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Cost and Yield Effects of Reduced Tillage Systems Used in the Northern and Central Great Plains

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ABSTRACT

Growing concern about increased production costs has accelerated the search for alternative crop tillage methods. Depletion of soil resources further enhances interest in moderating land surface disturbance by reducing tillage intensity. This report brings together conclusions from research trials and farmer experiences regarding use of reduced tillage methods in the northern and central Great Plains. Results are not reported uniformly; however, production costs, crop yields and rotations, chemical use, machine use, weed control, and gross and net returns are compared. The importance of good management is emphasized especially while switching from one tillage method to another.

Keywords: Conventional tillage, conservation tillage, reduced tillage, no-till, production costs, yields, gross returns, net returns.

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CONTENTS

SUMMARY

Each year additional land in the northern and central Great Plains is farmed with some sort of nonconventional tillage system. The experiments and studies mentioned in this report examined many of the systems currently in use. Attempts were made to collect information on as many studies as possible. As always, studies may have been unintentionally overlooked.

Generally, the yields of reduced tillage systems nearly always equalled or exceeded those of the conventional systems. The substitution of chemical weed control for mechanical tillage increases the quantity of residue on the soil surface thus decreasing soil loss through wind and water erosion as well as increasing the quantity of water retained in the soil and thus available during the cropping season.

Ecofallow is a conservation tillage method unique to the Great Plains. In corn, sorghum, and wheat production, ecofallow has proven to be an economically viable alternative to the conventional fallow procedure. While the initial costs are greater with ecofallow, the additional yields are sufficient to more than offset the added costs.

There were situations where conservation tillage systems performed worse than appropriate conventional tillage systems would have performed. In most cases, management problems or unusual weather conditions were at fault. Conservation tillage requires a level of management at least equal to--or better than--that with conventional tillage. In other cases, problems arose when chemicals were used at a level appropriate for conventional tillage without taking into account changes that occurred due to the switch in tillage systems. As more research is done and farmers become more familiar with conservation tillage methods, many of these problems will be eliminated.

Overall it appears that conservation tillage systems perform better in areas with longer growing seasons. In the northern areas of the Great Plains there is little, if any, yield advantage to conservation tillage while in the central Great Plains conservation tillage systems frequently outperform conventional tillage.

GLOSSARY

Bare fallow - a croping system using mechanical tillage to control weeds during the fallow period.

Black fallow - a cropping system using mechanical tillage to control weeds during the fallow period. As a result little, or no residue remains at planting time.

Chemical conservation - a reduced tillage system using chemicals to control weeds.

Chemical fallow - a cropping system that uses chemicals and subsurface tillage to control weeds during fallow with a minimum disturbance of crop residue.

Chisel-plant - a cropping system using a chisel plow for the primary tillage before crops are planted.

Chisel plow - a primary tillage tool that breaks up the soil rather than inverting it. About 50 to 75 percent of the crop residue is left on the surface.

Clean till fallow - the use of machine tillage without chemicals to control weeds during a fallow period.

Conservation tillage - any soil management practice that leaves the soil more resistant to erosion and conserves more moisture than does conventional tillage by retaining a portion of the previous crop's residue on the soil surface.

Conventional - a tillage system where 100 percent of the soil surface is mixed or inverted by plowing, disking, or other means to control weeds and prepare a seedbed.

Conventional fallow - a tillage system where machine tillage without chemicals is used to control weeds during a fallow period.

Double disk - a tillage system where the primary tillage implement is a tandem disk.

Ecofallow - the use of a combination of chemical application and mechanical tillage to control weeds throughout the fallow period of a crop-fallow rotation.

Fallow - the time between the harvest of one crop and the planting of the next crop.

Listing - a tillage system using a lister to form ridges between planted crop rows. During the growing season cultivation builds up the existing ridges and the next crop is planted on these same rows.

Minimum tillage - a system of limited tillage but where the total field surface is still worked by tillage equipment.

Moldboard plowing - a conventional tillage system where the entire soil surface is inverted with a moldboard plow.

Mulch tillage - preparation of the soil so that plant residues are left to cover the soil surface both before and after the new crop is established.

No-till - a system in which a crop is planted directly into soil that has not been tilled since the harvest of the previous crop. The seed is placed in a 1- to 2-inch wide strip opened with fluted coulters, narrow chisel points, or angled disks.

Noble blade - a tillage system where weeds are controlled using a subsurface sweep implement manufactured by the Noble Co.

One-way disk plowing - a tillage system using a one-way disk as the primary tillage implement. The entire soil surface is disturbed.

Reduced till (or tillage) - a tillage system in which the number of tillage operations is reduced. This may or may not be a conservation tillage system depending upon the quantity of residue left on the soil surface.

Stubble mulch - preparation of the soil so that plant residues are left to cover the soil surface both before and after the new crop is established.

Stubble undercut - a tillage system where large sweeps are used below the soil surface to control weed growth. Most of the previous crop residue remains on the surface to control wind and water erosion.

Subtilling - a tillage operation using chisels or sweeps to invert the soil below the soil surface thus leaving a majority of the previous crop's residue in place.

Sweep - a tillage implement with wide V-shaped bars that run beneath the soil surface to loosen the soil and control weeds.

Till plant - a tillage system where seedbed preparation and planting are done in one operation. Tillage is limited to a strip not wider than a third of the total area.

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INTRODUCTION

The acceptance and use of conservation* tillage methods depends in part upon the economic implications of the practices, relative to conventional methods 1/. Changing from one practice to another can affect the operator's economic returns through differences in production cost and/or yield. The percentage of residue buried by the most common tillage machines is shown in table 1. The higher proportion of residue on the soil surface from reduced tillage is important because it serves to decrease wind and water erosion and increase infiltration from precipitation. Herbicides replace some of the mechanical tillage operations as a means of controlling weed growth.

This report assembles the results of numerous completed studies. For ease in discussion the findings are grouped according to the land areas to which they apply. Those related to multistate locations are presented first. Then State by State, the more site-specific works are discussed for the major crops of the Northern and Central Great Plains regions: corn, grain sorghum, and wheat.

The same tillage practice may be called by various names in different farming areas. Also in some studies it is hard to know exactly what a term means. Therefore, it is difficult to compare results from different studies. A majority of the tillage systems examined in this report can be categorized into five general types:

- o Conventional tillage mixes or inverts 100 percent of the soil surface by plowing or disking to control weeds and prepare a seedbed.

- o Conservation tillage retains a portion of the residue from the previous crop on the soil surface in order to leave the soil more resistant to erosion and to conserve more moisture than conventional tillage.

1/ Terms marked with an asterisk (*) are defined in the Glossary.

- o Chemical conservation is a reduced tillage system using chemicals as the major means to control weeds.

- o Ecofallow is a specific chemical conservation system using a combination of chemical application and mechanical tillage to control weeds throughout the fallow period of a crop-fallow rotation.

- o No-till is where the crop is planted directly into soil that has not been tilled since harvest of the previous crop. The seed is placed in a 1- to 2-inch wide strip opened with fluted coulters, narrow chisel points, or angled disks.

In some cases it is not possible to identify a specific category into which a system fits due to insufficient information in the literature. Brief explanations of the various tillage systems are provided in the glossary.

Table 1--Amount of residue buried by tillage operations

Machine	Residue buried
	Percent
Moldboard plow	100
One way	40
Disk, tandem (1" depth):	
18 - 22" disks	40
24 - 26" disks	50
Disk, offset (1" depth):	
18 - 22" disks	40
24 - 26" disks	50
Chisel plow	25
Mulch treader	20-25
Sweep, 30" or larger	10
Rodweeder	5-10
Slot planter	0
Till planter, 3" deep on ridge	20

Source: (30). 2/

2/ Underscored numbers in parentheses refer to literature cited at the end of this report.

