sorghum - irrigated - plant April or May - fourth year.
   Irrigated wheat - plant early September - fourth year.

3. Irrigated wheat - harvest late June - first year.
   Fallow - herbicides, sweep tillage or chisel if grazed.
   Grain sorghum - dryland or limited irrigation - plant May - second year.
   Sunflowers - limited irrigation - plant April or early May - third year.
   Irrigated wheat - plant early September - third year.

4. Irrigated wheat - harvest late June - first year.
   Fallow - herbicides, sweep tillage or chisel if grazed.
   Corn for grain - irrigated - plant April - second year.
   Sunflowers - limited irrigation - plant April or early May - third year.
   Irrigated wheat - plant early September - third year.

Proper use of herbicides is mandatory. Operations between various crops are kept to a minimum, but may involve shredding, opening irrigation furrows, and applying fertilizer.

CONSERVATION TILLAGE GUIDELINES FOR WEST TEXAS

Characteristics of Region II

Region II consists of all or part of the following Land Resource Areas: High Plains, Rolling Plains, Edwards Plateau, Central Basin, North Central Prairies, Trans-Pecos, and a limited acreage of bottomland in the upper Rio Grande Valley (Figure 1, page 117). This region comprises approximately 67.5 million acres of which approximately 13 million acres is cropland. The souther High Plains with approximately 50 percent of the area cropped is more intensive cropped than the southern Rolling Plains which is the next most intensively cropped resource area. These two land resource areas comprise almost all of the cropland in Region II. Therefore, discussions will center on these two areas to the exclusion of the others. There are croplands found in the other land resource areas; however, guidelines developed for conservation tillage in High Plains and Rolling Plains can be modified to apply to those areas.

Topography of the southern High Plains is typically that of a broad level plain lacking in prominent hills and valleys. Scattered playa lakes occur throughout much of this area with some large saline playas occurring in the Tahoka area. The eastern and western edges of the southern High Plains are characterized by escarpments, broken with short valleys which form the upper ridges of streams, such as the Colorado and Brazos Rivers. The southern portion of this area feathers out over the Edwards Plateau without a discernable escarpment. Elevations of the southern High Plains range from about 2700 feet in Martin County to about 3900 feet in Bailey County.

The southern Rolling Plains has a generally rolling topography with occasional areas of level to nearly level land. The area is dissected by numerous entrenched drainage systems, but primarily those of the Colorado and Brazos River system. Elevations range from approximately 1400 feet in Shackelford County to about 2600 feet in Garza County.

Climate

Climate factors such as rainfall and temperature determine to a large degree the kinds of crops that can be successfully grown in an area. Rainfall, *both in terms of total effective rainfall and seasonal distribution drastically* affects the choice of cropping systems. Temperature affects crop production primarily through the length of the growing season. Average annual rainfall on the southern High Plains ranges from about 13 inches in Andrews County to about 21 inches in Floyd County. On the Rolling Plains, rainfall increases from about 18 inches on the west to about 24 inches on the eastern edge. However, much of the precipitation which falls on the High Plains and Rolling Plains comes as high intensity storms. Generally, rainfall of this type is highly localized so that variation is great even within short distances and from year to year. Also, the effective rainfall from thunderstorm-type precipitation tends to be lower than that for more gentle rainfall.

The average annual frost free period for the southern High Plains ranges from approximately 200 to 220 days, and for the southern Rolling Plains from about 215 to about 235 days.

Wind is another important climatic factor for Region II. Wind velocities are greatest from January through mid-July with peak velocities occurring generally in March and early April. Wind speeds in excess of 50 miles per hour are not uncommon for brief periods during these months. Serious wind erosion and blowing dust from unprotected soils are problems during these months, particularly from sandy soils.

Desiccating winds, or "hot, dry winds" (defined by the National Weather Service as the "simultaneous occurrence of relative humidity less than 30%, wind speed of 15 miles per hour or greater, and temperature equal to or greater than 75 degrees Fahrenheit") occur throughout much of the growing season but are most common in April, May, and June. Occurrence of these plant injurious winds is more common on the southern High Plains than in the Rolling Plains.

Soils

Soils of the southern High Plains range from clay loams to fine sands but are predominantly sandy. Generally, the soils are dark brown to reddish brown, moderately deep to deep, neutral to slightly alkaline in reaction, and are level to gently sloping. Caliche underlies many of the soils and some are calcareous to the surface. Major series are the Amarillo, Portales, Brownfield Pullman, Olton, Tivoli, Patricia, and Acuff. In the sandier southwestern portion of the southern High Plains, major soil series include the Triomas, Jalmar, and Penwell.

Soils of the southern Rolling Plains are more variable than those on the High Plains. Also, slopes are greater on the Rolling Plains than the High Plains.

Cropland soils are mostly fertile; moderately deep to deep; pale brown, reddish brown, to dark grayish brown; neutral to slightly alkaline; sandy loam, clay loam and clays over reddish, calcareous, loamy to clayey soils. Currently in some areas, there is an increasing incidence of saline seep occurrence in foot slope positions and along drainage ways. Major cropland series in this area include: Miles, Cobb, Abilene, Olton, Tillman, Brownfield, and Rowena.

Soil Management and Conservation Considerations

West Texas (Region II) presents some of the most challenging and difficult problems regarding the management and conservation of croplands. Since the soils of the southern High Plains occur mostly on level to nearly level slopes, water erosion is not as severe a problem as on the more rolling topography of the Rolling Plains. However, wind storms are frequent on the High

Plains and wind erosion is a great problem. Cover crops, proper residue management, and emergency tillage operations are requirements for crop production and soil protection throughout the entirety of the southern High Plains. Wind erosion is such a problem because the major period during which the highest intensity windstorms occur coincides with the period immediately prior to or following crop planting when the land is clean tilled with little residue on the surface in normal conventional tillage systems. This same situation exists for the southern Rolling Plains; however, the magnitude of the problem is generally not as great. Both areas, however, require careful management of soils during the spring.

Residue amounts produced on an annual basis in most of the cropping systems in this region are not sufficient to provide adequate protection of the soil against erosive forces of wind and water. Therefore, certain tillage operations are necessary. An example of this requirement is the need to moldboard plow certain sandy soils in the Rolling Plains and southern High Plains in order to provide for wind erosion control. A general guide for residue production in this region is approximately 1 pound of residue is produced per pound of lint cotton production; and for each pound of grain sorghum harvested, 1 1/2 pounds of residue are produced.

In the Rolling Plains after grain sorghum is harvested, the plants should be uprooted to stop growth and conserve soil moisture. In the High Plains, the grain sorghum stubble should be left standing as long as possible for wind erosion control. Moldboard plowing every 2 to 3 years on loamy sands, sands, or fine sandy loam soils to bring clayey material to the surface, has been shown to reduce wind erosion and provide other advantages such as cotton root rot control. Cultivation and "sandfighting" should be performed as required for weed and wind erosion control.

Subsoiling on row centers and listing over the plow marks ("ripper hipper" system) after harvest and building of row dams ("furrow dikes or dams") may offer potential for inclusion in tillage systems for this region.

Throughout both regions, soils tend to form tillage or compaction pans. These pans are caused mostly by relatively weak soil structure, low organic matter content, heavy equipment traffic, and improper tillage. Frequently, emergency tillage operations for wind erosion control and other trips across the land are made when the soil is too wet, thus hastening pan development. These compaction pans periodically must be broken up to allow for root growth and air and water penetration into subsoils.

Much of the precipitation which falls in this region occurs as high intensity rainstorms and since much of the topography in the Rolling Plains is sloping, conditions are conducive to potentially serious water erosion. For cropland protection, terraces are built in combination with grass waterways or other suitable conveyance practices to transmit water downslope and minimize soil erosion and sediment transport. Contour farming is also required in combination with terrace systems.

Since inadequate precipitation is a major production limiting factor, many water conservation practices are also used. Among those practices experiencing increasing interest is a recently revived basin tillage technique. This involves building small water blockage dams in row furrows at relatively short intervals. The small row sections trap water and permit greater infiltration into the soil thus increasing available water. Also in combination with terrace systems designed to control erosion, land levelling or smoothing is practiced to decrease slopes between terraces. This, combined with blocking the ends of the bench terraces, retains water between terraces thereby increasin infiltration and available soil water.

Crusting is also a severe problem on soils in this region, particularly as it affects seedling emergence. High intensity rainstorms received immediately following planting creates surface crust through which seedlings cannot emerge. These crusts must be broken by cultivation (scratching).

In 1976, the Research Committee of the Association of Texas Soil and Water Conservation Districts, with assistance from several interested state and federal agency personnel, developed a listing and prioritization of the conservation problems which they recognized in their individual districts. Following is a partial listing of those problems by land resource area as the District personnel indentified them:

A. Southern High Plains

Weed Control

Wind Erosion

Soil Moisture Conservation

Efficient Usage of Irrigation Water

Inefficient Tillage Systems

Soil Compaction

B. Southern Rolling Plains

Water Erosion

Weed Control

Soil Moisture Conservation

Wind Erosion

Inefficient Tillage Systems

Soil Compaction

Salinity (locally)

Conservation Tillage System Guidelines

Following are selected examples of possible conservation tillage systems for Region II, West Texas.

West Texas Conservation Tillage System No. 1.

