total population of farmers in the study area. Therefore, it was expected that the strongest approval would come from large operators, while mild approval would prevail among the small operators.

The survey of nonparticipants also produced unexpected results in the rate of disapproval among small farmers. Less than 13 percent of the small farmers disapproved of the program, while 20 percent or more of medium and large farmers disapproved of the program. No-opinion responses ranged from about 18 percent for large farmers to over 31 percent for small farmers.

Effect of Conservation Practices

Changes in land use and crop or livestock production occur incessantly in the Great Plains region because of the continuous changes in technical and economic conditions. Under these circumstances, land operators cannot be expected to accurately report the effect of a single variable, such as the Great Plains program, on changes in their farm operations. With this in mind, participants were asked how conservation practices had affected crop and livestock production, soil erosion, water use and supply, risk due to weather extremes, land values, work load, and wildlife habitat. No attempt was made to quantify the effects, only directional change was established.

Participants' views on the directional changes brought about by the program are summarized in table 4. More than two-thirds of the 153 participants believed the program decreased soil erosion, reduced the risk due to weather extremes, increased water supply, increased water use, and increased the value of the land they operated. A majority felt that participation had increased livestock production, increased crop production, and improved wildlife habitat. Only with respect to work load was there some uncertainty. Reponses were almost evenly split on whether work load had increased or decreased.

As expected, a higher proportion of the livestock producers, particularly those with large-scale operations, reported increased livestock production under the program. Most of the respondents reporting a decrease operated units with less than 50 percent in rangeland. These same operators reported increased crop production, while those with over 50 percent of their unit in rangeland reported a decrease or no change in crop production. Unfortunately, information from the survey was inadequate for making accurate estimates of the changes in crop production.

Full owners were more confident than other tenure groups of reduced soil erosion and risk due to weather extremes. Those with more than 50 percent of their operating units in rangeland reported an increase in water supply more frequently than other participants. Generally, those operators emphasizing crop production believed their workload increased because of the program. Those emphasizing livestock production believe their workload decreased. Small farm operators, particularly crop farmers, more frequently indicated a lack of improvement in wildlife habitat due to the program than did other operators.

Conclusions

In essence, this study showed that the Great Plains Conservation Program is widely accepted, particularly by program participants who have experienced the benefits that accrue from it. The challenge for program administrators now appears to be improved information dissemination among nonparticipants. □

Water conservation with stubble mulch fallow

B. W. GREB, D. E. SMIKA, and A. L. BLACK

ABSTRACT—Net gains in soil water storage during fallow due to increased quantities of wheat (Triticum aestivum L.) straw mulch varied from 0.5 to 1.5 inches at Sidney, Montana, 0.7 to 1.6 at Akron, Colorado, and 1.7 to 2.8 inches at North Platte, Nebraska. The net gains credited to higher applications of mulch were significant at the 95 percent level of probability in 12 of 16 experimental years. Greatest gains were made during the spring months of the 14-month fallow season. More than 70 percent of the net gains under heavier mulches was stored below the surface 2 feet of soil, thereby minimizing potential evaporation losses. Wheat yields on mulched land varied with spring growing conditions. When conditions were warm and dry, wheat responded favorably to the increased soil water. When spring temperatures were below normal, however, mulches exaggerated the temperature depression. This restricted plant tiller formation and reduced yields.

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It is commonly believed that the benefits of fallow are limited by low water storage efficiencies and the threat of wind erosion (*8, 9*). However, the economics of wheat production strongly favor the use of fallow in drier portions of the Central and Northern Great Plains (*12.*)

New evidence suggests that the original limitations of fallow can be overcome. Recent publications have shown that fallow efficiencies range from 25 to 45 percent with improved weed control and straw mulch management (*1, 2, 4, 10, 11*). Wind erosion is still a problem, but better cropping systems and improved equipment for maintaining soil clods and straw mulches have reduced this danger, especially on medium-textured soils (*1*, *15*).