MULTISTATE STUDIES

Conservation tillage utilizes resources differently than does conventional tillage. Crosson reaches some general conclusions comparing the use of inputs by the two systems (11). With conservation tillage fewer hours of labor are required, equipment costs are lower, maintenance cost is lower, and less fuel is used 3/. Crosson makes no generalizations about fertilizer use, because this factor varies depending upon the soil type, climate, crop, and the nutrient in question. Herbicide use is generally higher with conservation tillage; insecticide and fungicide use may or may not be higher. Overall, the total quantity of pesticides used is greater for conservation rather than conventional tillage. The general opinion is that conservation tillage requires better management than conventional tillage. Figures for the cost of this increase in skill, while generally low, are crude estimates at best. After taking into account all of these factors, the consensus of Crosson and others is that total nonland costs are lower with conservation tillage for cotton, corn, sorghum, wheat, and soybeans.

Crosson also makes some conclusions about the yield differences between tillage systems based upon recent research findings. He breaks these effects into long- and short-term differences (11). He proposes that erosion is never greater in conservation tillage than with conventional; therefore, there will never be a yield disadvantage to conservation tillage 4/. However, on a short-run basis, neither system has produced consistently higher yields.

Each year the No-Till Farmer (31) estimates the amount of no-tilled, minimally tilled and conventionally tilled acres of cropland. These data are published by category for each State. In 1982, about 30 percent of the cropland in the Northern Plains was tilled less than with conventional methods. This contrasts with only 15 percent in the Southern Plains area. This difference is due in part to the drier climate of the Northern Plains. However, State-level estimates show that the percentage of cropland in conservation tillage is smaller for more northern States with shorter growing seasons. In Kansas, 50 percent of the cropland is in conservation tillage compared to 44 percent in Nebraska, 19 percent in South Dakota, and 14 percent in North Dakota.

Several different conservation tillage systems are used in the Northern Great Plains area, according to C. R. Fenster (13). He reports that "According to the Soil and Water Conservation Needs Inventory, about 45 percent of the 37 million acres of fallow (15 million hectares) in the Northern Great Plains is farmed with stubble mulch* or another conservation tillage system." A second system used in this area is ecofallow* which combines herbicides and subsurface tillage to control weeds and conserve moisture.

In the Southern Great Plains acceptance of conservation tillage has been slower. The most widely utilized system there is stubble mulch tillage for wheat production.

3/ The occasional need for conventional tillage can be met by hiring rather than owning the necessary equipment.

4/ Crosson implicitly assumes that weed and disease problems will not increase with the change in tillage systems.

Smika promotes chemical fallow* as a management technique suitable for wheat production in the Central Great Plains area (43). This method conserves moisture as well as reduces wind erosion. A 10-bushel increase in average yields has been realized, 44 bushels compared to 34 bushels with a conventional fallow* system. Weed control costs are estimated at $18 to $24 per acre with chemical fallow compared to $17 to $23 per acre with conventional fallow. Fuel consumption is reduced by 50 to 70 percent with chemical fallow.

Fenster, Owens, and Follett compare wheat yields from three tillage systems under wheat-fallow and continuous wheat cropping systems for locations in nine States in the Great Plains: one-way disk plowing*, stubble-mulch tillage, and moldboard plowing* (15). In general, there were only slight yield differences between the three systems with no one system consistently better.

STUDIES RELATING TO INDIVIDUAL STATES

The authors examined a number of studies which relate to individual States or specific areas within those States. Here is a general discussion of those studies.

North Dakota

Two studies from North Dakota examine alternative tillage systems. Both deal with spring wheat grown in the eastern part of the State. Several different systems are compared in each study. One experiment deals only with fall primary tillage while the other compares fall and spring tillage systems.

Work from the Carrington Experiment Station (east-central North Dakota) is reported by Armand Bauer (7). Four fall tillage alternatives are compared: no fall tillage, moldboard plow, double disk*, and Noble blade* (table 2). Despite the difference in rainfall between the 2 years, the relative rankings of the four tillage systems (based on yields) were the same. Yields were highest when the moldboard plow was used in the fall, followed by the Noble blade system, the double disk, and no fall tillage alternatives.

An experiment comparing several conventional tillage systems to no-till has been going on at the Langdon Experiment Station (northeast North Dakota) since 1977 (35). Crop yields during the 4-year period (1977-1980) seemed directly related to plant stands at emergence and to soil moisture at planting. The no-till plots tended to have more soil moisture at planting than any other treatment. The fall chisel plow* produced the highest average yields of the wheat, barley, flax, and mustard crops for the 4-year period. No-till had the next highest yields followed by fall plowing and spring chisel plowing. This contrasts with the results when the spring wheat crop is considered separately. Fall plowing produced the highest wheat yields, followed by spring plowing, and no-till. Fall and spring chisel plowing produced the lowest yields (table 3).

In the Langdon study, planting costs were estimated based upon the number of field operations for each tillage system, excluding the cost of seed, starter fertilizer, and land. These figures show that fall plowing is the most costly system followed by spring chisel plow, no-till, fall chisel plow, and spring plow.

Table 2--Spring wheat yields, by tillage method, 1967 and 1969, Carrington, North Dakota

Tillage	Crop year: 1967	Crop year: 1969
	Bushels per acre 1/	
No fall tillage	14.8	41.6
Moldboard plow	18.0	49.3
Double disk	15.4	45.3
Noble blade	17.4	46.0

1/ The extreme variations in yield between crop years may be due in part to the difference in rainfall, 2.98 inches in 1967 and 11.44 inches in 1969.

Source: (7).

Table 3--Tillage study, Langdon, North Dakota

Tillage system	Four-year average wheat yields 1/	Field operations	Cost of operations 2/
	Bushels per acre	Number	Dollars per acre
Fall plow	36.1	10	54.50
No-till	34.8	6	52.00
Fall chisel plow	34.4	10	52.00
Spring chisel plow	33.5	10	53.00
Spring plow	35.8	9	50.00

1/ Average for 1977 thru 1980.
2/ Excluding cost of seed, starter fertilizer, and land.

Source: (35).

South Dakota

Two types of information are available for different tillage methods used in South Dakota: budget estimates and actual data. The budget analyses will be discussed first. This information is grouped first according to crop and then by results and areas as necessary to get meaningful combinations. The results of the actual field research are presented by individual projects, grouping these, where possible, by crop.

Firm Enterprise Data Systems (FEDS) budgets (12) calculate costs and returns for three major crops (corn, winter wheat, and spring wheat) in four South Dakota regions (eastern, east-central, western, and west-central). The data used to build the budgets come from a variety of sources including, but not limited to, Statistical Reporting Service (SRS) surveys, State research personnel, ERS, and informed individuals on a local level. The yields, input price, and product price data are updated annually while the production technology information is updated every 3 to 5 years. Based on this information, budgets are generated to estimate costs and returns under specific conditions. The two most recent sets of budgets for South Dakota are based on 1978 and 1979 prices (table 4). Comparing the 1979 price level budgets with those of 1978 reveals that the relative economic attractiveness of the various tillage systems is similar in most cases 5/. The discussion of South Dakota covers both sets of budgets unless otherwise noted. In some cases, budgets exist for only 1 year.

Budgets for corn are available for the eastern region. Yields are assumed to be 50 bushels per acre for each of the three tillage systems: conventional, conservation, and no-till. The most economically attractive system is no-till followed by conservation tillage. Conventional tillage is the least attractive.

Spring wheat budgets are available for the east-central, west-central, and western regions of South Dakota 6/. The yields from conventional tillage with fallow and minimum tillage with fallow are assumed to be equal. They are also assumed to be greater than the yield from conventional tillage continuously cropped. Within each system the yields vary according to the region. In the east-central and western regions conventional tillage with fallow provides a greater return than conventional tillage continuously cropped. These are the only two systems compared for these regions. For the west-central region also, conventional tillage with fallow is more economically attractive than conventional continuously cropped but the minimum tillage with fallow system is the most attractive of all.

Winter wheat budgets for the east-central and west-central regions compare three systems: conventional tillage with fallow, conventional tillage continuously cropped, and minimum tillage with fallow. As in previous South Dakota budgets the yields of conventional tillage with fallow and minimum tillage with fallow are assumed equal and are greater than the yields of conventional tillage continuously cropped. A very limited amount of information is available for the east-central region. The 1978 budgets reveal higher returns for conventional tillage with fallow relative to conventional tillage continuously cropped. There are conflicting results for the west-central region. As in the east-central region, conventional tillage with fallow and minimum tillage have higher returns than conventional tillage continuously cropped. But the rankings of minimum tillage and conventional tillage with fallow are different for the two sets of budgets. With 1978 prices minimum tillage is the most attractive but with 1979 prices conventional tillage with fallow is the best.