Cropping System: Continuous Grain Sorghum (Dryland)

Crop	Month	Tillage System Alternatives	
		High Plains	Rolling Plains
Grain Sorghum	Oct.-Nov.		Sweep Plow (after harvest, to kill growing plants)
	Dec.-Apr.	Sweep Tillage (as required during spring for weed control)	
	Mar.-May		Sweep Tillage (as required during spring for weed control)
	Apr. or June		Plant
	May	Plant	
	Sept.-Nov.		Harvest
	Oct.	Harvest	

Relatively small acreage of continuously cropped dryland grain sorghum is produced in West Texas.

Cultivate, as needed, after planting to control weeds and to break surface crusts.

West Texas Conservation Tillage System No. 2.

Cropping System: Grain Sorghum-Cotton (Dryland)

Crop	Month	Tillage System Alternatives	
		High Plains	Rolling Plains
Grain Sorghum	Nov.		Sweep Plow (after harvest, to kill growing plants)
	Dec.-Apr.	Sweep Tillage (as required during spring for weed control)	
	Mar.-May		Sweep Tillage (as required during spring for weed control)
	Apr. or June		Plant
	May	Plant	
	Sept.-Nov.		Harvest
	Oct.	Harvest	Shred
Cotton	Dec.	Shred	Shred
	Jan.	Chisel	Chisel
	Feb.	Herbicide (incorporated)	Herbicide (incorporated)
	Feb.	List	List
	May-June	Plant	Plant
	June	Cultivate (as required)	Cultivate (as required)
	Nov.	Harvest	Harvest

Grain sorghum stalks may be a problem for harvest of cotton if left on the surface.

Perennial weeds such as silverleaf nightshade may increase during this rotation if moldboarding is infrequent.

West Texas Conservation Tillage System No. 3.

Cropping System: Soybeans-Corn or Grain Sorghum (Irrigated)

Crop	Month	Tillage System Alternatives	
Corn or grain sorghum	Nov.	Shred	
	Nov.	List	
	Dec.-Feb.		Chisel-Fertilize (in furro
	Mar.-Apr.	Chisel-Fertilize (in furrow)	
	Mar.-Apr.	Tillage for weed control (1 or 2 as required)	
	Apr.-May		Sweep-rodweed (1 or 2 as required)
	May	Plant	Plant
	June	Herbicide	Herbicide
	Oct.	Harvest	Harvest
Soybeans	Jan.	Sweep Plow (uproot corn or grain sorghum stalks)	
	Mar.-Apr.	Fertilize (chisel)	
	Mar.-Apr.	Sweep-rodweed	
	May	Plant	
	Oct.	Harvest	

Cultivation or herbicides may be necessary for post-plant weed control.

In this system, one cannot use triazine herbicides on corn or grain sorghum, since soybeans are sensitive to these chemicals.

Grain sorghum or corn stalks may have to be plowed under prior to planting soybeans to facilitate harvest of the beans. The combine header must be set low to harvest beans; therefore, any stalks remaining on the surface at bean harvest could be troublesome.

West Texas Conservation Tillage System No. 4.

Cropping System: Cotton-Soybeans (Irrigated)

Crop	Month	Tillage System Alternatives
Cotton	Nov.-Dec.	Chisel-List (in one operation)
	Mar.-Apr.	Herbicide (incorporated)
	Mar.-Apr.	Fertilize
	May	Rodweed
	May	Plant
	Nov.	Harvest
Soybeans	Jan.	Herbicide-List (in one operation)
	Mar.-Apr.	Fertilize (chisel)
	May	Plant
	Oct.	Harvest

These two crops are compatible concerning herbicide usage. However, neither of these crops produces a heavy amount of crop residue; therefore, supplemental tillage is necessary for erosion control.

West Texas Conservation Tillage System No. 5.

Cropping System: Cotton-Grain Sorghum (Irrigated)

Crop	Month	Tillage System Alternatives	
Cotton	Oct.-Nov.	Shred	
	Nov.-Dec.	Chisel-List (in one operation)	
	Mar.-Apr.	Herbicide (incorporated)	
	Mar.-Apr.	Fertilize	
	May	Rodweed	
	May	Plant	
	Nov.	Harvest	
Grain Sorghum	Nov.	Shred	
	Nov.	List	
	Dec.-Feb.		Chisel-Fertilize (in furr
	Mar.-Apr.	Chisel-Fertilize (in furrow)	
	Mar.-Apr.	Tillage for weed control (1 or 2 as required)	
	Apr.-May		Tillage for weed control (1 or 2 as required)
	May	Plant	Plant
	June	Herbicide	Herbicide
	Oct.	Harvest	Harvest

Grain sorghum stubble should be shredded and disked prior to application of pre-plant incorporated herbicide (for cotton), because herbicides tend to be rendered ineffective by large amounts of residues.

In the southern Rolling Plains, harvest prior to frost may necessitate shredding and uprooting of stalks to prevent regrowth and consequent soil moisture loss.

West Texas Conservation Tillage System No. 6.

Cropping System: Grain Sorghum-Wheat (Irrigated)

Crop	Month	Tillage System Alternatives	
Grain Sorghum	Nov.	List	
	Dec.-Feb.		Chisel-Fertilize (in furrow)
	Mar.-Apr.	Chisel-Fertilize (in furrow)	
	Mar.-Apr.	Tillage for weed control (1 or 2 as required)	
	Apr.-May		Sweep-rodweed (1 or 2 as required)
	May	Plant	Plant
Wheat	Aug.-Sept.	Plant (into grain sorghum)	
	Oct.-Nov.	Harvest (grain sorghum)	
	June	Harvest (wheat)	
	June	Herbicide	

Wheat should be seeded directly into the grain sorghum crop before the last irrigation of the grain sorghum. This has been done by broadcasting or aerially distributing the wheat seed into the grain sorghum. This system allows for grazing of the grain sorghum stubble along with the wheat.

Depending on the availability of irrigation water, the wheat could be irrigated and the grain sorghum produced under dryland conditions.

Wheat seed are aerially seeded into standing grain sorghum or planted with a drill designed to be used in standing crops. Seeding is prior to last irrigation.

West Texas Conservation Tillage System No. 7.

Cropping System: Continuous Grain Sorghum (Irrigated)

Crop	Month	Tillage System Alternatives	
		System 1	System 2
Grain Sorghum	Nov.	Shred	
	Nov.	List	
	Dec.-Feb.		Chisel-Fertilize (in fur
	Mar.-Apr.	Chisel-Fertilize (in furrow)	
	Mar.-Apr.	Tillage for weed control (1 or 2 as required)	
	Apr.-May		Sweep-rodweed (1 or 2 as required)
	May	Plant	Plant
	June	Herbicide	Herbicide
	Oct.	Harvest	Harvest

These systems are adapted to both furrow or sprinkler irrigation. The systems represented here retain approximately 60 to 75% plant residue cover on the soil surface, respectively, at planting.

Grain sorghum in System 1 may be seeded with a conventional planter or a drill and can be cultivated after planting if required. Research has shown that grain yields in this system equal those where clean tillage is practiced.

System 2 involves planting into either standing stalks or shredded stalks A single row rather than double row per bed is recommended. A drill with disk opener has been used successfully in this system. These systems are not recommended where Johnsongrass or other perennial grass is a problem. There is also some potential for increased insect or disease problems, particularly in dry years.

West Texas Conservation Tillage System No. 8.

Cropping System: Continuous Cotton (Irrigated)

Crop	Month	Tillage System Alternatives
Cotton	Nov.-Dec.	Shred
	Nov.-Dec.	Chisel-List (in one operation)
	Mar.-Apr.	Herbicide (incorporated)
	Mar.-Apr.	Fertilize
	May	Rodweed
	May	Plant
	June-July	Cultivate (as necessary)
	Nov.	Harvest

Basin tillage or furrow diking may be included in this system during the winter to hold precipitation on the land and increase moisture storage. Herbicides may be incorporated by plowing out the soil from beds with a sweep, spraying the herbicide, and reforming beds. An alternative is to use a rolling cultivator for herbicide incorporation.

Cultivation and "sandfighting" should be performed as required for weed and wind erosion control.

This system is adapted to either furrow or sprinkler irrigation. Water furrows may be needed in June or July for gravity irrigation systems. Tillage operations to break up compaction pans, control perennial weeds, or wind erosion control should be included as needed.

West Texas Conservation Tillage System No. 9.

Cropping System: Continuous Cotton (Dryland)

Crop	Month	Tillage System Alternatives
Cotton	Dec.	Shred
	Jan.	Chisel
	Feb.	Herbicide (incorporated)
	Feb.	List
	May-June	Plant
	June-July	Cultivate (as required)
	Nov.	Harvest

Due to inadequate production (approximately one pound of crop residue per pound of lint produced), disease problems, and wind erosion, a greatly reduced tillage system for dryland continuous cotton is not currently feasible.

Subsoiling on row centers and bedding over the plow mark ("ripper hipper" system) after harvest and building of row dams ("furrow diking") may offer potential for inclusion in this cropping system.

Wind erosion control may be aided by application of 5 to 7 tons per acre of cotton burs in blank rows.

Deep moldboard plowing of soils with sandy surface textures to bring clayey material to the surface has been shown to reduce wind erosion. Cultivation and "sandfighting" should be performed as required for weed and wind erosion control.