The role of straw mulches in water conservation has been investigated only in recent years. Hanks and Woodruff (*5*) found that mulches conserve extra water during frequent rainy periods but have little effect during long dry periods. Soil water losses measured by solar distillation were reduced 16, 33, and 49 percent over a 20-day period at Akron, Colorado, with surface applications of 1,000, 2,000, and 3,000 pounds of wheat straw per acre, respectively (*3*). Part of this reduction was credited to a corresponding reduction in soil temperature with increased mulch (*3*). Unger and Parker (*13*) recently reported that cumulative evaporation from soil over a 16-week period was reduced 57 percent and 19 percent by straw applied to the surface and mixed with surface soil, respectively, compared with straw buried 1.17 inches deep.

Earlier data from Akron, Colorado, Sidney, Montana, and North Platte, Nebraska had shown that a significant increase in stored soil water occurred with 3,000 to 9,000 pounds of straw mulch per acre, compared with 0 or 1,500 pounds per acre, in six of nine experimental years (*4*). An almost linear relationship existed between mulching rates during fallow and net gains in soil water storage. Net soil water gains ranged from 0.4 inch to 2.6 inches per fallow season depending upon the rate of mulch, location, and season.

These same experiments, which now include 16 years of fallow water storage data and 13 years of wheat yield data, are reported herein.

Experimental Procedure

Procedures used for the three fallow experiments are outlined in table 1. Each experiment had similar objectives and included an alternate wheat and fallow block of plots. Wheat was the source of straw. The fallow period was 14 months long, beginning in mid-July. Straw yields were determined following harvest (*14*), and the designated application rates of straw mulch were established by removing excess straw or adding new straw.

Sweep and rod weeders were used on fallow at Akron and North Platte. Only sweeps were used at Sidney. The depth of subtillage, weed control, rate of straw loss, and maintenance of soil clods were similar at all locations.

By mid-May, normal overwinter losses plus the effect of tillage gener-

Table 1. Description of field plot procedures for stubble mulch fallow experiments.

Experimental Procedure	*Measurement Unit*	*Great Plains Locations* Sidney, Montana	Akron, Colorado	North Platte, Nebraska
Length of experiment	years	4	5	7
Soil type		Sprole sandy loam	Weld silt loam	Holdredge silt loam
Slope of plot area	percent	3 to 4	0.5	2 to 3
Experimental variables		Rates of straw	Rates of straw × dates[c] subtillage	Rates of straw × dates[d] straw burial
Rates of straw	pounds/acre	0, 1,500, 3,000, 6,000	1,500, 3,000, 6,000	0, 3,000, 6,000
Replications	number	3	3	3
Plot water control		Yes	Yes	Yes
Plot size	feet	25 × 100	36 × 100	20 × 100
Fallow tillage	number/year	4	4 to 6	4 to 6
Primary: sweep[a]	inches/blade	18 to 48	60	32 to 48
Secondary: variable		Sweep	Miller Rod[b]	Miller Rod[b]
Soil water sampling		Gravimetric, oven-dry basis	Gravimetric, oven-dry basis	Neutron scatter
Per plot	number	2	2	2
Times in year	number	5	5	5
Depth	feet	5	6	10

[a]Sweep V-shaped blades used at least twice if no burial of straw; 24-inch one-way disk for straw burial at North Platte.
[b]Rotating bar with tongs that lifts straw and clods over the bar.
[c]Fall, early spring, mid-spring.
[d]Fall, early spring, late spring, end of fallow.

Table 2. Effect of straw mulch rate on soil water storage during specific fallow periods.

Location and Years	*Applied Straw (lbs./acre)*	*Water Storage at Various Periods During Fallow (in.)* Harvest	Fall	Early Spring	Late Spring	End Fallow	*Net Water Gain (in.)*	*Fallow[a] Precipitation (in.)*	*Fallow Efficiency[b] (%)*
Sidney, Montana	0	1.0	1.3	3.7	4.2	3.4	2.4	12.6	16
4-year mean	1,500	0.9	1.3	3.7	4.8	3.8	2.9	12.6	23
	3,000	0.9	1.4	3.7	4.9	4.4	3.5	12.6	28
	6,000	1.1	1.3	4.0	5.5	5.0	3.9	12.6	31
Akron, Colorado	1,500	1.3	3.5	4.3	6.8	7.4	6.1	21.8	28
5-year mean	3,000	1.2	3.5	4.6	7.5	8.0	6.8	21.8	31
	6,000	1.5	4.2	5.0	8.5	9.2	7.7	21.8	35
North Platte, Nebraska	0	2.0	4.7	5.4	8.7	8.5	6.5	24.8	26
7-year mean	3,000[c]	1.2	4.9	7.0	9.2	9.4	8.2	24.8	33
	6,000	1.4	5.2	7.5	10.4	10.7	9.3	24.8	37

[a]Fallow period of 14 months, July to second September at each location.

