

# CONSERVATION TILLAGE

## FACTS

### Taking advantage of the Benefits of No-till

#### with Rainfall Probability Distributions

by

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**The Fact:** Rainfall probability distributions can help reduce the risk in making a wrong decision of crop choice in a given year, for no-till and reduce-till dryland production systems.

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#### Abstract

No-till and reduce-till (commonly referred to as conservation tillage) have become important soil-crop management systems on dryland farms of the Central Great Plains. These systems are important because they protect soil from erosion, increase soil-organic matter, improve precipitation-storage efficiency, increase biological yield, provide fuel and tractor-life savings of 25 to 50 percent, and increase the number of crop options for dryland rotations. In our region of the Great Plains, 12 to 20 inches of precipitation is typical. The traditional crop production system has been winter wheat-fallow. Using our best management practices, we might store in the soil 50 percent of the precipitation that falls during the fallow period for use by a subsequent crop. Improved precipitation storage efficiency (PSE) with no-till, has enabled researchers and farmers to look for more intensive crop rotations. However, these rotations require careful consideration of the probability of receiving adequate precipitation for crop growth and development. Long-term weather data and water-use-production functions can help guide farmers in making management decisions with respect to crop choice in a given year for conservation tillage systems.

#### Introduction: Dryland farming in the West Central Great Plains-a short history

The dominant dryland-crop-production system in this region for the last 50 years has been winter wheat-summer fallow (Haas et al. 1974). Summer fallow is the practice where: no crop is grown and all weeds are killed by cultivation or herbicides during the summer when a crop is normally grown. Summer fallow is done to store precipitation during the fallow year in anticipation of better yields and reduced risk of crop failure from drought the subsequent year. The average annual precipitation for northeastern Colorado is minimal for annual crop production and varies greatly from year to year, requiring producers to rely on stored water for crop success (Fig. 1).

In the "dirty thirties" summer fallow was conducted using moldboard or one-way disk plows that invert the soil and bury weeds. Unfortunately, this kind of tillage greatly increases soil water loss by evaporation. Researchers (USDA-ARS) at Akron, Colorado estimate that 0.4 inch of water is lost through evaporation within two days after tillage with a disk or chisel (Table 1). Precipitation storage efficiency (PSE) during the 30's was only 24%, mainly because of the kind of tillage used (Fig 2). In the 1950's and 60's, the "stubble mulch" system was developed. Stubble mulch relies on the use of sweep-plows, consisting of v-shaped blades, pulled at shallow depths to undercut weeds. Sweep-plow tillage causes the loss of about 0.1 inch of water within 2 days after tillage (Table 1). Using sweep-plows in stubble mulch increased fallow PSE to 33%.

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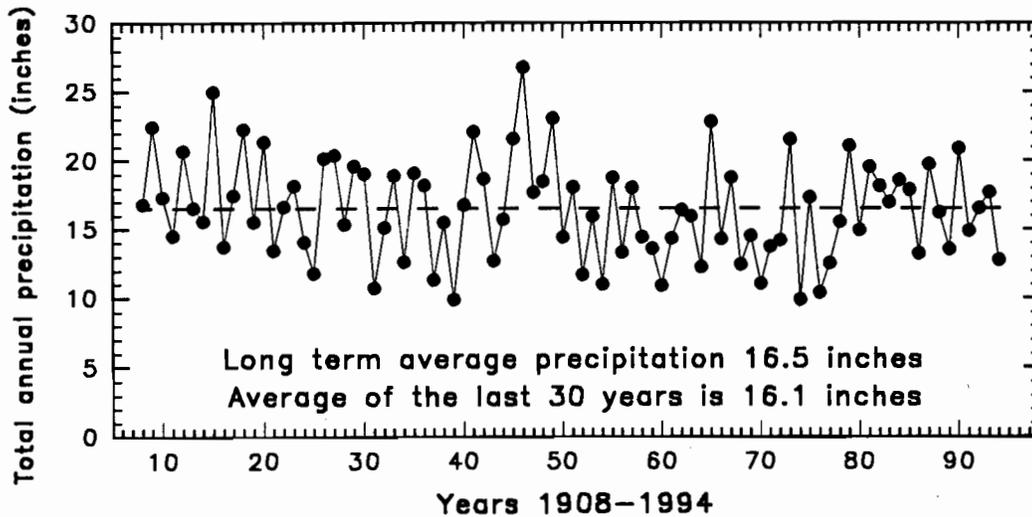


Fig 1. Long-term precipitation record at Akron, Colorado. The dashed line is the long-term average of 16.5 inches.

Herbicides have allowed us to develop reduce-till and no-till fallow. With reduce-till, residual herbicides are used to control weeds after wheat harvest. Tillage with sweep-plows are then used after the herbicide has begun to lose activity. In reduce-till PSE is near 40% (Fig 2). With no-till, both residual and contact herbicides are used. The soil surface and crop residues are never disturbed increasing PSE to near 50%. In this respect, no-till is our best management practice for storing soil water during fallow.