West Texas Conservation Tillage System No. 10.

Cropping System: Continuous Wheat (Dryland)

Crop	Month	Tillage System Alternatives
Wheat	June-Sept.	Sweep Tilage (as needed)
	Sept.	Drill
	June	Harvest

Chiseling may be required after harvest if the area has been grazed.

Subsoiling may be necessary every few years to disrupt compacted zones.

Disking may be required after harvest to reduce surface residue on high-yielding, heavy residue crops. Sweep tillage as needed for weed control.

Land infested by weeds such as cheat and wild oats may require crop rotation to help overcome this problem.

CONSERVATION TILLAGE GUIDELINES FOR CENTRAL AND EAST TEXAS

Characteristics of Region III

Region III consists of all or parts of the following Land Resource Areas: West Cross Timbers, East Cross Timbers, Grand Prairie, Blackland Prairies, Claypan Area, East Texas Timberlands, and a limited acreage of River Bottomland (Figure 1, page 117). This region comprises approximately 45 million acres, of which approximately 10 million acres is cropland. The Blackland Prairies with approximately 50 percent of its area cropped is more intensively cropped than any other land resource area in this region. Only the major cropland areas will be discussed for purposes of this report. Those areas to be discusse will include the northern Grand Prairie, Cross Timbers, Blackland Prairies, and a portion of the Bottomlands land resource area.

Topography of the Blackland Prairies is nearly level to rolling, well dissected prairies, with moderate to rapid surface drainage. Most of the flood plains are slowly drained. Elevation of the Blackland Prairies ranges from about 250 feet in Lavaca County to approximately 750 feet in Williamson County.

The Grand Prairie is a region of undulating to hilly, deeply incised prairies with moderate to rapid surface drainage. Some of the more steeply sloping areas are rather stony. Elevation of the Grand Prairie ranges from nearly 1200 feet in Hamilton County to approximately 600 feet in Denton County.

The Cross Timbers areas are also undulating to hilly and deeply incised by streams. Elevations range from approximately 1000 to 1200 feet.

Climate

Climatic factors such as rainfall and temperature determine to a large degree the kinds of crops that can be successfully grown in an area. Rainfall, both in terms of total effective rainfall and seasonal distribution, drastically affects the choice of cropping systems. Temperature affects crop production primarily through the length of the growing season. Average annual rainfall in the Blackland Prairies ranges from approximately 30 inches at the southern extremity (Bexar County) to near 45 inches in the northeastern extremity of the Blackland Prairies in Red River County. Rainfall distribution in the Grand Prairie ranges near 29 inches per year in Mills County to approximately 36 inches per year in Tarrant County.

Average date of the last killing frost in the spring in Central and East Texas ranges from March 1 in Bexar County on the southern tip of the Blackland Prairies to approximately March 25 in the West Cross Timbers in Montague County. The average date of the first killing frost in the fall ranges from November 10 in Montague County to approximately December 1 in Bexar County. This results in an average length of frost-free period ranging from 225 to 270 days.

Soils

Soils of the Blackland Prairies are typically moderately deep to deep, dark colored, uniformly textured clayey soils overlying light colored marls, chalks, or shells. Most of the soils have a high $CaCO_3$ content and some are calcareous to the surface. The heavy clays occur on level to sloping topography. These soils also shrink and swell with moisture changes. Large cracks generally form during dry periods, particularly in the latter part of the growing season. Common Blackland soils are the Houston Black, Heiden, Austin, and Branyon. Associated with the Blacklands soils are "Graylands" soils. These soils are neutral to slightly acid, medium to heavy textured surface soils over dense dark gray to red mottled clayey subsoils. Generally, these soils have less $CaCO_3$ than soils of the Blacklands; however, some become calcareous with depth. Soils typical of this area are Wilson and Crockett series. Another soil common in this area is Burleson, which has a uniformly high clay content with depth.

Cultivated soils of the Grand Prairie are restricted mostly to the northern portion of that area. These soils are generally moderately deep, well drained, slowly permeable, and occurring on nearly level to sloping topography. These soils generally overlie weakly cemented or fractured limestone and interbedded shells and marls. Typical soils of this area include the Denton and Purves series. Bottomlands soils are interfingered with soils of other land resource areas in this region.

Soils in Bottomlands are generally more variable than surrounding upland soils. In general, soils of Bottomlands occur on level to nearly level topography, vary greatly in drainage, vary in reaction from slightly acid to slightly alkaline with some soils being calcareous to the surface, have textures which range from sandy to clayey for both surface and subsoils, and other properties show similar ranges in characteristics. Typical of the soils of the Red River Bottomlands are the Red Lake, Oklared, and Kiomatia series. Common soils found in the Brazos and Colorado River Bottomlands are the Ships, Weswood, and Yahola series. Trinity River Bottom soils are dominantly Trinity and Kaufman series.

Soils of the Cross Timbers areas are typically slightly acid loamy sands and sandy loams in surface horizons with sandy clay loam to clay subsoils. Representative series of these areas include Windthorst, Nimrod, Duffau, Galey, and Konowa. The land surface ranges from gently rolling to very rolling with broad divides. Dissection of the area by streams is pronounced. In general, these soils are light colored on the surface, low in organic matter, infertile, and subject to erosion.

Soil Management and Conservation Considerations

Management and conservation of croplands in Central and East Texas is challenging; however, many Blackland farmers are currently practicing some form of conservation tillage. Soils in the Blackland area require careful management to protect production potential. Blackland soils generally occur on sloping land. Rapid runoff has resulted in erosion of much of the surface soil, thus making the land more subject to drouth. A major problem in the Blacklands is soil conservation. Soil erosion increases as slopes increase. Runoff is generally related to the moisture content of the soil at the time of rainfall occurrence and to the duration and intensity of the rainstorm. These clay soils, when dry, contain cracks that take water rapidly until the soil becomes wet and the cracks close. After closure of these cracks, infiltration rate declines markedly and potentially a high rate of runoff ensues.

Soil moisture conservation is very important for efficient crop production in the Blacklands. These clay soils are high in montmorillonite which tends to shrink on drying and form soil cracks. This cracking increases the loss of soil moisture through evaporation. Soil cracking also tends to cause root pruning. Such practices as terracing, contour farming, and proper management of crop residues tend to reduce runoff and result in more moisture entering the soil profile. Soil should be bedded early and disturbed as little as possible to conserve soil moisture. Minimum disturbance planters (double disk or other) should be used rather than the traditional "buster" planter, to conserve moisture and avoid disturbing herbicide layering. Planting operations should involve minimal soil disturbance also to conserve moisture.

Drainage may be a problem on the more level Blackland soils. Clayey texture prevents rapid adjustment of soil moisture and soil air in the root zone of crops. Blacklands soils favor bed planting for most crops, otherwise young plants may be drowned out by excess rain. The bedding on the contour also forms simulated terraces which may carry water to the drainage outlets.

Soils of the graylands are generally considered to be less productive than Blackland soils. Grayland soils are less rolling, less subject to erosion, and less well drained than the Blackland soils. The surface soils are normally thin and overlie claypan subsoils. Soils are especially drouthy. Grayland soils also tend to crust more readily than the Blackland soils.

In the sloping soils of the Grand Prairie, the relatively low amounts of rainfall combined with slopes presents a problem concerning soil moisture. Soil moisture conservation is critical to sustained cropping in this area. Additionally, these steep slopes present problems concerning water erosion of cultivated soils. The soils of the Grand Prairie are often cropped with small grains because of the shallow, drouthy nature of many of the soils. The small grains mature in the spring before the hot dry summer has depleted the soils of moisture.

Soils of the Cross Timbers are subject to wind erosion hazards particularly those in row crop production. In peanut production, disease control is essentia For that reason, all organic residues are buried. This leaves the sandy soils highly susceptible to wind erosion. Careful management which includes strip cropping, cover crops, or strip tillage must be practiced to control soil movement.

In 1976, the Research Committee of the Association of Texas Soil and Water Conservation Districts, with assistance from several interested state and federal agency personnel, developed a listing and prioritization of the conservation problems which they recognized in individual districts. The following is a partial listing of those problems in the Blackland Prairies, Grand Prairie, Cross Timbers, and East Texas Timberlands Land Resource Areas as the district personnel identified them:

A. Blackland Prairies

- Water Erosion
- Soil Compaction
- Weed Control
- Soil Moisture Conservation
- Inadequate Drainage
- Inefficient Tillage Systems

B. Grand Prairie

- Weed Control
- Soil Moisture Conservation
- Water Erosion
- Inefficient Tillage Systems
- Soil Compaction
- Inadequate Drainage

C. Cross Timbers

- Water Erosion
- Wind Erosion
- Weed Control
- Soil Compaction
- Inefficient Tillage Systems

D. East Texas Timberlands

- Water Erosion
- Weed Control
- Soil Moisture Conservation
- Soil Compaction
- Inefficient Tillage Systems

Conservation Tillage System Guidelines

Following are examples of selected possible conservation tillage systems for Central and East Texas, Region III.

Central and East Texas Conservation System No. 1.