[b]Fallow efficiency (%) = $\frac{\text{Net gain soil water (in.)} \times 100}{\text{Fallow precipitation (in.)}}$

[c]Five-year mean.

Table 3. Precipitation and water storage efficiency by fallow periods at three Great Plains locations.

Location and Years	Applied Straw (lbs./a.)	Harvest to Fall Pptn. (in.)	Harvest to Fall Eff. (%)	Fall to Early Spring Pptn. (in.)	Fall to Early Spring Eff. (%)	Early Spring to Late Spring Pptn. (in.)	Early Spring to Late Spring Eff. (%)	Late Spring to End Fallow Pptn. (in.)	Late Spring to End Fallow Eff. (%)	Total Fallow Year Pptn. (in.)	Total Fallow Year Eff. (%)
Sidney, Montana	0	1.0	30	2.1	114	6.2	8	3.3	−27	12.6	16
4-year mean	1,500	1.0	40	2.1	114	6.2	18	3.3	−30	12.6	23
	3,000	1.0	50	2.1	110	6.2	19	3.3	−15	12.6	28
	6,000	1.0	20	2.1	129	6.2	24	3.3	−15	12.6	31
Akron, Colorado	1,500	6.6	33	2.2	36	7.7	32	5.3	11	21.8	28
5-year mean	3,000	6.6	35	2.2	50	7.7	38	5.3	9	21.8	31
	6,000	6.6	45	2.2	36	7.7	45	5.3	13	21.8	35
North Platte, Nebraska	0	7.0	39	2.0	35	10.1	33	5.7	− 4	24.8	26
7-year mean	3,000[b]	7.0	53	2.0	105	10.1	22	5.7	4	24.8	33
	6,000	7.0	54	2.0	115	10.1	29	5.7	6	24.8	37
Mean, All Locations, Rates, Years		5.3	43	2.1	78	8.3	29	4.9	3	20.6	31

Column group heading: Precipitation and Water Storage Efficiency During Fallow Periods[a]

[a]Fallow efficiency (%) $= \frac{\text{Net gain soil water (in.)} \times 100}{\text{Fallow precipitation (in.)}}$

[b]Five-year mean.

ally reduced the straw to about 60 percent of the original mulch at all three locations.

Parallel dikes were maintained between plots to prevent migration of runoff water from plot to plot. Available soil water was that amount held at less than 15 bars tension. The soils at all locations hold a maximum of 12 to 14 inches of available water to the 6-foot depth, but such quantities seldom occur because of limited rainfall.

Because of the generally low soil fertility at Sidney, 30 pounds of nitrogen and 44 pounds of phosphorus were applied per acre before wheat planting. Straw and grain yields were obtained from areas of at least 18 square feet. Four samples were hand harvested in each plot. A field combine was also used to determine grain yields at Akron and Sidney.

Results and Discussion

Water Storage in Fallow

In general, available soil water was low at the beginning of fallow (Tables 2 and 3). Straw mulch treatments caused differences in soil water storage during the first fall at Akron and North Platte. The largest net gains in soil water storage at Sidney occurred during the winter, while at Akron and North Platte the largest gains were made during the spring.

The effect of varying rates of straw mulch on fallow efficiencies during specific periods within the fallow season are given in table 3. In most cases, soil water storage between harvest and fall dormancy was fairly uniform at the three locations, ranging from 30 percent to 54 percent. Winter precipitation averaged only 2.1 inches—1.0 inch less than normal—for the 16 experimental years. Nevertheless, water storage during winter was good at Sidney and North Platte. Some values in table 3 exceed 100 percent for the storage of winter precipitation because blowing snow was deposited in standing stubble. Changes in soil water storage imposed by differing amounts of straw mulch caused corresponding variations in average fallow efficiencies. These efficiencies ranged from 19 to 31 percent at Sidney, 28 to 35 percent at Akron, and 26 to 37 percent at North Platte.