The increased water savings with no-till has prompted researchers to examine more intensive non-traditional crop rotations (Peterson et al. 1992, Halvorson et al. 1994). These include: wheat-corn-fallow, wheat-millet-fallow, wheat-corn-millet-fallow, wheat-millet-sunflower-fallow etc. That research indicates that we can grow successfully more than one crop in two years. An examination of the response of non-traditional dryland crops to no-till reveals an advantage for dryland corn (Fig 3).

Table 1. Effect of tillage on residue reduction and soil water loss 1 through 4 days after tillage (from Good and Smika 1978).

Tillage implement	Residue reduction	Soil water loss (inches) in the 0 to 5 inch depth		
		1 day	2 day*	4 day
Tandem disk	75	-----**	-----	-----
One-way disk	50	0.33	0.39	0.51
Chisel	10	0.29	0.35	0.48
Sweep-plow	10	0.10	0.11	0.14
Rod-weeder	15	0.04	0.10	0.22

\* Values are linear interpolations between measured values at 1 and 4 days.

\*\* data not collected for tandem disk in this study

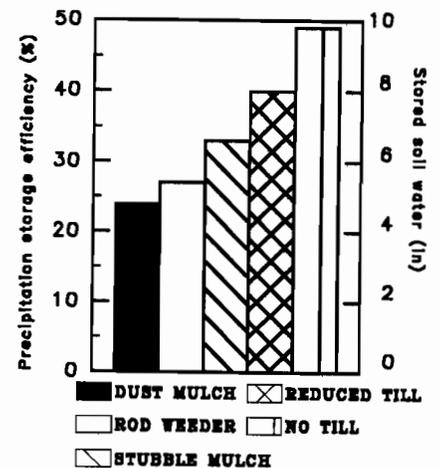


Fig 2. PSE and stored soil water for various fallow methods (from Nielsen and Anderson 1993)

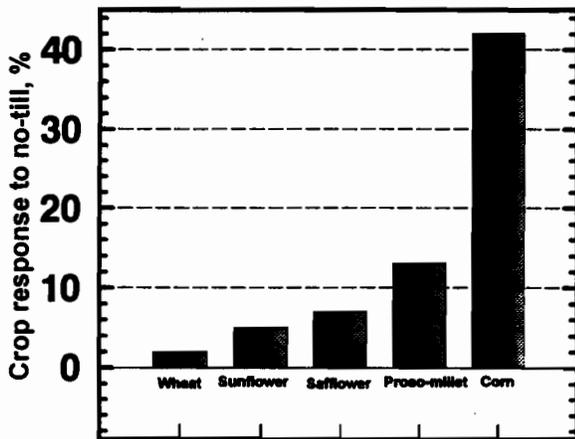


Fig 3. The percentage increase in yield using no-till over conventional-till in a dryland cropping system where the previous crop is winter wheat.

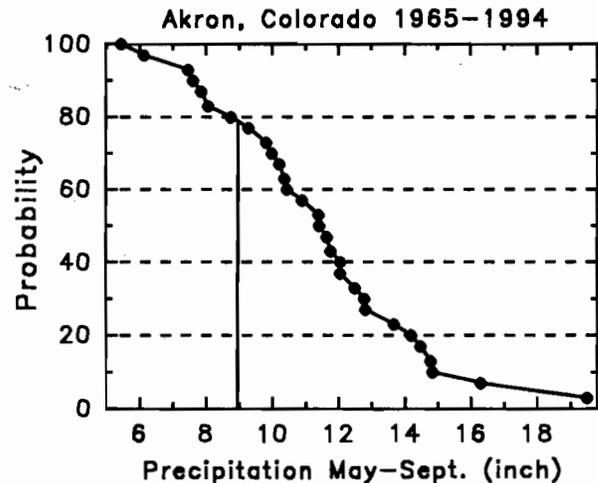


Fig 4. Rainfall-probability distribution for the growing season at Akron.

However, success of more intensive rotations depends on conservation-tillage management. Moisture is valuable and tillage not needed to control weeds can be costly. For the production of dryland wheat, at least 7 inches of total water are needed before any yield will be harvested. That 7 inches can come from stored soil water or precipitation. After the first 7 inches of water, any additional water (whether it be stored or fall as rain) produces about 6.5 bushels of grain per inch of water. For dryland corn the relationship is about 10 bushel per inch of stored soil water or precipitation after the first 9 inches. Using the tillage-water-loss relationships in table 1 we can calculate that two one-way disk operations result in the loss of 1 inch of soil water. This translates into a 10 bushel yield loss costing as much as \$20-\$30.

We have established that more intensive rotations will work. However, with our variable climate farmers are cautious about adopting these systems. Their caution is justified because such schemes require additional management, capital, knowledge and some additional risk.

