Ecofallow comes of age in the Central Great Plains

B. W. Greb and R. L. Zimdahl

*ABSTRACT: Winter wheat (*Triticum aestivum L.*), the dominant dryland crop in the semiarid Central Great Plains, succeeds fallow in rotation. Under the established commercial practice of conventional spring tillage fallow, weeds and volunteer wheat grow in the stubble from harvest until the first tillage the next April or May. This vegetative growth consumes scarce water and some nitrate nitrogen. Ten years of tests at Akron, Colorado, showed that herbicides used in minimum tillage fallow—ecofallow—suppressed an average 70 percent of potential weed and volunteer wheat growth from application, 7 to 10 days after July wheat harvest, until fall dormancy. At the end of fallow, soil water storage was 3.9 centimeters (1.53 in) greater and nitrate nitrogen was 29 kilograms per hectare (26 lb/a) greater than with conventional spring tillage fallow. These extra growth inputs subsequently increased wheat yields 495 kilograms per hectare (7.4 bu/a) with 1.8 fewer tillages per fallow season. In response to recent Environmental Protection Agency labeling of certain herbicides, ecofallow is undergoing rapid commercial expansion.*

WINTER wheat (*Triticum aestivum* L.) is harvested on about 3.2 million hectares (8.0 million acres) each season in a winter wheat-fallow rotation in the semiarid Central Great Plains (*5, 6*). Traditionally, most farmers leave their wheat stubble undisturbed from harvest in July until initial spring tillage. There is no attempt to control weeds, although some farmers in the southern part of the region disk the stubble shortly after harvest to promote volunteer wheat for fall grazing. In either case, weeds and volunteer wheat consume residual soil water—the 2.5 to 5.0 centimeters (1-2 in) remaining at harvest. Post-harvest rainfall, which averages 10 to 20 centimeters (4 to 8 in) up to fall dormancy, about November 10, is also consumed.

Samplings of post-harvest weed growth vary from 900 to 2,700 kilograms of dry matter per hectare (800 to 2,400 lb/a), depending upon available water supply (*3, 5, 11*). Weed growth of 1,120 kilograms per hectare (1,000 lb/a) consumes about 7.6 centimeters (3 in) of water and 36 kilograms per hectare (32 lb/a) of available nitrogen (*3, 11*). At peak growth, weeds can consume 0.50 to 0.75 centimeters (0.2 to 0.3 in) of water a day (*11*).

Disking stubble after harvest promotes volunteer wheat growth and leaves little or no capability for snow catchment to help recharge the soil profile with water. Snow trapped in standing wheat stubble contributes 35 to 55 percent of the water stored during the entire fallow season in the northern part of the region (*4, 10*). Snowstorms, which involve 60 percent of the snowfall precipitation in this area, are wind-driven. The wind blows snow off pastures, planted winter wheat, and areas of flattened wheat stubble (*4, 5*).

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In recent years, some farmers have undercut new stubble with large V-blade sweep plows shortly after harvest to kill weeds. A second undercutting is sometimes used to suppress volunteer wheat. This system is much better than no weed control at all after harvest (*3*), but it destroys 10 to 15 percent of the stubble per operation, and it causes the loosened stubble to lodge gradually because of strong winds and blowing snow. Sweep plowing is also time consuming when large areas must be plowed, including the previous season's fallow, which needs weed control and seedbed preparation. Consequently, herbicides are a logical solution to fall weed control in wheat stubble.

An ideal herbicide for a winter wheat-fallow system would kill all weeds quickly after wheat harvest, then keep the soil free of vegetation until winter wheat seeding. It would also need to be economical and leave no harmful residues. Unfortunately, a herbicide for all soil types and seasons does not exist. No-till fallow (complete chemical fallow) is technically feasible, but it is not economical because of the high cost of effective contact herbicides needed to maintain weed-free fallow (*2*).

There has been good progress reported with partial chemical fallow, a system termed "minimum tillage fallow" or "ecofallow" (*3, 9*). In ecofallow, weeds and volunteer wheat are controlled with contact and pre-emergence herbicides from shortly after wheat harvest until late the next spring, then two or three subsurface tillage operations are used to control weeds.

We now have data on the net benefits of using ecofallow in comparison with conventional spring tillage fallow at Akron, Colorado, over a 10-year period, 1968-1978.

Fallow and cropping methods

In 1967 we installed test situations on a level Rago silt loam (Pachic Argiustoll) with a uniform texture to a depth of more than 180 centimeters (70 in). The site was divided into four replicated blocks of alternate wheat-fallow plots so that test results of both fallow and crop yields could be obtained each year. Individual plots were 11 × 31 meters (36 × 100 ft), a convenient size for herbicide application, tillage, and sampling. Of several fallow methods tested, only ecofallow versus conventional spring disk fallow are described here.

Conventional spring tillage fallow required five operations per fallow season: initial spring tandem disking in late April, sweep plowing with 1.8-meter (6-ft) V-blades during late May, and three rod-weedings (with semichisels attached), one each in late June, July, and August.