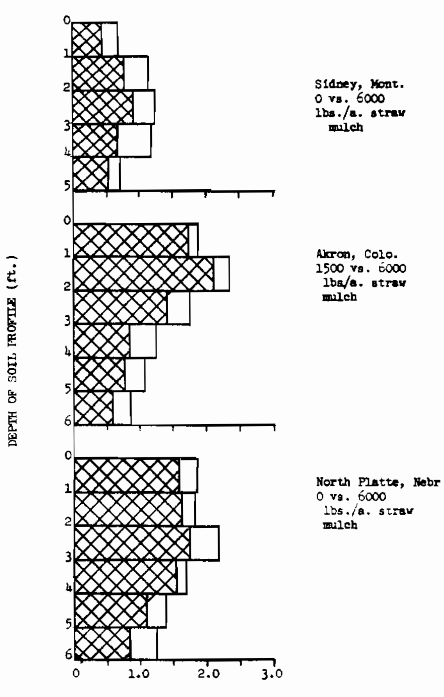

Figure 1. Distribution of soil water in the profile at end of fallow (low mulch is checked; high mulch is checked plus white).

During the spring fallow period, soil water storage increased as rates of mulch increased at both Sidney and Akron. The average fallow efficiency at Akron during this period was higher than at the other two locations. During 10 weeks of summer, soil water storage was poor at all three locations, regardless of mulch treatment. However, water storage averaged about 0.4 inch more with the highest rate of mulch than with the lowest rate of mulch.

By the end of the fallow period, the extra water gained with mulches was distributed throughout the soil profile. More than 70 percent of the net gain was below the 2-foot soil depth (Figure 1). This deep penetration reduces surface evaporation, which may explain why water storage gains established by mid-June showed little change during the remaining warmest 10 weeks of fallow.

Variations in soil water storage at the end of fallow by individual years at each location are not shown. Nevertheless, net soil water gains credited to higher applications of mulch were significant at the 95 percent level of probability in 12 of 16 experimental years. Gains varied from 0.5 to 1.5 inches at Sidney, 0.7 to 1.6 inches at Akron, and 1.7 to 2.8 inches at North Platte. With one exception, the data from all locations for all years showed a progressive differential in soil water storage with increasing application rates of straw, regardless of the amount of precipitation during the fallow year. The four-year results at Sidney, with less than normal precipitation, were not unlike previously ascertained fallow efficiencies (*1*).

However, the fallow efficiencies at Akron and North Platte were considerably higher than those obtained in former years when less effective practices and equipment had been used (8, 9).

Wheat Yields

Grain and total dry matter yields obtained on fallow treatments at the three locations are shown in Table 4. In 1966 and 1968 increased yields of wheat at Sidney correlated with increased soil water storage under mulch obtained during the preceding fallow season. In 1965 and 1967, when wheat yields did not respond to soil water storage at Sidney, the spring growing season was characterized by below-normal air temperatures and above-normal precipitation.

Grain yields at Akron increased as mulch rate increased in 1964 and were positively related to soil water storage during fallow. The wheat was hailed out too early in the spring of 1965 to judge yield expectancy. In 1966, despite hail on June 8, a significant increase in total dry matter was obtained with higher rates of mulch during fallow. In 1967 grain yields did not significantly respond to the increased stored soil water, probably because of above-normal spring precipitation. In 1968 grain yields increased slightly, yet straw yields were depressed about 500 pounds per acre under higher mulches. Below-normal temperatures in April and early May of 1968 appeared to restrict tiller formation and reduce potential straw yield. During the warm, dry June that followed, water became the limiting factor in grain formation.

At North Platte, grain yields in 1964 and 1965 were markedly reduced; low spring temperatures under high rates of mulch seriously reduced tiller formation. However, with the warmer spring conditions in 1967, soil water became the limiting factor, and grain yields increased as mulch rates increased.

Judging from the yield variations at these three semiarid experimental locations, surface mulch during fallow appears to influence crops in two ways. First, mulches tend to reduce surface soil temperatures, perhaps as much as 3°F to 10°F under certain conditions (3, 6). Second, mulches increase the level of soil water storage at the end of fallow. If spring growing conditions are relatively warm and dry, wheat responds favorably to this increased soil water (7). If spring air

Table 4. Wheat yields in relation to rates of straw mulch used in fallow and spring growing conditions at three Great Plains locations.