5/ For this report, economic attractiveness is based upon the return to land, overhead, risk, and management per acre. The figure return to land, overhead, risk, and management is calculated by subtracting variable costs and ownership costs from the gross receipts from production.

6/ The 1978 budgets are the only ones available for the Western region.

Table 4--South Dakota FEDS budget information by crop

Crop/region	Tillage system	Yield		Total variable cost		Income above variable cost		Return to land overhead, risk and management	
		1978	1979	1978	1979	1978	1979	1978	1979
		Bushels per acre		Dollars					
Corn:									
Eastern	Conventional tillage	50	50	66.25	77.49	27.25	39.51	13.34	5.08
	Conservation tillage	50	50	68.21	74.97	25.29	42.03	13.86	13.75
	No-till	50	50	63.96	65.89	29.54	51.11	19.53	22.87
Spring Wheat:									
East Central	Conventional tillage (fallow)	28	28	35.08	30.12	41.36	47.16	27.09	21.14
	Conventional tillage (continuous)	20	20	27.69	29.22	26.91	25.98	17.73	4.45
West Central	Conventional tillage (fallow)	25	25	40.55	35.37	27.70	33.63	19.37	10.86
	Conventional tillage (continuous)	18	18	34.00	28.95	15.14	20.73	10.20	2.91
	Minimum tillage	25	25	38.10	30.52	30.15	38.48	23.78	28.11
Western	Conventional tillage (fallow)	25	--	28.10	--	40.15	--	29.28	--
	Conventional tillage (continuous)	16	--	24.71	--	18.97	--	9.44	--
Winter Wheat:									
East Central	Conventional tillage (fallow)	32	--	30.02	--	50.30	--	41.25	--
	Conventional tillage (continuous)	18	--	27.90	--	17.28	--	11.56	--
West Central	Conventional tillage (fallow)	19	19	36.90	27.58	10.79	24.86	4.18	16.67
	Conventional tillage (continuous)	15	15	32.19	26.82	5.46	14.58	1.14	-3.31
	Minimum tillage	19	19	34.60	28.21	13.09	24.23	8.35	5.30

-- = Not applicable.

Source: (12).

This difference in rankings can be attributed to an unexplained increase in machinery and equipment ownership costs for minimum tillage relative to conventional tillage with fallow for the 1979 budgets that was not in the 1978 budgets.

Three studies were found which deal with minimum tillage research in South Dakota. They range in scope from an estimate of summer fallow costs to a report on a tillage study done by South Dakota State University to a multiyear study of a farm in Elkton, South Dakota.

In one of these studies, John C. McMartin used a partial budget approach to compare the costs of conventional summer fallow to those of chemical fallow* for Spink County in northeast South Dakota (33). The cost with conventional tillage was estimated as $12.62 per acre. With conservation tillage, the cost was $23.59 per acre. He concluded the paper with three comments comparing the two systems:

1. Under the conventional tillage system, it is unlikely that weeds would have been controlled the first fall.

2. The conservation tillage will usually result in greater yields on the succeeding crop because of the added moisture held by the crop residue.

3. The conservation tillage system will control erosion by wind and water erosion.

Quentin S. Kingsley reported on eight experiments to evaluate tillage methods and water-use efficiency in the drier areas of South Dakota (25). These experiments involve various combinations of five tillage treatments, eight crop sequences, and four fertility or fertilization ratios ($N:P_2O_5$). Several conclusions were reached from the results. Corn yields were not significantly affected by tillage treatment except chisel plow with 30 lbs. of P_2O_5 which produced 7.4 bushels more than stubble mulch at the same fertilizer level. With continuous winter wheat, survival over the winter was much better with mulch tillage than with the chisel plow system. In a spring wheat--oats cropping sequence, the effects of tillage methods were minimal. In a winter wheat--oats sequence, wheat yields were 8 bushels greater with chisel plowing than with mulch tillage* at the highest fertility ratio (45 lb. N, 30 lb. P_2O_5). Oats yields in the crop sequence showed no consistent pattern. Kingsley concluded by saying:

> Tillage methods comparing mulch tillage with 32-inch sweeps versus chisel plow with 16-inch sweeps are about equal as to their effect on crop production. No-till planting operations in dry soil has not worked well due partly to harvesting compaction of the soil and dry surface. Some-till helps kill weeds and loosens the soil for aeration and moisture intake. Most-till or black fallow tillage increases wind and water erosion.

The most rigorous research work in South Dakota was a series of field trials at the Duane Ellis farm in Elkton, South Dakota (45) 7/. This project compared three tillage systems (conventional, chisel plant,* and till plant*) in actual use over a period of 5 years continuously producing corn. There are records of yields, labor inputs, and fuel inputs for the years 1975-79. Then based upon 1978 price levels, gross returns, fuel costs, and labor costs per acre were calculated.

Based upon available data, several comments can be made about the performance of these three tillage systems on the Duane Ellis farm. Corn yields (5-year average) were lowest, 53 bushels per acre, with the conventional tillage system. The chisel-plant system was the next best at 55 bushels, and the till plant system produced the highest yields, 65 bushels per acre. Based upon a November 1978 market price of $1.73 per bushel for corn, these yields equate to gross returns of $91.69 per acre for conventional tillage, $95.15 per acre for chisel-plant tillage, and $112.45 per acre for the till plant system. In general, yields and gross returns increased as the amount of machine tillage decreased.

As anticipated, fuel and labor inputs decreased as the amount of tillage decreased. Therefore, the costs for these inputs are reduced also. Calculations indicate that chisel plant tillage requires approximately 26 percent more labor and fuel inputs, and conventional tillage requires 76 percent more of these same inputs than the till plant system.

Wyoming

Tillage information was found for two wheat studies and one corn study in Wyoming. All of these are related to the energy-use studies by Fornstrom (16, 17 and 44).

Records were kept of wheat yields for four summer fallow tillage methods from 1964 to 1975 at the Archer Research and Extension Center, Cheyenne, Wyoming (16). Based on average yields over all the years, the stubble mulch with fall tillage system had the highest absolute yield (18.5 bushels per acre). Statistically, however, this was not significantly different from the yields realized with the bare fallow* method (18.1 bushels per acre). The remaining two methods, stubble mulch and chemical fallow with fall tillage, had significantly lower yields, 16.7 bushels per acre and 16.4 bushels per acre, respectively.

A 37-year study at the Sheridan Substation in north Wyoming formed the basis of the wheat yield estimates used by Smith and Fornstrom in (44) (table 5). Similar yields were observed from the winter wheat-summer fallow rotation and the winter wheat-chemical fallow (no-till) rotation. In addition, on an average annual yield basis, continuous no-till cropping outyielded the more conventional crop-summer fallow rotation for both winter wheat and spring wheat.

7/ Cooperating in this project are Brookings County Conservation District, Soil Conservation Service, South Dakota State University, the Cooperative Extension Service, and the farmer, Duane Ellis.

Table 5--Estimated wheat yields, by crop, for six cropping rotations

Cropping rotation	Estimated wheat yield per crop*
	Bushels per acre
Winter wheat-summer fallow	24.2
Spring wheat-summer fallow	22.1
Winter wheat-spring wheat-summer fallow	19.4
Winter wheat-chemical fallow (no-till)	24.2
Continuous no-till winter wheat	13.4
Continuous no-till spring wheat	12.4

*Yields are estimated from an actual 37-year study on similar wheat cropping rotations at the Sheridan Substation. New rotations have been added to the study as they were developed. Those yield estimates are based on information from shorter periods of time.

Source: (44).

A study at the Torrington Research and Extension Center in southeast Wyoming (17) compared a chisel-based tillage system to a plow-based tillage system for corn production (table 6). Yield data from 1977, 1978, and 1979 revealed no significant differences in grain yields between treatments. There was some variation in corn silage yields between years, but averages for the 3 years indicated no distinct advantage to either tillage system for silage production.

Kansas

A good bit of research has been done on reduced tillage systems used in Kansas dating back to 1952. The information available reports results from both informal and formal research trials. The cropping systems examined include wheat-fallow rotations and wheat-sorghum-fallow rotations.