### Reducing the risk with production functions and probability distributions

In the preceding paragraph, we mention that wheat will produce about 6.5 bushels of grain per inch of water after the first 7 inches of water. This relationship between wheat yield and available water is a water-use-production function (Nielsen, 1995). Production functions have been developed for other dryland crops grown under field conditions at the USDA-ARS Central Great Plains Research Station in Akron Colorado. Some of these are given below:

Proso millet (lbs/acre)	=	237	x	(inch of water)	-818
Corn yield (bushels/acre)	=	10.4	x	(inch of water)	-95
Wheat yield (bushels/acre)	=	6.5	x	(inch of water)	-44
Sunflower (lbs/acre)	=	161	x	(inch of water)	-843

How to use these functions can be explained by an example: Let's assume a farmer in Washington County (near Akron) wishes to plant dryland corn. The farmer probes the soil the last day of April to assess soil available water to a 6 foot depth. For our example, the farmer finds 8.0 inches of available water in the profile<sup>1</sup>. The farmer knows that the total long term-average precipitation for the months of May, June, July, August and September is 11.5 inches.

<sup>1</sup> On April 25th, 1995, we measured 8 inches of available water in the top 6 feet of the soil profile, in wheat stubble to be planted to corn.

If our field were to receive the average precipitation, the yield potential could be calculated as:

$$\text{Corn yield} = 10.4 \times (8.0 \text{ inches available in profile} + 11.5 \text{ inches as rain}) - 95$$

$$\text{Corn yield} = 108 \text{ bushels}$$

That looks dandy, but how do we know if our farmer will get the average rainfall? How can we even guess if he/she will even get 50% of the average, or 75% of the average? This is where long term weather records can help. At Akron we have precipitation records since 1908 (Fig 1). However, if we take the last 30 years (which were drier than average) we can plot a rainfall-probability distribution for the corn growing months of May through September (Fig. 4). In Fig. 4. we see that 80% of the time (8 out of 10 years based on the last 30 years of data) we have at least 9 inches of precipitation for May through September. Our function can then be used to determine yield on an 80% probability:

$$\text{Corn yield} = 10.4 \times (8.0 \text{ available in the profile} + 9 \text{ inches } 80\% \text{ of the time}) - 95$$

$$\text{Corn yield} = 82 \text{ bushels}$$

This is a very good yield for dryland corn, but is not unreasonably high. However, we need to be cautious. Many years available water in the soil profile the last day of April may be less than 8 inches. Also, precipitation that falls during silking and pollination, influences corn yields more than that which falls at other growth stages. Timing can be as important as total amount of precipitation received. Silking and pollen shed (depending on the year and the variety) generally occur in Washington county the last week of July or the first two weeks of August. Pollen shed lasts about 9 days. During this period water use is about 1/3 of an inch per day. So, for maximum pollination, we need at least 3 inches of water available to the crop during this period. Again, some of this water can fall as rain and some can come from soil water storage. A rainfall-probability distribution for this three week period would be helpful. But soil water available during this time is just as important. So with respect to dryland corn we can't speculate any more about the probability of success.

For crops like proso millet (hershey) and sunflowers, water stress at bloom or during seed development is not as critical and the use of rainfall-probability distributions can be more predictive. Since proso doesn't root as deeply as corn (only about 3.5 feet) we have less soil profile to extract from and therefore less water available.

$$\text{Proso-millet yield} = 237 \times (5.4 \text{ available in the profile} + 9 \text{ inches } 80\% \text{ of the time}) - 818$$

$$\text{Proso-millet yield} = 2595 \text{ lbs (about 50 bushel)}$$

Sunflower will grow roots as deeply as corn, but has a lower wilting point and will extract more water from the same soil profile than will corn. For sunflower we might have 10 inches available:

$$\text{Sunflower yield} = 160.5 \times (10 \text{ available in the profile} + 9 \text{ inches } 80\% \text{ of the time}) - 843$$

$$\text{Sunflower yield} = 2207 \text{ lbs of sunflower.}$$

The grain yields predicted above represent an *educated guess* based on long-term weather records and yield-water-use relationships developed over the years at Akron. The actual yields realized depend on management, variety, climate and the soils being farmed. The approach used in the above discussion doesn't include heat units, hail damage, and/or extremes in temperature that could dramatically effect final yield. On the other hand, these relationships are better than guessing and provide an estimate of what to expect for a certain rainfall probability.

## Summary

Tillage practices that invert the soil (disking and moldboard plowing) disrupt the protective surface-residue barrier. This opens and exposes moist subsoil to drying winds and direct sunlight. The greater the tillage depth, usually the greater the moisture loss. Non-traditional rotations are being studied that take advantage of the additional water, fuel and tractor savings with no-till. The use of rainfall-probability distributions for a given region, combined with water-use-production functions and soil sampling for available-soil water can be used to help a producer decide which crop to plant in a given year.

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