Cropping System: Cotton-Grain Sorghum

Crop	Month	Tillage System Alternatives	
		Low Johnsongrass Infestation	Medium Johnsongrass Infestation
Cotton	Aug.	Shred	Shred
	Sept.	Herbicide (as required)	
	Aug.-Oct.	Sweep Plow (to uproot stalks)	Sweep Plow (to uproot stalks)
	Nov.-Dec.	List (small point)	Herbicide-Disk
	Nov.-Dec.		Disk
	Nov.-Dec.		List
	Dec.-Mar.	Fertilize	Fertilize
	Feb.-Apr.	Tillage (for weed control)	
	Apr.	Plant-Herbicide	Plant-Herbicide
	Apr.	Roll	Roll
	May-June	Cultivate (as necessary)	Cultivate (as necessary)
	Sept.	Harvest	Harvest
		Bedded	
Grain Sorghum	Sept.	Shred	
	Sept.	List	
	Fall-Winter	Tillage (for weed control)	
	Feb.	Fertilize	
	Mar.	Plant-Herbicide	
	Mar.	Roll	
	Spring	Cultivate (as necessary)	
	July	Harvest	

Conservation tillage systems for fields containing low or medium infestation of johnsongrass are given above. The primary difference is the use of preplant incorporated herbicides on cotton where johnsongrass is more prevalent.

Consider the use of glyphosate, applied through recirculating sprayers, to control johnsongrass in cotton. Glyphosate may also be applied to johnsongrass during the fall after harvest of cotton or grain sorghum if infestations warrant.

Central and East Texas Conservation Tillage System No. 2.

Cropping System: Continuous Grain Sorghum

Crop	Month	Tillage System Alternatives	
		Bedded	Flat
Grain Sorghum	July-Aug.	Shred	Shred
	July-Aug.	Herbicide	
	July-Aug.	List	Sweep Plow (to uproot stal
	Fall-Winter	Tillage (for weed control)	Sweep Tillage (for weed co
	Feb.	Fertilize	Fertilize
	Mar.	Plant-Herbicide	Plant-Herbicide
	Mar.	Roll	Roll
	Spring	Cultivate (as necessary)	Cultivate (as necessary)
	July	Harvest	Harvest

Use of a disk opener planter may be necessary if residue in the bed is not decomposed by time of planting. Continuous grain sorghum should be limited to areas relatively free of johnsongrass.

One alternative is to plant in narrow rows of sufficient width to allow mechanical cultivation.

Post-plant triazine herbicides may be used to advantage.

Bedded land may be plowed during the fall by rolling cultivator or disk bedder to control weeds.

Grain sorghum should be planted flat only on slopes less than 2% and with other erosion control systems as needed.

In this cropping system, use sweep plowing to undercut stalks and sweep tillage as required to control weeds in late summer or fall.

Central and East Texas Conservation Tillage System No. 3.

Cropping System: Continuous Small Grain

Crop	Month	Tillage System Alternatives
Small Grain	June-Sept.	Sweep Tillage (for weed control)
	Sept.	Disk-Harrow (if needed to break clods)
	Sept.-Oct.	Drill
	Feb.-Mar.	Fertilize
	Fall-Winter	Herbicide
	June	Harvest

Exceptionally large amounts of residue <u>may</u> require reduction by tillage operations.

Tillage with a sweep cultivator, as required for weed control, should be practiced.

Deep tillage should be performed as required to disrupt compacted sort zones.

During the fallow period, spot treating with a herbicide such as glyphosate may be required to control rhizome johnsongrass. Broadleaf weed control may be required during late fall or winter.

Fertilizer phosphorus may be applied with the seed. Nitrogen should be chiseled into the soil preplant or topdressed.

Central and East Texas Conservation Tillage System No. 4.

Cropping System: Continuous Peanuts

Crop	Month	Tillage System Alternatives
Peanuts	Nov.	Plant (rye)
	Nov.	Fertilize
	Apr.	Moldboard Plow (irrigation) or Disk (dryland)
	Apr.	Herbicide
	Apr.	Disk
	May	Plant (irrigation) or
	June	Plant (dryland)
	July	Herbicide
	Oct.-Nov.	Harvest

Rotate with a strip crop or plant strips of small grain, grain sorghum, or forage sorghum to assist in control of wind erosion.

Central and East Texas Conservation Tillage System No. 5.

Cropping System: Continuous Cotton

Crop	Month	Tillage System Alternatives
Cotton	Sept.	Shred
	Sept.-Oct.	Sweep Plow (to uproot stalks)
	Dec.-Jan.	Fertilize-Herbicide-Disk
	Dec.-Jan.	Disk
	Nov.-Dec.	List
	Apr.	Plant-Herbicide
	Apr.	Roll
	May-June	Cultivate (as necessary)
	Sept.	Harvest
	Sept.	Herbicide (as needed after harvest)

Cotton should not be planted continuously for an extended period due to erosion hazards and/or possibility of increased cotton root rot infestations. Cotton may be produced in a narrow row configuration.

Immediately after shredding, sweep plowing should be performed to uproot plants. Tillage with a rolling cultivator or disk bedder may be required to control winter weeds after listing.

Central and East Texas Conservation Tillage System No. 6.

Cropping System: Continuous Soybeans

Crop	Month	Tillage System Alternatives
Soybeans	Mar.	Herbicide (incorporated)
	Mar.-Apr.	List
	May	Plant
	June	Cultivate (as necessary)
	Oct.	Harvest

A winter cover crop of wheat or rye may be planted into soybeans by aerial seeding in September (prior to soybean harvest). An alternative system involves drill seeding wheat or rye following harvest of the soybean crop.

In Northeast Texas, some farmers are using wheat and soybeans in a double-cropping system with mixed success.

Central and East Texas Conservation Tillage System No. 7.

Cropping System: Small Grain-Grain Sorghum

Crop	Month	Tillage System Alternatives
Small Grain	Aug.	Shred
	Aug.	Sweep Plow (to undercut stalks)
	Sept.	Sweep Tillage (if required for weed control)
	Sept.	Disk-Harrow (if needed to break clods)
	Sept.-Oct.	Drill
	Sept.	Fertilize
	Winter-Spring	Herbicide (if required after tillering)
	Feb.-Mar.	Fertilize
	June	Harvest
Grain Sorghum	Aug.-Oct.	List (when moisture is adequate)
	Fall-Winter	Tillage (as required to control weeds)
	Dec.-Feb.	Fertilize
	Mar.	Plant-Herbicide
	Mar.	Roll
	Apr.	Cultivate (as required)
	July	Harvest
	Fall	Herbicide (when growth of weeds demands before time to plant small grains)

A small grain may be included in rotation with grain sorghum to help reduce johnsongrass and other weed infestations.

CONSERVATION TILLAGE GUIDELINES FOR SOUTHEAST TEXAS

Characteristics of Region IV

Region IV consists of the upper Coast Prairie and the Coast Marsh Resource Areas (Figure 1, page 117). This region comprises approximately eight million acres of which approximately two million acres are cultivated cropland. The upper Coast Prairie comprises about 7 and ½ million acres of this region. Only a limited portion of the half million acres of the Coast Marsh is cropped. This is primarily limited to rice production.

Land use in the Coast Prairie is very diversified, with land being utilized for cropland, range, and urban and industrial purposes. Crops produced in the area are rice, grain sorghum, cotton, corn, and improved pastures. Cropland is rapidly being taken out of production for urban, industrial, and recreational developments. In some counties, water for agricultural uses is also becoming more limited and expensive.

Topography of the Coast Marsh is typically that of a low, wet, level, marshy coastal area. The marsh is often covered with sea water in some areas. The upper Coast Prairie comprises a strip of low lying, practically flat, undissected plain bordering the Gulf of Mexico and extending northeastward from the Guadalupe River to the Louisiana border. This nearly level land is affected by slow surface drainage. It is crossed by numerous rivers including the Guadalupe, Lavaca, Navidad, Colorado, San Bernard, Brazos, San Jacinto, Trinity, Neches, and Sabine Rivers.

The Coast Prairie ranges in elevation from sea level to approximately 250 feet in Waller County. Elevation of the Coast Marsh ranges from sea level to generally less than 10 feet above sea level.

Climate

Climatic factors such as temperature and rainfall determine the type of crops that may be successfully grown in an area. Total and seasonal distribution of rainfall dramatically affects the choice of cropping systems. Temperature most affects crop production through the length of the growing season.

Average annual rainfall in Southeast Texas ranges from 34 to 60 inches, with the lower rainfall occurring on the western edges of Victoria County, while the higher rainfall occurs near the Sabine River on the eastern edge of the area.

Average date of the last killing frost in the spring in Southeast Texas ranges from February 15 in Calhoun County to March 1 on the northern edge of the Coast Prairie. The average date of the first killing frost in the fall ranges from November 25 on the northeastern edge of the Coast Prairie to approximately December 15 in Calhoun County. This results in an average length of frost free period ranging from 265 days to 300 days.

Soils

Soils of the Southeast Texas region are extremely variable. Soils having agricultural significance are roughly classed into three groups: upland clays and clay loams, upland sandy loam soils, and alluvial soils deposited by the Brazos, Colorado, Trinity, and other streams dissecting the area. Soils of the Coast Marsh are relatively unimportant with regards to row crop production.