One study comparing wheat yields with mulch fallow to those of black fallow* was conducted at the Colby Branch Experiment Station (northwestern, Kansas), from 1952 to 1958 (6). Wheat yields after stubble mulch tillage were 27.0 bushels per acre which is nearly 22 percent greater than the 22.2 bushels per acre realized with black fallow.

Table 6--Corn silage and grain yields for chiseled and plowed tillage treatments

Year	Silage yields		Grain yields	
	Chiseled	Plowed	Chiseled	Plowed
	-- Tons per acre 1/ --		- Bushels per acre 2/ -	
1977	29.9[a] 3/	26.1[b]	149	152
1978	23.9	23.2	127	142
1979	28.7[b]	34.5[a]	163	161
Average	27.5	27.9	146	152

1/ At 70 percent moisture content.
2/ At 15.5 percent moisture content.
3/ Yields followed by different letters are significantly different at the 0.5 level. Yields with the same or no superscript letters are not significantly different.

Source: (17).

No consistent yield effects have been documented for reduced tillage in Kansas thus far. Work at the Garden City Branch Experiment Station in southwest Kansas found yield differences between conventional and chemical fallow in a wheat-fallow system to be very small (34). Yields over a 6-year period averaged 34 bushels per acre for chemical fallow and 33 bushels per acre for conventional fallow. Also, very little difference in wheat yields was found between types of tillage in a wheat-sorghum-fallow cropping system. Some difference was observed in the sorghum yields in the wheat-sorghum-fallow rotation. The 8-year average sorghum yields were 56 bushels per acre for chemical fallow and 49 bushels per acre for conventional fallow.

In contrast at the Tribune Branch Experiment Station in western Kansas (20), an increase of 6 bushels per acre of wheat was attributed to the use of chemicals to replace some of the tillage operations during the fallow period in a wheat-fallow rotation. In the wheat-sorghum-fallow rotation, wheat yields increased 4 bushels per acre with the use of chemicals. A 13 bushels per acre increase in sorghum yield also resulted from the substitution of chemicals into a wheat-sorghum-fallow cropping system.

Based upon the yield data of the Tribune Branch Experiment Station study just mentioned, T. Roy Bogle compares the costs and returns of the two types of tillage systems (table 7) (8). The additional $2.70 variable cost ($9.73 - $7.03) of reduced tillage with chemicals resulted in an increased 7-bushel yield worth $28.00 (7 bushels x $4.00 per bushel). Thus, switching to reduced tillage system was worth an additional $25.30 ($28.00 - $2.70).

Table 7--Cost and yield effects of changing tillage system in wheat production

Item	Reduced tillage and chemicals	Conventional tillage
	Dollars	
Harvest year:		
Chemical spray 1/	3.00	--
Spraying	.90	--
Undercut	1.20	2.40
Fallow year:		
Undercut	1.20	1.20
Undercut plus fertilizer application	1.96	1.96
Rod-weeder	1.47	1.47
Total tillage plus chemical	9.73	7.03
	Bushels per acre	
6-year average yields	36	29

1/ One pound atrazine applied to wheat stubble.

-- = Not applicable.

Source: (8).

Another partial budget approach described by Pretzer also looked at only those cost items which change when a reduced tillage system replaces a conventional system (37). Items which will change are herbicides, fuel and oil, interest on operating costs, and machinery fixed costs from adding to or modifying existing equipment. In a wheat-fallow rotation the change to reduced tillage costs $3.49 more per acre. In a wheat-sorghum-fallow rotation, costs rose even more--$9.72--when the switch was made to reduced tillage. Pretzer made no estimates of yield changes and therefore did not estimate the effect on income.

Some information is available on the influence of different tillage systems on sorghum yields in a wheat-sorghum-fallow rotation. Willis Brandyberry, a farmer in Hill City, Kansas (northwestern Kansas), reported that chemical fallow sorghum always outyielded conventional sorghum for him (9). The sorghum yields with chemical fallow ranged from 11 percent to 200 percent greater than the yields from using conventional methods. Derek Kats of Prairie View, Kansas, also reported better sorghum yields when chemicals replace tillage operations. He reported that no-till sorghum required about $7.00 per acre greater investment but that the yields were also greater, approximately 15 bushels per acre (24).

A more structured study at the Colby Branch Experiment Station (northwestern Kansas) looked at five different chemical/tillage systems for a wheat-sorghum-fallow rotation (29). No significant differences in wheat yield were found due to the type of chemical/tillage system used. Average wheat yields for the 3-year study range from 33.0 bushels per acre to 34.6 bushels per acre for the various treatments. Likewise, there does not appear to be a consistent yield advantage to a specific chemical/tillage treatment in the production of sorghum. For the 5-year study, mean sorghum yields ranged from 37.7 bushels per acre to 49.7 bushels per acre but no one system was consistently better than the others.

Colorado

Information was available for four research projects in eastern Colorado dealing with winter wheat-fallow rotations.

Proceedings from the numerous ecofallow conferences held throughout Nebraska contain much information about the winter wheat-fallow rotation method known as ecofallow which is gaining in popularity in western Nebraska and eastern Colorado. Greb traced the progress in fallow systems and wheat yields since 1916 (table 8) (18). Over time, the use of tillage has decreased while winter wheat yields have increased. Greb also reported an average increase of 7.1 bushels per acre of wheat from the use of fall herbicide weed control in a wheat-fallow rotation as compared to the conventional spring tillage method for two experiments in Akron, Colorado. The actual yield increases range from 3.8 bushels per acre to 13.7 bushels per acre.

Greb and Zimdahl reported additional information from the Akron, Colorado tests (19). The additional stored soil water and nitrate nitrogen obtained with ecofallow resulted in an average 21-percent increase in grain yield (from 34.5 bushels to 41.9 bushels) and a 22-percent increase in straw yield over conventional fallow. The benefits of this increase in residue are twofold: soil erosion is reduced and the infiltration of precipitation is increased. The production and harvesting costs involved with ecofallow were estimated to be only slightly higher than those of the conventional method.

In Anderson's examination of the economics of ecofallow, partial budgets indicate an increase in net income of $22.15 per acre when ecofallow replaces conventional fallow, even though operating costs of ecofallow following harvest are $3.75 per acre higher than those of conventional tillage ($21.25 - $17.50) (3). Additional cost factors to be considered before switching to ecofallow include (1) the interest charges on chemicals purchased 24 months before the next wheat crop is harvested; (2) the opportunity cost associated with time freed up by the use of chemical fallow, that is the time that can be diverted to other income producing activities; and (3) differences in machinery investment costs. Anderson concluded that the combined effects of these factors could result in an increase in income for the farmer who switches to ecofallow.

Table 8--Progress in fallow systems and wheat yields; U.S. Central Great Plains Research Station, Akron, Colorado

Time period	Changes in fallow systems	Average annual precipitation	Drought years	Fallow water storage 1/	Fallow efficiency	Wheat yield	Water use efficiency 2/
		Inches	Number	Inches	Percent	Bushels per acre	Bushels per acre per inch
1916-30	Maximum tillage; plow; harrow dust mulch	17.3	1.0	4.0	19.0	15.9	.46
1931-45	Conventional tillage; shallow disk, rod weeder	15.8	5.0	4.4	24.0	17.3	.54
1946-60	Improved conventional tillage; begin stubble mulch 1957	16.4	3.0	5.4	27.0	25.7	.78
1961-75	Stubble mulch; begin minimum tillage with herbicides (1969)	15.3	4.0	6.2	33.0	32.2	1.05
1976-90	Projected estimates; minimum tillage; begin no-till 1983	3/ 16.2	3.0	7.2	40.0	40.0	1.23

1/ Based on 14 months fallow, mid-July to second mid-September.
2/ Assuming 2 years precipitation per crop in a wheat-fallow system.
3/ Assuming average precipitation 1976-90.

Source: (18).

Chemical fallow trials in southeast Colorado have experienced some difficulties with herbicide residuals affecting stands (27). Because of the high pH and low organic matter content of the soil, the effective use of residual-type herbicides is quite difficult. Where the appropriate application rate can be established and used for existing soil conditions, chemical fallow has been quite successful. Kit Carson County and Elbert County have both had fairly successful trials. Knapp concluded that "as residual and application rate problems are ironed out, the chemical fallow application or chemical and sweep* combination fallow treatments can be competitive costwise with the traditional sweep or sweep-one way fallow farming methods" (27).