Location and Years	*Grain TDM*[a]	*Rates of Straw Mulch (lbs./acre)* 0	1,500	3,000	6,000	*Spring Growing Conditions from Normal* Temperature	Rainfall
Sidney, Montana[b]							
1965	G	1,140	1,140	1,130	1,000	Below	Above
	TDM	3,200	2,900	2,800	2,300		
1966	G	1,430	1,640	1,690	1,900	Above	Below
	TDM	3,900	4,220	4,070	4,580		
1967	G	1,900	1,880	2,040	1,900	Below	Above
	TDM	4,960	4,420	4,900	4,490		
1968	G	2,830	2,890	3,120	3,220	Normal	Below
	TDM	6,950	7,100	7,640	7,880		
Average	G	1,850	1,890	1,990	2,010		
	TDM	4,750	4,660	4,850	4,810		
Akron, Colorado							
1964	G		930	1,130	1,320	Above	Below
	TDM		3,340	4,250	4,720		
1966[c]	G					Above	Below
	TDM		3,090	3,680	4,000		
1967	G		1,300	1,270	1,380	Normal	Above
	TDM		4,410	4,450	4,570		
1968	G		1,880	1,930	1,930	Much Below	Below
	TDM		5,130	5,240	4,740		
Average	G		1,370	1,440	1,540		
	TDM		3,990	4,400	4,150		
North Platte, Nebraska							
1963	G	1,440		1,440	1,440	Above	Normal
	TDM	6,330		6,400	5,960		
1964	G	3,000		2,340	2,580	Much Below	Above
	TDM	9,450		9,990	8,760		
1965	G	2,880		2,460	2,100	Much Below	Normal
	TDM	8,760		8,740	8,730		
1966	G	3,300		3,120	3,120	Below	Below
	TDM	10,120		9,980	10,130		
1967	G	2,100		2,160	2,340	Above	Below
	TDM	9,110		8,150	8,820		
Average	G	2,540		2,300	2,320		
	TDM	8,750		8,650	8,480		

[a]TDM—Total Dry Matter.
[b]Wheat yields from nitrogen-phosphorus fertilizer plots.
[c]Wheat hailed June 8, 1966, only TDM obtained.

temperatures are much below normal, mulches exaggerate this temperature depression and may restrict tiller and head formation, which in turn may reduce grain yield potential.[1] Cold springs are usually wet springs, thus available water would not be as critical to grain yields as would tiller production.

There was little evidence that soil nitrate was seriously involved at any of the three locations. Average nitrate nitrogen in the upper 6 feet of soil at the end of fallow in early September was over 100 pounds per acre for all levels of mulch for most years at Akron and North Platte. With the application of 30 pounds of nitrogen per acre at Sidney, the total available nitrogen was comparable to that of the other two locations.

These studies, conducted at three widely separated Great Plains locations, demonstrated that increasing amounts of straw mulch consistently increased storage of soil water in fallow during 16 years of testing. The mean net gain in soil water that can be expected from the normal mulch production of 2,400, 3,600, and 5,500 pounds per acre at Sidney, Akron, and North Platte, respectively, should approach 1.0, 1.2, and 2.0 inches per fallow season.