The upper portion of the Coast Prairie is predominantly Beaumont clay and Lake Charles clay, along with the associated Morey soils. The Beaumont and Lake Charles soils are deep, slightly acid to neutral, dark colored, nearly level clay soils. The Beaumont soils are poorly drained, while the Lake Charles soils are somewhat poorly drained. The Morey soils are located in areas slightly higher than the Beaumont and Lake Charles soils and have surface layers of silt loam overlying silty clay loam subsoils. The Morey soils are also poorly drained.

The lower Coast Prairie is typified by soils of the Lake Charles association and the Edna-Bernard association. These soils occupy approximately half the total area of the Coast Prairie.

Edna and Bernard soils are upland soils having fine sandy loam or clay loam surfaces and subsoils with clay or clay loam textures. Edna soils are poorly drained while Bernard soils are somewhat poorly drained. These dark colored soils are slightly acid in reaction.

A narrow belt of nearly level, loamy Prairie soils lies inland from the Lake Charles and Edna-Bernard associations. These soils are primarily of the Katy, Hockley, and Clodine series. These soils have loamy or clayey subsoils. They are somewhat poorly drained and are moderately to very slowly permeable. These soils are primarily cropped to rice; however, in some areas, they are used for grain sorghum, cotton, and corn production.

The Colorado, Brazos, and Trinity Rivers dissect this region. The soils of the Brazos and Colorado Rivers bottomlands are reddish brown in color, slightly acid to calcareous, and loamy to clayey in texture. Major soil series include Brazoria and Norwood. Soils of the Trinity River are dark gray in color, slightly acid to calcareous, and loamy to clayey in texture. Major soils are Trinity and Kaufman series.

Soil Management and Conservation Considerations

Management and conservation of croplands in Southeast Texas are unique. Soils in the Coast Prairie tend to occur on nearly level plains with slow water runoff and generally poor internal drainage. This condition affects production and management of most crops produced in the area. Waterlogged or wet soils in the early spring may affect seedbed preparation, herbicide applications, fertilization, and timely planting of crops. Prolonged rainy periods during the growing season may result in poor soil aeration and reduced growth and lowered yields for such crops as soybeans, cotton, corn, and grain sorghum. Poor drainage may also delay harvest of these crops. For drainage considerations, planting on beds is recommended for all crops except rice, small grains, and hay crops.

Proper water management for rice production in Southeast Texas often requires land levelling. New environmental regulations also may require more precise water management, especially concerning tail water losses, which may contain pesticides or nutrients.

The major soil management problem, especially in sandy loam and silt loam soils, is often soil compaction. Frequently, these soils may be tilled or be subjected to vehicle traffic while the soil is wet. This compounds soil compaction problems. These compaction problems restrict plant rooting, and in crops other than rice, low soil oxygen levels may adversely affect plant growth and consequent yields.

Crusting is also a problem of soils in this region, particularly as it affects seedling emergence. Weak surface structure and low organic matter content may enhance surface crusting of soils after high intensity rainstorms. Cultivation may be required to break these surface crusts.

The terrain in Southeast Texas is nearly level; hence, soil erosion by water is not a major problem. Neither is wind erosion a major problem in this area.

Conservation tillage systems for rice production involve drastically different considerations than for systems not including rice. Disease and insect problems are more likely to occur when large amounts of organic residue are left on the surface, expecially in rice and soybean rotations. High levels of organic matter under anaerobic conditions in rice culture create severe reducing conditions that cause hydrogen sulfide production, which leads to root kills and increased disease problems. Tandem disks may be helpful in rice production since there is a need to bury organic matter and maintain a plow pan or restrictive layer for water conservation purposes. For other crops, minimum disturbance planting equipment is recommended.

In 1976, the Research Committee of the Association of Texas Soil and Water Conservation Districts, with assistance from several interested state and federal agency personnel, developed a listing and prioritization of the conservation problems which they recognized in their individual districts. The following is a partial listing of those problems in the Coast Prairie Land Resource Area as the District personnel identified them:

Inadequate drainage
Soil compaction
Weed control
Inefficient irrigation systems
Soil moisture conservation
Water erosion
Inefficient tillage systems

Conservation Tillage System Guidelines

Following are examples of selected possible conservation tillage systems for Southeast Texas, Region IV.

Southeast Texas Conservation Tillage System No. 1.

Cropping System: Continuous Grain Sorghum

Crop	Month	Tillage System Alternatives
Grain Sorghum	Aug.-Sept.	Shred
	Aug.-Sept.	Subsoil-List
	Jan.-Feb.	Fertilize
	Mar.	Tillage (if necessary for weed control)
	Mar.	Plant-Roll-Herbicide
	Apr.	Cultivate (as required)
	July	Harvest

Continuous grain sorghum is generally not suggested because of increased infestations of weeds (especially johnsongrass), insects and diseases. Winter weeds may be controlled by use of appropriate triazine herbicides in November.

The subsoil-list operation mentioned above features an operation consisting of subsoiling on row centers and forming beds in the same operation. Sufficient residue may remain at planting to require running a coulter ahead of the planter.

Southeast Texas Conservation Tillage System No. 2.

Cropping System: Cotton-Corn

Crop	Month	Tillage System Alternatives
Cotton	Aug.-Sept.	Shred
	Sept.	Subsoil-List
	Jan.-Feb.	Fertilize-Herbicide (Incorporated)
	Jan.-Feb.	List
	Mar.	Tillage (if necessary for weed control)
	Mar.	Plant-Roll
	Apr.-June	Cultivate (if necessary)
	August	Harvest
Corn	Aug.-Sept.	Shred
	Sept.	Subsoil-List
	Jan.-Feb.	Fertilize
	Mar.	Tillage (if necessary for weed control)
	Mar.	Herbicide (Incorporated)
	Mar.	Plant-Roll
	Apr.	Cultivate (if necessary)
	Aug.-Sept.	Harvest

Various implements may be used for incorporation of herbicides; however, best mixing of herbicide with soil may occur with tandem disking.

Southeast Texas Conservation Tillage System No. 3.

Cropping System: Rice-Grain Sorghum

Crop	Month	Tillage System Alternatives
Rice	July	Shred
	Aug.	Tandem Disk
	Sept.	Tandem Disk
	Dec.	Tandem Disk (with harrow behind disk)
	Dec.	Land Plane
	Jan.	Spring-tooth harrow
	Feb.-Mar.	Land Plane (if needed)
	Feb.-Mar.	Install Levees
	Mar.	Spring-tooth harrow
	Mar.	Fertilize-Herbicide
	Mar.	Plant
	July	Harvest
Grain Sorghum	Aug.	Tandem Disk
	Aug.-Sept.	Tandem Disk
	Sept.	Land Plane
	Jan.-Feb.	Fertilize
	Jan.-Feb.	List
	Feb.-Mar.	Tillage (if necessary for weed control)
	Mar.	Plant-Roll-Herbicide
	Apr.	Cultivate (as required)
	July	Harvest

This system is most commonly used when ratoon cropping is not practiced.

Continuous rice cropping is not suggested because of weed and disease control problems, and lack of time for adequate land preparation.

Southeast Texas Conservation Tillage System No. 4.

Cropping System: Grain Sorghum-Soybeans

Crop	Month	Tillage System Alternatives
Grain Sorghum	Nov.	Subsoil-List
	Jan.-Feb.	Fertilize
	Mar.	Tillage (if necessary for weed control)
	Mar.	Plant-Roll-Herbicide
	Apr.	Cultivate (as required)
	July	Harvest
Soybeans	July-Aug.	Shred
	Aug.-Sept.	Tandem Disk
	Feb.-Mar.	Tillage (as needed for weed control)
	Apr.	Fertilize-Herbicide (Incorporated)
	Apr.	List
	May	Tillage (as needed for weed control)
	May	Plant-Roll
	June	Cultivate (as required)
	Oct.	Harvest

Following a dry fall or winter, southern blight may present a problem on soybeans if high levels of residue remain. Phosphorus may be chiseled in the bed or applied at time of planting. Post-emerge directed herbicides may *substitute for some cultivations in soybeans.*

Various implements may be used for incorporation of herbicides; however, a tandem disk may give best results.

Southeast Texas Conservation Tillage System No. 5.

Cropping System: Grain Sorghum-Cotton

Crop	Month	Tillage System Alternatives
Grain Sorghum	Aug.-Sept.	Shred
	Sept.	Subsoil-List
	Jan.-Feb.	Fertilize
	Feb.	Tillage (as required for weed control)
	Mar.	Plant-Roll-Herbicide
	Apr.	Cultivate (as required)
	July	Harvest
Cotton	Aug.	Shred
	Aug.-Sept.	Subsoil-List
	Jan.-Feb.	Fertilize-Herbicide (Incorporated)
	Jan.-Feb.	List
	Mar.	Tillage (as required for weed control)
	Mar.	Plant-Roll
	Apr.	Cultivate (as required)
	Aug.	Harvest

Southeast Texas Conservation Tillage System No. 6.