Nebraska

More information is available for Nebraska than for the other States. The use of conservation tillage systems is actively promoted by numerous groups in Nebraska, making information readily available. The studies emphasize three crops--wheat, corn, and grain sorghum--and examine many different reduced tillage systems, including ecofallow. Formal university and Cooperative Extension Service research, computerized budgets, and farmers' testimonials all reveal differences in costs or yields between tillage systems.

Fenster reported that in 1976 ecofallow was used on about 15,000 acres of corn and sorghum annually in southwestern Nebraska, with the 1977 acreage expected to reach 30,000 acres (13). Generally, bare fallow costs more than stubble mulch fallow because moldboard plowing is more costly than subtilling* or disking. Minimum tillage in corn and grain sorghum in central and eastern Nebraska reduces tillage costs and increases yields.

Since 1973 the Nebraska acreage farmed using a 3-year, winter wheat--corn or sorghum--ecofallow rotation has increased steadily to an estimated 350,000 acres for 1982 (table 9). The 2-year, wheat-ecofallow rotation has not increased quite as rapidly because of some problems with herbicide application and the lack of an appreciable yield advantage (46).

Crop enterprise budgets for 1980 and 1982 were selected from the numerous sets of budgets available from the AGNET 8/ agricultural computer network of the University of Nebraska. Costs are calculated for winter wheat, corn, and grain sorghum production using different tillage systems as appropriate for four regions in Nebraska. Cooperative Extension personnel familiar with each cropping area provided input data for AGNET budgets. Machinery complements and input costs are calibrated to represent actual conditions in each individual area. Crop yield estimates vary among regions and among systems as necessary to correspond with actual yields. This AGNET budget information is grouped according to crop for ease in discussion (1).

8/ AGNET is an interactive computer system that was developed at the University of Nebraska, Lincoln. AGNET is designed to be an easily accessible and usable source of information for farmers, ranchers, and agricultural business persons, especially those having little prior experience with computers.

Table 9--Ecofallow acreage in Nebraska

Year	Land using ecofallow system	Year	Land using ecofallow system
	Acres		Acres
1973	200	1978	100,000
1974	5,000	1979	180,000
1975	12,000	1980	210,000
1976	18,000	1981	300,000
1977	60,000	1982	350,000 estimated

Source: (46).

Winter wheat is produced in the panhandle, southwest, and central regions of Nebraska. With the exception of the panhandle region, yields vary among tillage systems. In the southwest, clean till fallow* yields were estimated at 37 bushels per acre compared with 42 bushels per acre for other crop-fallow systems. In 1980, the tillage system with the lowest cost per unit of production was stubble-mulch fallow. In 1982, ecofallow was the system with the lowest cost per unit of production (table 10).

There are AGNET corn budgets for two regions. In the northeast, yields from conventional tillage and conservation tillage were estimated to be 75 bushels per acre. Based upon this assumption, conservation tillage is the system with the lowest cost per bushel in the 1980 and 1982 budgets. In the central region, a nonconventional system was also the least costly on a per unit of production basis partly because of a 15 bushels per acre yield advantage (table 11).

Grain sorghum budgets are available for the central region for 1982. In these budgets, ecofallow yields are higher than conventional tillage yields, 75 bushels per acre to 63 bushels per acre. However, because total costs are much greater for ecofallow, the conventional tillage system is still the least costly per bushel of production (table 12).

Actual yield data are available from a number of sources. The studies dealing with yields from several crops in a rotation are discussed first, followed by those emphasizing individual crops.

Table 10--AGNET budget information for winter wheat

Region/ Tillage system	Estimated yield		Total cash costs and labor		Total fixed costs		Total cost per acre 1/ (including overhead and management)		Total cost per unit of production 2/	
	1980	1982	1980	1982	1980	1982	1980	1982	1980	1982
	- Bushels per acre -		------------------- Dollars per acre -------------------						- Dollars per bushel -	
Panhandle:										
Stubble mulch fallow	34	34	38.53	53.78	91.72	114.23	137.02	175.54	4.03	5.16
Black fallow	34	34	40.01	55.79	95.97	120.57	142.84	184.00	4.20	5.41
Ecofallow	34	34	57.83	72.96	77.93	90.13	143.61	171.70	4.22	5.05
Southwest:										
Stubble mulch fallow via tillage	42	42	41.79	50.10	75.16	91.70	124.92	150.22	2.97	3.58
Clean-till fallow	37	37	41.72	49.76	75.50	92.44	124.43	149.84	3.35	4.05
Ecofallow followed by corn in 3-yr. system	42	42	45.12	52.80	75.86	76.93	129.10	138.31	3.07	3.29
Continuous wheat with chemical weed control	--	30	--	53.11	--	46.28	--	106.39	--	3.55
Central:										
Continuous cropped	--	37	--	41.00	--	91.38	--	139.68	--	3.78
Fallow every 3rd year	--	47	--	47.79	--	126.17	--	183.04	--	3.89

1/ Overhead costs are calculated as 5 percent of total cash costs. Management costs are calculated as $0.15 x estimated yield.
2/ Based on estimated yield.
-- = Not applicable.
Source: (1).

Table 11--AGNET budget information for corn

Region/ Tillage system	Yield		Total cash costs and labor		Total fixed costs		Total cost per acre (including overhead and management)		Total cost per unit of production	
	1980	1982	1980	1982	1980	1982	1980	1982	1980	1982
	Bushels per acre		Dollars per acre						Dollars per bushel	
Northeast:										
Conventional	75	75	102.12	116.80	83.58	112.83	197.75	242.37	2.64	3.23
Conservation	75	75	99.42	117.05	80.47	108.69	191.94	238.62	2.56	3.18
Central:										
Conventional	--	55	--	71.03	--	98.49	--	178.17	--	3.24
Ecofallow following wheat 3 yr. rotation	--	70	--	90.80	--	122.90	--	224.95	--	3.21

-- = Not applicable.

Source: (1).