REFERENCES CITED

1. Black, A. L., and J. F. Powers. 1965. *Effect of chemical and mechanical fallow methods on moisture storage, wheat yields and soil erodibility.* Soil Sci. Soc. Am. Proc. 29: 465-468.
2. Black, A. L., and B. W. Greb. 1968. *Soil reflectance, temperature and fallow water storage on exposed subsoils of a Brown soil.* Soil Sci. Soc. Am. Proc. 32: 105-109.
3. Greb, B. W. 1966. *Effect of surface-applied wheat straw on soil water losses by solar distillation.* Soil Sci. Soc. Am. Proc. 30: 786-788.
4. Greb, B. W., D. E. Smika, and A. L. Black. 1967. *Effect of straw mulch rates on soil water storage during summer fallow in the Great Plains.* Soil Sci. Soc. Am. Proc. 31: 556-559.
5. Hanks, R. J., and N. P. Woodruff. 1958. *Influence of wind in water vapor transfer through soil, gravel, and straw mulches.* Soil Sci. 86: 160-164.
6. Jacks, G. V., W. D. Brind, and R. Smith. 1955. *Mulching.* Tech. Comm. No. 49. Commonwealth Bur. of Soil Sci., England.
7. Johnson, Wendell, C. 1964. *Some observations on contribution of an inch of seeding-time soil moisture to wheat yield in the Great Plains.* Agron. J. 56: 29-35.
8. Kuska, J. B., and O. R. Mathews. 1956. *Dryland crop-rotation and tillage experiments at the Colby (Kans.) Exp. Station.* Circ. 979. U. S. Dept. Agr., Washington, D. C. p. 40-59.
9. Mathews, O. R., and T. J. Army. 1960. *Moisture storage on fallowed wheatland in the Great Plains.* Soil Sci. Soc. Am. Proc. 24: 414-418.
10. Smika, D. E., and C. J. Whitfield. 1966. *Effect of standing wheat stubble on storage of winter precipitation.* J. Soil and Water Cons. 21: 138-141.
11. Smika, D. E., and G. A. Wicks. 1968. *Soil water storage during fallow in the Central Great Plains as influenced by tillage and herbicide treatments.* Soil Sci. Soc. Am. Proc. 32: 591-595.
12. Smika, D. E. 1969. *Summer fallow for wheat production in the Great Plains.* Agron. J. 62:15-17.
13. Unger, Paul W., and J. J. Parker, Jr. 1968. *Residue placement on decomposition, evaporation, and soil moisture distribution.* Agron. J. 60: 469-472.
14. Whitfield, C. J., J. J. Bond, B. W. Greb, T. M. McCalla, and F. M. Sidoway. 1962. *A standardized procedure for residue sampling.* ARS 41-68. U. S. Dept. Agr., Washington, D. C. p. 3-9.
15. Zingg, A. W., and C. J. Whitfield. 1957. *A summary of research experience with stubble-mulch farming in Western States.* Tech. Bul. 1166. U. S. Dept, Agr., Washington, D. C. p. 5-6.

[1]Smika, D. E. 1969. "Soil temperature and wheat straw mulch effects on plant development and nutrient content and uptake by wheat." Unpublished Ph.D. Thesis, Kans. State Univ., Manhattan. 192 pp.

Effect of climate, impoundments, and land use on stream salinity

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ABSTRACT - Average salinity of the Washita River in Oklahoma increased substantially between 1954 and 1967. Among all variables studied, climatic changes appeared to exert the greatest influence on stream salinity levels. After correcting for the effect of climatic change, this trend remained evident and appeared to be more closely related to changing land use than to the recent introduction of numerous impoundments at upstream locations.

Effects of changing trends in land use and the extensive application of selected soil and water conservation practices on the quantity and quality of downstream flow are being evaluated in western Oklahoma. Of particular concern in studies of downstream flow in the Washita River Basin in Oklahoma are those conservation practices and land uses that enhance water loss and thus concentrate salts by evaporation and evapotranspiration or that dissolve additional salts by causing more water to infiltrate soils and saline geologic deposits. The result of either of these processes is increased stream salinity.

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In 1965 a study was initiated in the upper Washita Basin to (1) determine salinity trends in the Washita River and to (2) identify the causative factors and evaluate their contributions if a major increase in salinity was observed. To attain these objectives, long-term water quality and flow records had to be available and watershed characteristics had to be extensively surveyed and documented. Sampling sites at Carnegie and Durwood were chosen for the preliminary study (Figure 1). Water quality and streamflow data have been collected at these sites since 1954 (5, 6). Moreover, the area between the two sites includes a 1,130-square-mile watershed that has been surveyed and studied continually since 1961 by the Agricultural Research Service.

The Carnegie station, approximately 300 river miles northwest of Durwood, receives about 25 inches of rainfall a year. Durwood receives about 40 inches of rainfall annually. The watersheds above Carnegie and Durwood encompass 3,129 and 7,202 square miles, respectively.

Nearly all existing floodwater-retarding structures and some ponds in the upper reaches of the Washita River watershed have been installed