Cropping System: Rice-Soybeans

Crop	Month	Tillage System Alternatives	
		Sandy Soils	Clayey Soils
Rice	Nov.	Tandem Disk	Tandem Disk
	Dec.	Tandem Disk (with harrow behind disk)	Tandem Disk (with harrow behind disk)
	Dec.	Land Plane	Land Plane (if needed)
	Jan.	Spring-tooth harrow	
	Feb.-Mar.	Land Plane	Tandem Disk
	Feb.-Mar.	Install Levees	Install Levees
	Mar.	Fertilize	Fertilize
	Mar.	Spring-tooth harrow	
	Mar.	Plant	Spring-tooth harrow
	Mar.		Plant
	July	Harvest	
	Aug.		Harvest
	Sept.-Oct.	Harvest (ratoon crop)	
Soybeans	Sept.		Remove Levees
	Oct.		Tandem Disk-Herbicide
	Oct.		Tandem Disk
	Dec.-Feb.		List
	Dec.-Feb.	Remove Levees	
	Mar.-Apr.	Tandem Disk-Herbicide	
	Mar.-Apr.	Tandem Disk (with harrow behind disk)	
	Apr.	List	
	May	Tillage (as needed for weed control)	Tillage (as needed for weed control)
	May	Plant-Fertilize	Plant-Roll-Fertilize
	June	Cultivate (as required)	Cultivate (as required)
	Oct.	Harvest	Harvest

On sandy soils, fall diskings (if dry enough) and early listing may help to conserve planting moisture.

On clayey soils, land plane in December if needed to break clods.

Herbicides for weed control in rice may be applied either before or after planting or a combination of the two.

Southeast Texas Conservation Tillage System No. 7.

Cropping System: Rice-Pasture

Crop	Month	Tillage System Alternatives	
		Sandy Soils	Clayey Soils
Rice	July-Sept.	Tandem Disk	Tandem Disk
	Nov.	Tandem Disk	Tandem Disk
	Dec.	Tandem Disk (with harrow behind disk)	Tandem Disk (with harrow behind disk)
	Dec.	Land Plane	Land Plane (if needed)
	Jan.	Spring-tooth harrow	
	Feb.-Mar.	Land Plane	Tandem Disk
	Feb.-Mar.	Install Levees	Install Levees
	Mar.	Spring-tooth harrow	
	Mar.	Fertilize	Fertilize
	Mar.	Plant	Spring-tooth harrow
	Mar.		Plant
	July	Harvest	
	Aug.		Harvest
	Sept.-Oct.	Harvest (ratoon crop)	
Pasture	Oct.	Plant	Plant

If red rice is a significant weed problem, the early disking in July through September may aid in its control.

Overseeded ryegrass greatly increases grazing during winter and spring.

Preplant or postemergence herbicides are available for weed control in rice.

Southeast Texas Conservation Tillage System No. 8.

Cropping System: Corn-Soybeans

Crop	Month	Tillage System Alternatives
Corn	Oct.-Nov.	Subsoil-List
	Jan.-Feb.	Fertilize
	Mar.	Tillage (if necessary for weed control)
	Mar.	Plant-Roll-Herbicide
	Apr.	Cultivate (as required)
	Aug.-Sept.	Harvest
Soybeans	Sept.	Shred
	Feb.-Mar.	Tandem Disk-Herbicide
	Feb.-Mar.	Tandem Disk
	Apr.	Fertilize
	Apr.	List
	May	Tillage (if needed for weed control)
	May	Plant-Roll
	June	Cultivate (as required)
	Oct.	Harvest

CONSERVATION TILLAGE GUIDELINES FOR SOUTH TEXAS

Characteristics of Region V

Region V consists of the Rio Grande Plain and the lower Coast Prairie Land Resource Area (Figure 1, page 117). This region comprises approximately 22 million acres of which approximately 5 million acres is cropland. The southern Coast Prairie, commonly referred to as the Coastal Bend, is intensively cropped, as is the Lower Rio Grande Valley and the Winter Garden area. The Winter Garden is comprised of all or parts of Zavala, Frio, Atascosa, Dimmit, La Salle, Uvalde, and Medina Counties. Most of the remainder of South Texas is presently utilized as range.

Topography of the Rio Grande Plain is essentially that of a nearly level to rolling, slightly to moderately dissected brushy plain with slow to rapid surface drainage. The area is bordered or traversed by the Rio Grande, Nueces, Frio, and San Antonio Rivers. The South Texas region ranges in elevation from sea level on the coast to approximately 1000 feet along its northwestern edge.

Climate

Climatic factors such as rainfall and temperature determine the range of crops that may be grown successfully in an area. Rainfall, both in terms of total rainfall and seasonal distribution, markedly affects the choice of cropping systems. Temperature affects crop production, primarily through the length of the growing season. Average annual rainfall in South Texas ranges from approximately 36 inches on the eastern edge of the lower Coast Prairie in Refugio County to approximately 16 inches per year in the northwestern portion of the Rio Grande Plain near Del Rio.

Average date of last killing frost in the spring in South Texas ranges from February 1 to March 1, while the average date of the first killing frost in the fall ranges from November 20 to December 30. This results in an average length of frost free period ranging from 260 to 330 days.

Soils

Soils in the South Texas region are perhaps more diverse than in any other region of the State; six taxonomic orders of soils are identified in the Rio Grande Plain. Rather than trying to describe the entire area, only those areas of rather intensive cropping will be described herein.

Soils of the Lower Coast Prairie (Coastal Bend Area) are dark colored, slightly acid to calcareous clay loams and clayey soils, changing gradually with depth to light colored calcareous clays. Among the main series are: Victoria, Orelia, and Clareville soils.

Soils of the Lower Rio Grande Valley are basically formed on deltas or coastal terraces. Soils are mostly deep, well drained, nearly level to gently sloping soils. Most of the soils are calcareous. The soils are generally dark brown to dark grayish brown in color in surface horizons. Surface textures range from fine sandy loam to clay, with subsoils ranging from sandy clay loam to clay. Internal drainage varies from moderately to very slowly permeable. Representative soils of this group include the Laredo and Harlingen on the low terraces and the Hidalgo and Willacy series on somewhat higher positions.

Soils of the Winter Garden area of the South Texas are also quite variable. Some of the cropland soils are deep nearly level to gently sloping, well drained, dark colored, loamy and clayey calcareous soils. These soils are typified by such series as Uvalde, Knippa, and Montell. Other soils of the Winter Garden area may be characterized as deep, nearly level to gently sloping, well drained, noncalcareous soils. These Duval and Miguel soils have fine sandy loam surface textures overlying clay or sandy clay loam subsoils.

Soil Management and Conservation Considerations

Management and conservation of cropland soils of South Texas are at least as variable and complex as the soils. A major problem over the entire South Texas region is conservation of soil moisture. In that part of the region with limited rainfall and where evaporation and transpiration rates are high, improved management practices are needed including conservation tillage and proper crop residue management. A major objective is to hold the rainfall on the land through terracing or contour farming until it can be absorbed by the soil. Tillage should be kept to a minimum, since excess tillage wastes soil moisture, damages soil structure, and causes formation of tillage pans. In the Coastal Bend area, it is estimated that approximately 50 percent of the acreage is presently under conservation tillage systems. However, little conservation tillage is practiced in the Rio Grande Valley or the Winter Garden area. Weed control will probably be the major problem in establishing conservation tillage systems in this region.

Some portions of the South Texas region are nearly level. Consequently, drainage is sometimes a problem on these soils. This condition may affect production and management of crops through delayed seedbed preparation, herbicide application, fertilization, and planting. Additionally, it may result in reduced crop growth and lower yields, as well as delayed harvest.

On those soils which are nearly level, water erosion is not often a severe problem. However, on more sloping soils, water erosion may remove considerable amounts of surface soil. Terraces and contour farming can be utilized in conjunction with grassed waterways to reduce runoff, erosion, and transport of sediment.

Soils of loamy surface texture frequently tend to form tillage or compaction pans. These pans are caused by relatively weak soil structure, low organic matter content, and improper tillage. Chiseling or some other deep tillage practice may be required every 2 to 4 years to break these compaction pans and allow for adequate root growth and air and water penetration into the subsoil. However, deep tillage in saline soils may cause severe problems.

Conservation tillage may result in increased soil moisture conservation and concurrent increased occurrence of saline seeps in some areas.

Crusting is also a problem on some soils in this region, particularly as it affects seedling emergence. Weak surface structure, combined with high intensity rainstorms commonly necessitate a cultivation operation to break surface crusts.

In 1976, the Research Committee of the Association of Texas Soil and Water Conservation Districts, with assistance from several interested state and federal agency personnel, developed a listing and prioritization of the conservation problems which District personnel recognized in their areas. Following is a partial listing of those problems as the District personnel identified them.

A. Rio Grande Plain

Soil Moisture Conservation

Weed Control

Water Erosion

Soil Compaction

Inadequate Drainage

Salinity (locally)

Inefficient Tillage Systems

B. Coast Prairie

- Inadequate Drainage
- Soil Compaction
- Weed Control
- Soil Moisture Conservation
- Water Erosion
- Inefficient Tillage Systems

Conservation Tillage System Guidelines

Following are examples of selected conservation tillage systems for South Texas, Region V.

South Texas Conservation Tillage System No. 1.