Table 12--AGNET budget information for grain sorghum

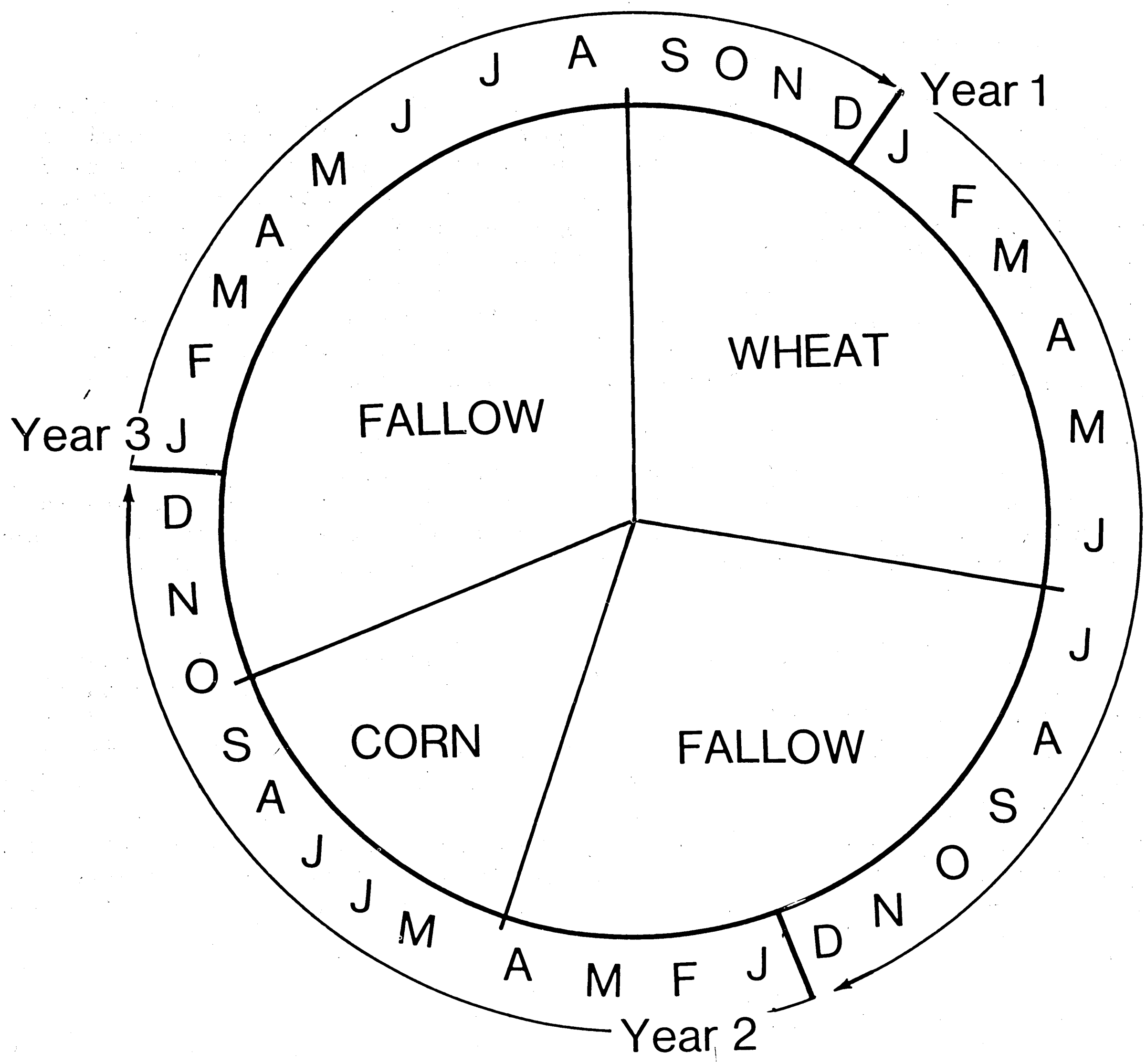
Region/ Tillage system	Yield		Total cash costs and labor		Total fixed costs		Total cost per acre (including overhead and management)		Total cost per unit of production	
	1980	1980	1980	1982	1980	1982	1980	1982	1980	1982
	Bushels per acre		Dollars per acre						Dollars per bushel	
Central:										
Conventional	--	63	--	63.62	--	94.34	--	167.07	--	2.65
Ecofallow following wheat 3 yr rotation	--	75	--	85.56	--	120.21	--	217.27	--	2.90

-- = Not applicable.

Source: (1).

Three studies documenting yields from several crops in a rotation all deal with some form of ecofallow. Wicks and Fenster (47) report 20-25 bushels per acre increases in corn or sorghum yields with a 3-year ecofallow rotation compared with conventional tillage. (The cropping sequence of a 3-year ecofallow rotation is illustrated in figure 1). However, wheat yields did not always increase in a 2-year rotation. They generalize that the savings from reduced tillage almost equal the additional cost of herbicide treatment. Thus the advantage comes from increased yields and reduced erosion.

Figure 1. **Cropping Sequence in the 3-Year Ecofallow Rotation**



Source: (22).

Paul Schaffert, a farmer in Red Willow County, promotes ecocallow wholeheartedly (10). Based upon a wheat-corn-fallow rotation his wheat and corn yields have both increased since his switch to ecofallow from conventional tillage. Dryland corn yields average 15 to 20 bushels higher than the 50 bushels per acre he produced under conventional tillage about 8 years earlier. His wheat yields have also increased, by about 4 bushels per acre. Schaffert attributed these increases in yields to the additional moisture available with ecofallow. Lower fuel costs and less time spent in the field are two additional benefits that he has noticed since his change in tillage systems.

These increases in yields with ecofallow are further supported by a study of a sorghum-winter wheat ecofallow system in Nebraska (28). In this study emphasizing crop diseases, ecofallow sorghum outyielded conventional tillage sorghum 63 bushels per acre compared with 43 bushels per acre. Likewise winter wheat yields were also greater, 43 bushels per acre compared with 39 bushels per acre.

Two studies in western Nebraska compare wheat yields under different tillage systems for a wheat-fallow rotation. Two sites at the High Plains Agricultural Laboratory near Sidney, Nebraska, showed a consistent advantage of 3.0 and 5.2 bushels per acre for chemical fallow over sub-till* and plow treatments, respectively (14). A 6-year long study at North Platte also revealed an advantage to fallow systems using less tillage or chemicals or both to control weeds (21). Average yield for the period 1965-70 for a system using the plow was 39.8 bushels per acre. The stubble mulch system yielded 42.8 bushels per acre. Combinations of mulch and chemicals produced 43.1 to 45.0 bushels per acre. The system using chemicals only produced the greatest average yield, 46.9 bushels per acre.

Research comparing corn yields from conventional tillage with those of alternative tillage systems encompasses a variety of systems from ecofallow to no-till. Ecofallow corn and milo yields are estimated to outyield conventional tillage yields by 20 to 30 bushels per acre in central Nebraska according to Lydic (32).

The findings of other, more extensive research further substantiate that there is no yield disadvantage to reduced tillage. On one farm in Stanton County in northeast Nebraska, minimum tillage corn had an average yield of 95.9 bushels per acre while the cotrol plot of conventional tillage yielded 86.4 bushels per acre. A second farm produced yields of 111 bushels per acre and 96 bushels per acre of corn with minimum tillage compared with 90 bushels per acre where conventional tillage was practiced (36). In another trial the yields from till planting and conventional tillage are not significantly different (30). The 10-year averages are 121 bushels per acre for till plant and 119 bushels per acre for conventional tillage.

Additional corn crop yield information from eastern Nebraska showed no significant yield differences between conventional tillage and numerous other conservation tillage systems (tables 13 and 14) (2). Wiese and Hergert concluded that yields with no-till system were equal to other tillage systems, but the total management requirement was higher (48). Corn yields from 15 locations in Nebraska averaged 116 bushels per acre for conventional

Table 13--Corn yield as influenced by tillage treatments, 1972-75, Concord, Nebraska

Tillage	Yield
	Bushels per acre
Conventional 1/	94.6
Limited 2/	96.0
Till plant 3/	100.2
Slot plant 4/	72.8

1/ Disk, moldboard plow, disk, plant.
2/ Disk twice, plant.
3/ Shred stalks, till plant.
4/ Shred stalks, slot plant.

Source: (2).

Table 14--Corn yield as influenced by tillage treatments, 1972-75, Lincoln, Nebraska

Tillage	Yield
	Bushels per acre
Moldboard plow 1/	78.4
Chisel plow 2/	81.0
Sweep plow 3/	80.5
Disk-chisel plow 4/	80.4
Coulter-chisel plow 5/	86.0
Till plant 6/	85.8
Slot plant 7/	83.2

1/ Chop stalks, disk, plow in fall; disk, plant in spring.
2/ Chop stalks, plow in fall; disk, plant in spring.
3/ Chop stalks, plow in fall; disk, till-plant in spring.
4/ Disk-chisel in fall; disk-chisel with sweeps, plant in spring.
5/ Coulter-chisel in fall; disk, plant in spring.
6/ Chop stalks, till plant in spring.
7/ Chop stalks, slot planting in spring.

Source: (2).

tillage and 118 bushels per acre for no-till. Average yields over a 4-year period in northeast Nebraska during moisture stress years were 40.9, 47.8, and 46.2 bushels per acre for conventional, no-till, and listing* systems, respectively.

Information on the actual cost of crop production with conservation tillage systems used in Nebraska comes in several forms. One source, a set of budgets, is based on costs of field operations taken from the 1978 Nebraska Farm Custom Rates information. Several farmers have given talks at conferences discussing how conservation tillage methods they have tried compare with conventional tillage methods previously used. Further comparisons of the cost of tillage systems come from research done by the University of Nebraska and other agricultural groups in the State.

Klein estimated crop production costs for crops and tillage systems representative of southwest Nebraska (26) for several western Nebraska counties (table 15) (26). Klein based these estimates upon the 1978 Nebraska Farm Custom Rates Neb Guides and do not include interest, management, and overhead charges. A comparison of three tillage systems for wheat shows that the stubble-mulch and ecofallow systems were both estimated to yield 42 bushels per acre while clean fallow yields only 37 bushels per acre. Because of these yield differences both stubble mulch and ecofallow had lower costs per unit, $3.04 per bushel and $2.96 per bushel, than clean fallow, $3.30 per bushel, even though the total cost figures were higher.