Cropping System: Corn-Grain Sorghum (Dryland)

Crop	Month	Tillage System Alternatives	
		Bed Planted	Flat Planted
Corn	July-Aug.	Shred	Offset Disk
	Aug.	Subsoil-List	
	Oct.-Feb.		Sweep Tillage (as require for weed control)
	Nov.	Row Disk	
	Nov.-Feb.	Tillage (as required for weed control)	
	Feb.	Fertilize	Fertilize
	Feb.-Mar.	Plant	Plant
	Feb.-Mar.	Herbicide	Herbicide
	Apr.	Cultivate (as required for weed control)	Cultivate (as required for weed control)
	July-Aug.	Harvest	Harvest
Grain Sorghum	Aug.	Shred	Offset Disk
	Aug.	Subsoil-List	
	Oct.-Feb.		Sweep Tillage (as require for weed control)
	Nov.	Row Disk	
	Nov.-Feb.	Tillage (as required for weed control)	
	Feb.	Fertilize	Fertilize
	Feb.-Mar.	Plant	Plant
	Feb.-Mar.	Herbicide	Herbicide
	Apr.	Cultivate (as required for weed control)	Cultivate (as required for weed control)
	July	Harvest	Harvest

Flat planting should only be considered on slopes less than 0.75%. Deep plowing may be required occasionally to break tillage pans. Flat planting may not be applicable for saline soils.

Fertilizer should be applied at the time of the last tillage operation before planting.

In the Lower Rio Grande Valley, dryland grain sorghum may be double-cropped with a crop of dryland corn planted in September. Corn seed production <u>may</u> not be feasible under this system because of weed problems and uncertain fall rainfall.

South Texas Conservation Tillage System No. 2.

Cropping System: Corn-Cotton (Irrigated and Dryland)

Crop	Month	Tillage System Alternatives
Corn	Aug.	Shred (cotton stalks)
	Aug.	Sweep Plow (to uproot cotton stalks) and List (all in one operation)
	Sept.-Jan.	Tillage (as required for weed control)
	Dec.-Jan.	Fertilize
	Jan.-Mar.	Plant
	Jan.-Mar.	Herbicide
	Feb.-Apr.	Cultivate (as required for weed control)
	July-Aug.	Harvest
Cotton	Aug.	Shred
	Aug.	Subsoil-List
	Nov.	Row Disk
	Dec.-Feb.	Tillage (as required for weed control)
	Dec.-Feb.	Fertilize
	Feb.-Mar.	Plant
	Mar.	Herbicide
	Apr.	Cultivate (as required for weed control)
	Aug.	Harvest

In Lower Rio Grande Valley plant about one month earlier than in the Coastal Bend. Deep tillage operations such as subsoiling should be performed as needed to break hardpans.

In cotton, directed spray postemerge herbicide applications may be substituted for cultivations. Preplant incorporated herbicides may be applied earlier in the year, at the risk of losing soil moisture. As outlined above, these herbicides may be applied and incorporated to a shallow depth after cotton is planted.

South Texas Conservation Tillage System No. 3.

Cropping System: Grain Sorghum-Cotton (Irrigated and Dryland)

Crop	Month	Tillage System Alternatives
Grain Sorghum	Aug.	Shred (cotton stalks)
	Aug.	Sweep Plow (uproot cotton stalks) and List (all in one operation)
	Sept.-Jan.	Tillage (as required for weed control)
	Dec.-Jan.	Fertilize
	Jan.-Mar.	Plant-Herbicide
	Feb.-Apr.	Cultivate (as required for weed control)
	June-July	Harvest
Cotton	July	Shred
	July-Aug.	Subsoil-List
	Nov.	Row Disc
	Dec.-Feb.	Tillage (as required for weed control)
	Dec.-Feb.	Fertilize
	Feb.-Mar.	Plant-Herbicide
	Apr.	Cultivate (as required for weed control)
	Aug.	Harvest

Deep tillage operations such as subsoiling should be performed as needed to break hardpans.

In cotton, directed spray postemerge herbicide applications may be substituted for cultivations. Preplant incorporated herbicides <u>may</u> be applied earlier in the year, at the risk of losing soil moisture. As outlined above, these herbicides may be applied and incorporated to a shallow depth after cotton is planted.

South Texas Conservation Tillage System No. 4.

Cropping System: Continuous Corn (Irrigated and Dryland)

Crop	Month	Tillage System Alternatives Bed Planting	 Flat Planting
Corn	July-Aug.	Shred	
	Aug.	Subsoil-List	Offset Disk
	Sept.-Feb.		Tillage (as required for weed control)
	Nov.	Row Disk	
	Nov.-Feb.	Tillage (as required for weed control)	
	Feb.	Fertilize	Fertilize
	Feb.-Mar.	Plant	Plant
	Feb.-Mar.	Herbicide	Herbicide
	Apr.	Cultivate (as required for weed control)	Cultivate (as required for weed control)
	Aug.	Harvest	Harvest

Western corn rootworms may cause severe problems in continuous corn in some areas. Crop rotation is the best practice for control of this insect.

Flat planting of corn may be adapted to some sprinkler irrigated areas and in dryland areas with less than 0.75% slope on fine and medium textured soils and up to 1.5% slope on coarser textured soils.

Dryland corn is not suggested in the Winter Garden area.

Irrigated corn planted on bedded land may require that water furrows be reshaped after planting.

South Texas Conservation Tillage System No. 5.

Cropping System: Small Grain - Grain Sorghum (Dryland and Irrigated)

Crop	Month	Tillage System Alternatives	
Wheat	July	Shred	
	Aug.	Sweep Plow (to uproot grain sorghum stalks)	
	Sept.-Oct.	Fertilize	
	Sept.-Oct.	Tillage (as required for weed control)	
	Oct. or Dec.-Jan.	Plant	
	May	Harvest	
		Bed Planted	Flat Planted
Grain Sorghum	June-Sept.	Sweep Tillage (as required for weed control)	Sweep Tillage (as required for weed control)
	Sept.	List	
	Oct.-Feb.	Tillage (as required for weed control)	Sweep Tillage (as required for weed control)
	Feb.	Fertilize	Fertilize
	Mar.	Plant-Herbicide	Plant-Herbicide
	Apr.	Cultivate (as required for weed control)	Cultivate (as required for weed control)
	July	Harvest	Harvest

Plant winter wheat in October and spring wheat in late December or early January.

Small grains may reduce weed populations, including johnsongrass, by forming a dense canopy in early spring. This condition reduces weed seed germination and hampers growth of small weeds.

Herbicide may be substituted for plowing in preparing land for wheat planting.

South Texas Conservation Tillage System No. 6.

Cropping System: Continuous Grain Sorghum (Dryland)

Crop	Month	Tillage System Alternatives	
		Bed Planted	Flat Planted
Grain Sorghum	July-Aug.	Shred	Offset Disk
	Aug.	Subsoil-List	
	Oct.-Feb.		Tillage (as required for weed control)
	Nov.	Row Disk	
	Nov.-Feb.	Tillage (as required for weed control)	
	Dec.-Feb.	Fertilize	Fertilize
	Feb.-Mar.	Plant-Herbicide	Plant-Herbicide
	Apr.	Cultivate (as required for weed control)	Cultivate (as required fo weed control)
	July	Harvest	Harvest

Flat-planting should be considered only on slopes less than 0.75% for medium and fine textured soils, but may be practiced on slopes up to 1.5% on coarse-textured soils. Bed-planting is appropriate for all slopes, but should be on the contour for slopes greater than 1%. Deep tillage may be required occasionally to break hardpans. Fertilizer should be applied at the time of the last plowing before planting.

Continuous grain sorghum should only be planted on land that is relatively low in johnsongrass infestation.

CONSERVATION TILLAGE SYSTEMS RESEARCH NEEDS

Concurrent with development of the conservation tillage guidelines, associated research needs were identified by program participants. The list of needs given below is not intended to be exhaustive and no attempt has been made to prioritize the needs. There was a strong recommendation from all involved that research efforts be expanded in the areas of conservation tillage systems and related cropping systems. Research needs identified are:

1. Develop the most appropriate conservation tillage system(s) and specific practices for various cropping systems in different areas of the State.
2. Develop herbicides or application techniques for herbicides which do not require total residue burial during herbicide incorporation for use in cotton or soybeans. Determine interaction of herbicide application rates and techniques with varying levels of surface crop residue.
3. Determine the impact of conservation tillage systems on available soil moisture, water use efficiency, infiltration rates, and permeability of soils at different periods of the year.
4. Determine effects of conservation tillage systems on physical and chemical properties of soils.
5. Evaluate effectiveness of fertilizer application techniques and placement for conservation tillage systems.
6. Design of tillage equipment for use in conservation tillage systems.
7. Determine effects of various crop residue management systems on insect and disease incidence.
8. Evaluate the applicability of multiple cropping in combination with conservation tillage systems.

9. Determine the feasibility of flat planting as compared with conventional bed and furrow planting for cropping regions of the State.

10. Determine the economic feasibility of a change from conventional tillage to conservation tillage as affected by changes in equipment inventory, production economics, and other factors.

11. Develop equipment to apply herbicides and plant with minimum soil disturbance for crops such as cotton, corn, grain sorghum, and soybeans.

12. Determine appropriate integrated pest management programs for conservation tillage systems.

13. Develop effective combinations of tillage and crop residue management systems that will control wind and/or water erosion.

14. Develop an effective system of estimating crop stage periods for the total year for use in conservation planning and other activities involving use of wind erosion equations. A climatic curve for wind, similar to the EI curve useful with the Universal Soil Loss Equation, is also needed.