Similarly, grain sorghum yields were higher with ecofallow than with conventional tillage at 47 bushels per acre and 40 bushels per acre, respectively. These yields in turn lowered the cost per unit for ecofallow to $2.17 per bushel compared with $2.67 per bushel for conventional tillage.

Farmers giving testimonies at ecofallow conferences generally supported the ecofallow system. Paul Schaffert recorded corn yields of 67 bushels per acre with conventional tillage and 92 bushels per acre with ecofallow in 1979 (10, 42). The costs per unit to produce this corn were estimated at $3.04 per bushel for conventional tillage and $2.32 per bushel for ecofallow. That same year his ecofallow wheat yielded 47 bushels per acre while his conventional tillage wheat gave 39 bushels per acre. The production costs for the ecofallow wheat were estimated at $3 per bushel. All of his cost figures include overhead and management.

Dwight Balternsperger, a farmer from Bushnell, Nebraska, has spoken several times at ecofallow conferences (4, 5). In 1979, he estimated a savings of $6.66 per acre by switching to ecofallow wheat from a stubble mulch system. The next year he estimated fallow and preplanting costs at $17.65 per acre for ecofallow and $25.50 per acre for conventional tillage. Thus, a savings of $7.55 per acre was realized from a change to ecofallow.

Some cost figures have come out of the controlled scientific studies of conservation tillage systems in Nebraska. While cost estimation was the major objective of some research, it was more of a byproduct of other efforts.

Table 15--Estimated crop production costs, southwest Nebraska

Crop, tillage	Average yield	Land area involved	Cost other than land 1/	Land cost	Total cost cost	Cost per unit
	Bushles per acre	Acres	-------- Dollars	--------		Dollars per bushel
Wheat, stubble mulch fallow	42	2.0	67.57	60.00	127.57	3.04
Wheat, clean fallow	37	2.0	62.19	60.00	122.19	3.30
Wheat, ecofallow	42	2.0	64.13	60.00	124.13	2.96
Grain Sorghum, conventional	40	1.0	76.81	30.00	106.81	2.67
Grain Sorghum, ecofallow	47	1.0	72.08	30.00	102.08	2.17

1/ Custom rates on jobs done. Does not include interest on operating money, overhead, management charges.

Source: (26).

One study of row crop systems focused on corn production using chisel plow, listing, slot planting, and bed planting (30). The authors of that study concluded that when land, water, seed, fertilizer, insecticide, hauling, drying, and storage costs were included, about $10 per acre on dryland corn can be saved with conservation tillage with no loss in yields. They estimated total production costs at $159 per acre for till plant, $160 per acre for slot plant and $169 per acre for conventional tillage.

A second study compared four tillage systems used to grow grain sorghum (26). The costs of no-till and conventional tillage were nearly equal, $34.10 per acre and $34.80 per acre with stubble undercut* being slightly cheaper $31.47 per acre (table 16). Continuous no-till sorghum was the costliest system, $35.44 per acre. The suggestion is that the increased moisture available with a no-till system may increase yields sufficiently so that the net returns are greater than those of systems with lower input costs.

H. Doug Jose, an Extension Economist at the University of Nebraska, analyzed the net present value of the cash flow from machinery ownership for a 320-acre row crop farm (table 17) (23). The disk and till plant systems required the lowest cash outflow of the six systems. Consequently if yields for all systems would be equal, the disk and till plant systems would provide the greatest returns.

Some of the most extensive comparisons of tillage systems in use in Nebraska have been by Retzlaff (40, 41). He concentrated on three types of wheat fallow systems: ecofallow, chemical fallow, and conventional. Comparing the energy requirements of the three types of systems, both chemical and ecofallow required less energy than a conventional system.

Additional work by Retzlaff addresses several other factors to be considered when comparing alternative tillage systems. He has compared specific systems representative of chemical, ecofallow, and conventional tillage methods (38, 39). Based on the results of 8 years of research at the Panhandle Experiment Station, there were no significant differences in winter wheat yields among the three methods.

The equipment needed for the different types of tillage systems varies by system (table 18). The cost of these equipment complements also varies. Conventional tillage requires the largest investment in equipment, $80,965. The equipment for ecofallow costs $58,305, and machinery for the least costly, chemical system, costs $38,300.

Another part of Retzlaff's work compared the difference in fallow and preplanting costs among the tillage systems (table 19). Six specific systems were selected as representative of common conventional, chemical, and ecofallow systems. The fallow and preplant costs per acre were then estimated using 1978 chemical and 1976 custom rates. Of the six systems examined, the three with the lowest costs were either chemical or ecofallow systems. Conventional systems were two of the three costliest systems.

Table 16--Cost estimates of four sorghum production systems

Tillage system/line item	Cost
	Dollars
No-till sorghum following wheat (chemical):	
Spray after harvest (custom)	3.50
Chemical 2 quarts 4L AAtrex + 2, 4-D	5.00
Apply Anhydrous (applicator)	3.35
Nitrogen 65 pounds	7.80
Preemergence spray Igran + AAtrex	7.50
Planter	4.45
Seed	2.50
Total	34.10
Conventional tillage sorghum following wheat:	
2 Tandem Discs @ $2.69	5.38
Apply Anhydrous-Custom	3.35
Nitrogen 65 pounds	7.80
Planter	4.45
Seed	2.50
Herbicide in band	6.00
2 cultivations @ $2.66	5.32
Total	34.80
Sorghum following wheat (stubble undercut):	
Undercut with sweep	2.86
AAtrex 2 pounds	5.00
Undercut and Apply N	2.86
Nitrogen 65 pounds	7.80
Planter	4.45
Seed	2.50
Herbicide in band	6.00
Total	31.47
Sorghum - continuous - no-till:	
Pre-emergence spray custom applied	3.50
Paraquat and Atrazine	13.80
Anhydrous applicator	3.39
Nitrogen 65 pounds	7.80
Planter	4.45
Seed	2.50
Total	35.44

Source: (26).

Table 17--Net present value of cash flow from machinery ownership and operation for 320-acre farm in row crop production 1/

	Tillage system number 2/					
	Conventional tillage	Chisel	Spring chisel	Disk	Till plant	No-till
	Dollars					
Cash outflow						
Initial investment	69,150	66,350	66,350	61,750	58,650	50,000
Tax on sale of machinery 2/	1,826	1,752	1,752	1,630	1,549	1,320
Annual operating costs 3/	102,766	98,755	95,347	86,234	86,715	102,625
Total cash outflow	173,742	166,857	163,449	149,614	146,914	153,945
Cash inflow						
Investment credit	6,915	6,635	6,635	6,175	5,865	5,000
Value of used machinery	7,303	7,007	7,007	6,521	6,194	5,280
Tax savings for depreciation	11,096	10,647	10,647	9,909	9,408	8,022
Tax savings for operator	25,690	24,689	23,835	21,557	21,679	25,658
Total cash inflow	51,004	48,978	48,124	44,162	43,146	43,960
Net present value	-122,738	-117,879	-115,325	-105,452	-103,768	-109,985

1/ Discount rate of 9 percent compounded annually.
2/ Tax X present value factor of 0.42241 (present value of $1 in 10 years at 9 percent).
3/ Total annual costs X present value factor of 6.41766 (rent value of $1 per year for 10 years at 9 percent).

Source: (23).

Table 18--Selected equipment and their costs for chemical, ecofallow, and conventional tillage systems

Item	Chemical	Ecofallow	Conventional
		Dollars	
Tractor	23,500	27,735	27,735
Tractor #2	--	12,000	24,500
Drill	13,000	11,000	10,000
Plow	--	--	4,560
Field cultivator	--	--	4,200
Rodweeder	--	--	4,200
Sweep chisel	--	5,700	5,700
Sprayer	1,800	1,800	--
	38,300	58,305	80,965

-- = Not applicable.

Source: (39).

Table 19--Estimated costs per acre for the six selected tillage systems using 1978 chemical costs and 1976 custom rates

System, line item	Cost dollars	System, line item	Cost dollars
Conventional			
System A		System B	
Plow	6.00	Subsurface sweep 4x @ 2.75/per operation	11.00
Field cultivate 3x @ 2.75/per operation	8.25	Rodweed 2x @ 2.50/per operation	5.00
Rodweed 2x @ 2.50/per operation	5.00	Total cost per acre	16.00
Total cost per acre	19.25		
Chemical			
System C		System D	
Paraquat 1/4 pound @ 20/pound + x77 surfactant @ .30/acre	5.30	Paraquate 1/4 pound @ 20/pound + x77 surfactant @ .30/acre	5.30
Atrazine 1/2 pound @ 3.00/pound	1.50	Atrazine 1 pound @ 3.00 pound	3.00
Bladex 1 1/2 pounds @ 3.60/pound	5.40	Spray 1 application	2.25
Spray 1 application	2.25	Total cost per acre	10.55
Total cost per acre	14.45		
Ecofallow			
System E		System F	
Paraquat 1/4 pound @ 20/pound x77 surfactant @ .30 acre	5.30	Atrazine 1 pound @ 3.00/pound	3.00
Spray 1 application	2.25	Spray 1 application	2.25
Subsurface sweep 3x @ 2.75 per operation	8.25	Subsurface sweep 2x @ 2.75/per operation	5.50
Rodweed 2x @ 2.50 per operation	5.00	Total cost per acre	10.75
Total cost per acre	20.80		

Source: (39).

Taking into account the initial machinery investment, the annual operating costs and the differences in taxation, the cash flows of the three types of systems were compared (table 20). The net present values of the cash inflows and outflows were estimated for a 600-acre operation for a 10-year time frame at a constant 9 percent interest rate. Based on the earlier assumption of equal yields, the cost per bushel of producing winter wheat with ecofallow was $0.90; for chemical fallow, $0.95; and conventional tillage, $1.03.

Table 20--Present value 1/ comparisons per chemical fallow, ecofallow, and conventional tillage for cash outflows and cash inflows for a 10-year period with 9-percent interest on 600 acres

Item	Year	Chemical fallow Annual	Chemical fallow 10-year period	Ecofallow Annual	Ecofallow 10-year period	Conventional Annual	Conventional 10-year period
				Dollars			
Cash Outflow							
1) Initial investment	0	38,300-	38,300	58,305-	58,305	80,965-	80,965
2) Tax on gain on machinery 2/	10	2,394-	1,011	3,644-	1,539	5,000-	2,137
3) Annual operating costs	1-10						
a) Repairs 4 percent of each machine investment		1,915		2,332		4,045	
b) Fuel for field operations		586		648		1,230	
c) Labor 3/ @ $4.00 per hour for field operations		792		756		1,680	
d) Taxes, insurance, shelter @ 1.5 percent of machine investment		575		875		1,214	
e) Chemicals 4/		6,150		1,800		0	
f) Labor and costs for planting, seed, fertilizing, fertilizer, harvest, trucking. Same for all three systems.		16,080		16,080		16,080	
Total for #3 (items a-f)		26,098-	167,488/year	22,491-	144,340	24,252-	155,641
Cash Inflow							
4) Value of machinery at end of period	10	9,575+	4,045	14,476+	6,157	20,241+	8,550
5) Tax savings, investment credit	0	3,839+	3,830	5,831+	5,831	8,097+	8,097
6) Tax savings depreciation 10 percent/year (Depreciation allowance x 25 percent)	1-10	958+	6,148	1,458+	9,358	2,024+	12,989
Net present value			- 192,776		- 182,838		- 209,107
Total bushels produced 10 years			204,000		204,000		204,000
Cost/bushel			.945		.896		1.03
Cost/acre 34 bushels/acre			32.13		30.47		35.02

1/ SPPV - single payment value.
2/ Tax on gain in machinery = 25 percent value of machinery at the end of 10 years x 25 percent tax bracket.
3/ Labor for field operations are 19.8 minutes for chemical fallow, 18.9 minutes for ecofallow, and 42 minutes for conventional tillage.
4/ Chemical fallow cost = $10.25 per acre, ecofallow = $3.00 per acre.
Source: (39).

CONCLUSIONS: YIELD EFFECTS BY CROP AND LOCATION

The affects of nonconventional tillage systems on yields varied between studies. The results of those studies previously mentioned in this report which compare the yields with conventional tillage to conservation or no tillage are summarized by crop in appendix table 1 for grain sorghum, corn, and wheat, respectively. A closer look reveals a pattern to yield differences depending upon the crop and location.

In grain sorghum studies in Kansas and Nebraska, yields from conventional system were consistently greater than the yields with conventional tillage systems. Chemical conservation tillage, ecofallow, and no-till systems all outyielded conventional tillage.

Corn production information was available from South Dakota, Wyoming, and Nebraska. In South Dakota and Wyoming there was little if any difference between conservation tillage systems and conventional tillage. However, in Nebraska, a majority of the reduced tillage systems outyielded conventional tillage. Only two of the nine studies in Nebraska did not indicate a yield advantage to conservation tillage in corn production.

Wheat yields with conservation tillage varied a great deal for different locations. In North Dakota conventional tillage systems outyielded conservation tillage systems. Further south in South Dakota, Wyoming, and Nebraska, yields from conservation tillage and conventional tillage were about equal with conservation tillage occasionally having a slight advantage. In Kansas and northeast Colorado, conservation tillage and chemical conservation tillage had consistent yield advantages over conventional tillage. Conservation tillage trials in southeast Colorado experienced severe problems with herbicide carryover mainly because of the types of soils involved.

Overall, conservation tillage systems perform better in areas with longer growing seasons. In the northern areas of the Great Plains there is little, if any, yield advantage to conservation tillage. In the central Great Plains, however, conservation tillage systems frequently outperform conventional tillage.

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Appendix table 1. Effect of conservation tillage on crop yields, various studies

Study location	Crop		
	Grain sorghum	Corn	Wheat
	Change in yield from conventional tillage		
Akron, Colorado (18 and 19)	--	--	+7.1 to + 7.4 bushels
Central Great Plains (43)	--	--	+10 bushels
Great Plains (15)	--	--	No consistent difference
Garden City, Kansas (34)	+7 bushels	--	+1 bushels
Tribune, Kansas (20)	+13 bushels	--	+6 bushels
Hill City, Kansas (9)	+11 to +200%	--	--
Prairie View, Kansas (24)	+15 bushels with no-till	--	--
Colby, Kansas (6 and 29)	--	--	0 to +5 bushels
Stanton County, Nebraska (30, 35, and 36)	--	+2 to +21 bushels	--

continued--

Appendix table 1. Effect of conservation tillage on crop yields, various studies --continued

Study location	Crop: Grain sorghum	Crop: Corn	Crop: Wheat
	Change in yield from conventional tillage		
Lincoln, Nebraska (2)	--	No significant change	--
Nebraska (30)	--	No significant change	--
Nebraska (28)	--	--	+4 bushels
Western Nebraska (42)	--	+25 bushels with ecofallow	--
Sidney, Nebraska (14)	--	--	+5.2 bushels
North Platte, Nebraska (21)	--	--	+3.3 to +5.2 bushels
Nebraska (47)	+20 to +25 bushels with ecofallow	+20 to +25 bushels with ecofallow	No change
Red Willow Co., Nebraska (10)	--	+15 to +20 bushels with ecofallow	+4 bushels with ecofallow
Custer County, Nebraska (32)	--	+20 to +30 bushels with ecofallow	--
Langdon Exp. Station, North Dakota (35)	--	--	-2 bushels
Carrington Exp. Sta., North Dakota (7)	--	--	Lower yields

continued--

Appendix table 1. Effect of conservation tillage on crop yields, various studies --continued

Study location	Grain sorghum	Corn	Wheat
	Change in yield from conventional tillage		
Elkton, South Dakota (45)	--	+2 bushels with chisel plant +12 bushels with till plant	+2 bushels with chisel plant +12 bushels with till plant
Torrington, Wyoming (17)	--	No change	--
Cheyenne, Wyoming (16)	--	--	-1.7 to +0.4 bushels
Sheridan, Wyoming (44)	--	--	No change

-- = Not applicable.