15. Determine the need for tillage operations designed to "aerate" the soil where weed control is not a consideration.

APPENDIX

Following are listings of the participants at the Regional and State Workshops which were held to develop the Conservation Tillage Guidelines.

REGION I

Name	Agency*	Location
Earl C. Gilmore	TAES	Vernon
B. A. Stewart	USDA-SEA-AR	Bushland
Norman P. Bade	USDA-SCS	Vernon
Jerry J. Waller	USDA-SCS	Temple
G. B. Thompson	TAES	Amarillo
Richard B. Heizer	USDA-SCS	Amarillo
David G. Bordovsky	TAES	Munday
L. E. Clark	TAES	Vernon
Cleve J. Gerard	TAES	Vernon
R. R. Allen	USDA-SEA-AR	Bushland
Paul W. Unger	USDA-SEA-AR	Bushland
Wayne H. Hudnall	West Texas State University	Canyon
Frank C. Petr	TAEX	Amarillo
Harold V. Eck	USDA-SEA-AR	Bushland
Aubra C. Mathers	USDA-SEA-AR	Bushland
Allen F. Wiese	TAES	Bushland
B. L. Harris	TAEX	College Station
A. Edwin Colburn	TAEX	College Station
R. W. Berry	TAEX	Lubbock

REGION II

Name	Agency*	Location
B. L. Harris	TAEX	College Station
Frank M. Hons	Texas Tech University	Lubbock
H. Dale Pennington	TAEX	Lubbock
Willis B. Gass	TAEX	San Angelo
Robert W. Berry	TAEX	Lubbock
Levon L. Ray	TAES	Lubbock
Jaroy Moore	TAES	Pecos
W. M. Lyle	TAES	Lubbock--Halfway
Elmer B. Hudspeth	USDA-SEA-AR	Lubbock
John R. Abernathy	TAES	Lubbock
J. D. Bilbro	USDA-SEA-AR	Big Spring
Richard Zartman	Texas Tech University	Lubbock
Jerry J. Waller	USDA-SCS	Temple
Norman P. Bade	USDA-SCS	Vernon
D. W. Fryrear	USDA-SEA-AR	Big Spring
Charles W. Wendt	TAES	Lubbock
R. D. Brigham	TAES	Lubbock
Norman Hopper	Texas Tech University	Lubbock
A. Edwin Colburn	TAEX	College Station

REGION III

Name	Agency*	Location
B. L. Harris	TAEX	College Stat
Robert B. Metzer	TAEX	College Stat
A. Edwin Colburn	TAEX	College Stat
Bob Kral	USDA-SCS	Corsicana
John E. Adams	USDA-SEA-AR	Temple
W. M. Miller	USDA-SCS	Temple
Claude Compton	USDA-SCS	Nacogdoches
John Morrison	USDA-SEA-AR	Temple
G. F. Arkin	TAES	Temple
John E. Bremer	TAEX	College Stat
Dave N. Weaver	TAEX	College Stat
Earl Burnett	USDA-SEA-AR	Temple
Joe E. Cole	TAEX	Dallas
Ashley C. Lovell	TAEX	Bryan
George D. Alston	TAEX	Stephenville
Clarence W. Richardson	USDA-SEA-AR	Temple
L. P. Wilding	TAES	College Stat

REGION IV

A. Edwin Colburn	TAEX	College Stat
John E. Bremer	TAEX	College Stat
B. L. Harris	TAEX	College Stat
Arlen Klosterboer	TAEX	Beaumont
Robert B. Metzer	TAEX	College Stat
C. C. Bowling	TAES	Beaumont
E. Ford Eastin	TAES	Beaumont
Charles W. Helpert	TAES	Beaumont
J. W. Stansel	TAES	Eagle Lake
Garry N. McCauley	TAES	Beaumont
Fred T. Turner	TAES	Beaumont
N. G Whitney	TAES	Beaumont
A. R. Gerlow	TAEX	Bryan
J. P. Craigmiles	TAES	Beaumont
Henry C. Bogusch, Jr.	USDA-SCS	Temple
Curtis Cox	USDA-SCS	Bryan
Walter J. Walla	TAEX	College Stat
John W. Sij	TAES	Beaumont
Homer Paschal	TAES	Beaumont

REGION V

Name	Agency*	Location
Henry C. Bogusch, Jr.	USDA-SCS	Temple
Dennis W. Neffendorf	USDA-SCS	Harlingen
John E. Bremer	TAEX	College Station
Jerry B. Lee	USDA-SCS	Harlingen
Fred Minzenmayer	USDA-SCS	Alice
L. P. Wilding	TAES	College Station
T. C. Longnecker	TAES	Corpus Christi
James R. Mulkey, Jr.	TAES	Uvalde
A. Edwin Colburn	TAEX	College Station
John E. Matocha	TAES	Corpus Christi
Ruben Frankenhauser	USDA-SCS	Robstown
B. L. Harris	TAEX	College Station
Lucas Reyes	TAES	Corpus Christi

STATE WORKSHOP

Name	Agency*	Location
Fred H. Squyres	TSSWCB	Dumas
Josephine Chupik	TSSWCB	Temple
William B. Bayer	Farmer	Bloomington
Alvis L. Lipscomb	Farmer	Victoria
W. Y. Reece	TSSWCB	Lubbock
Clifford L. Williams	USDA-SCS	Temple
Richard B. Heizer	USDA-SCS	Amarillo
Jerry J. Waller	USDA-SCS	Temple
James O. Neighbors	USDA-SCS	Temple
William M. Miller	USDA-SCS	Temple
Joe E. Cole	TAEX	Dallas
Frank C. Petr	TAEX	Amarillo
Joe Freeman	TSSWCB	Temple
Willis B. Gass	TAEX	San Angelo
John L. Kazda	USDA-SCS	Gainesville
Bob Kral	USDA-SCS	Corsicana
Lanny O. Ashlock	TAEX	Corpus Christ
C. D. Welch	TAEX	College Stati
Mel Davis	TSSWCB	Temple
James M. Moore	TSSWCB	Temple
Earl Burnett	USDA-SEA-AR	Temple
John Morrison	USDA-SEA-AR	Temple
John G. Thomas	TAEX	College Stati
Murray H. Milford	Texas A&M University	College Stati
Glen L. Wistrand	USDA-ESCS	Temple
W. T. Crumley	TSSWCB	Graham
Kenneth L. Smith	TAEX	Overton
R. B. Metzer	TAEX	College Stati
John E. Bremer	TAEX	College Stati
Kirby Huffman	TAEX	Uvalde
Ashley C. Lovell	TAEX	Bryan
Omar J. Garza	TSSWCB	Alice
Fred Minzenmayer	USDA-SCS	Alice
Barney L. Jefferson	TSSWCB	San Angelo
Elmer R. Seidensticker	TSSWCB	Kerrville
Donald W. Fryrear	USDA-SEA-AR	Big Spring
Paul W. Unger	USDA-SEA-AR	Bushland
Ronald R. Allen	USDA-SEA-AR	Bushland
A. C. Spencer	TSSWCB	Temple
B. A. Stewart	USDA-SEA-AR	Bushland
Norman P. Bade	USDA-SCS	Vernon
Henry C. Bogusch, Jr.	USDA-SCS	Temple
Jerry B. Lee	USDA-SCS	Harlingen
Claude K. Compton	USDA-SCS	Nacogdoches
Dennis W. Neffendorf	USDA-SCS	Harlingen
Richard Zartman	Texas Tech University	Lubbock
Curtis C. Cox	USDA-SCS	Bryan

Name	Agency*	Location
Jay Kuykendall	TSSWCB	Temple
Billy W. Hipp	TAES	Dallas
Atlan Pfluger	TDWR	Austin
Terrell Robison	TDWR	Austin
Allen V. Sheppard	TSSWCB	Yoakum
Clyde J. Gottschalk	TSSWCB	Temple
C. R. Taylor	TAES	College Station
Clarence W. Richardson	USDA-SEA-AR	Temple
Dale D. Allen	USDA-SCS	Temple
W. W. Grisham, Jr.	TAEX	College Station
David C. Powell	TSSWCB	Mt. Enterprise
Larry P. Wilding	TAES	College Station
E. M. Trew	TAEX	College Station
W. B. Anderson	TAES	College Station
Richard W. Weaver	TAES	College Station
P. L. Adkisson	Texas A&M University	College Station
Don F. Newman	EPA	Dallas
B. L. Harris	TAEX	College Station
A. Edwin Colburn	TAEX	College Station

*Abbreviations:

TSSWCB - Texas State Soil and Water Conservation Board
USDA-SCS - United States Department of Agriculture - Soil Conservation Service
TAEX - Texas Agricultural Extension Service
USDA-SEA-AR - United States Department of Agriculture - Science and Education Administration - Agricultural Research
TAMU - Texas A&M University
USDA-ESCE - United States Department of Agriculture - Economics, Statistics, and Cooperative Service
TAES - Texas Agricultural Experiment Station
TDWR - Texas Department of Water Resources
EPA - Environmental Protection Agency

Cooperative Extension Work in Agriculture and Home Economics, The Texas A&M University System and the United States Department of Agriculture cooperating. Distributed in furtherance of the Acts of Congress of May 8, 1914, as amended, and June 30, 1914. AGR 16

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