The ecofallow treatment involved a single herbicide application consisting of amitrole plus atrazine at 1.12 kilograms each per hectare (1 lb/a) for the fallow years 1968 to 1972.[1] For the fallow years 1973 to 1977, 0.28 kilogram of paraquat per hectare (0.25 lb/a) plus 1.40 kilograms of atrazine per hectare (1.25 lb/a) or 0.56 kilogram of glyphosate per hectare (0.50 lb/a) plus 1.40 kilograms of atrazine per hectare (1.25 lb/a) were tested. All herbicides were applied with water at 400 kilograms per hectare and 0.1 percent surfactant.

In all years, the herbicides were applied within 10 days after the July wheat harvest. Our objective was to kill all broadleaf and grassy weeds with the contact herbicides—amitrole, paraquat, or glyphosate. Atrazine was applied to prevent germination of new weeds and to kill or suppress growth of volunteer wheat until late spring. V-blade sweep plows, operated 7.6 centimeters (3-in) deep, were used late in June to control emerging weeds. This was followed by one or two rod-weedings (with semichisels attached) at the same depth during July and August to control weeds and prepare the seedbed.

After fallow on all plots, winter wheat ('Scout' in years 1968-1972 and 'Centurk'

[1]This paper reports results of research only. Mention of herbicides does not constitute a recommendation for use by the U.S. Department of Agriculture, nor does it imply registration under FIFRA as amended.

in years 1973-1977) was seeded at a rate of 28 kilograms per hectare (25 lb/a) in 33-centimeter-wide (13-in) rows using a deep furrow shoe planter.

Soil water at the end of fallow was determined gravimetrically in 30-centimeter (1-ft) increments to a depth of 180 centimeters (6 ft). Soil nitrate nitrogen was analyzed by the phenoldisulphonic acid method in 0- to 30-, 30- to 60-, and 60- to 120-centimeter (0- to 1, 1- to 2, and 2- to 4-ft) depth increments. Samples for analysis were taken from three cores in each of the four replicated plots per treatment.

Three weed growth samples per treatment plot were taken the year of harvest in late September. Samples were areas 1 meter square (39.3 sq in) within the wheat stubble. Each sample was oven dried 24 hours at 70 degrees Celsius (158°F) before weighing. Grain yields were determined by combining a 4.9- × 31-meter (16- × 100-ft) area. Straw yield and protein samples were taken by hand from two 1.3- × 1.2-meter areas per plot. These samples were air dried for 3 weeks before threshing. Grain yields were calculated at 9 percent moisture. Grain protein was determined by the Kjeldahl distillation method.

Annual precipitation on a harvest-to-harvest crop year basis averaged 348 millimeters (13.7 in), 65 millimeters (2.56 in) below the 1911 to 1978 average.

Table 1. Comparison of ecofallow with conventional spring tillage fallow in a winter wheat-fallow rotation at Akron, Colorado. Average for 10 years, 1968-1978.

Parameter measured	*Treatment* Conventional Spring Tillage Fallow	Ecofallow*	*Difference*†
Weed growth after harvest‡ (kg/ha)	1,155	355	− 800
Soil water content at end of fallow (cm)	16.4§	20.2§	3.8
Gain in soil water during fallow (cm)	9.9§	13.7§	3.9
Soil nitrate content at end of fallow (kg/ha)	80	114	34
Gain in soil nitrate during fallow (kg/ha)	58	87	29
Number of mechanical tillages	4.6	2.8	− 1.8
Wheat, grain yield (kg/ha)	2,315	2,810	495
Wheat, straw yield (kg/ha)	3,680	4,500	820
Wheat, total dry matter (kg/ha)	5,995	7,310	1,315
Protein content of grain (%)	11.0	11.8	0.8

*Five tests with amitrole + atrazine; five tests of pooled results with glyphosate + atrazine or paraquat + atrazine (equally effective).
†All numerical values between ecofallow and conventional spring tillage fallow were significantly different at the 95% level of confidence (Duncan's multiple range test).
‡Measured late September each fallow year.
§Available water above 8% wilting point.

Results and discussion

In comparison with no weed control, ecofallow treatment reduced weed growth an average of 70 percent from date of herbicide application until fall dormancy (Table 1, Figure 1). This suppression of weed growth helped increase soil water storage an average of 3.9 centimeters (1.53 in) and the accumulation of soil nitrate nitrogen by 29 kilograms per hectare (26 lb/a) at the end of fallow.

The extra soil water stored and soil nitrate nitrogen obtained with the use of ecofallow was reflected in an average 21 percent increase in winter wheat grain yield and a 22 percent increase in straw yield over conventional spring tillage fallow. The grain yield differential averaged 495 kilograms per hectare (7.4 bu/a) The protein content of grain also increased slightly with ecofallow (Table 1).

As shown in table 2, the suppression of dry weight of weeds ranged from 550 to 1,165 kilograms per hectare (490 to 1,040 lb/a). This was because varying amounts of water were available for weed growth after harvest. Such fallow years as 1969, 1973, 1976, and 1977 had significantly more water available after harvest than did the other years.

Amitrole suppressed post-harvest weeds less effectively than glyphosate and paraquat. It did not kill kochia (*Kochia scoparia* L.) as efficiently as the other two contact herbicides. Kochia usually makes up 5 to 20 percent of the broadleaf weed population in wheat stubble. Atrazine effectively controlled all weeds and volunteer wheat from application until after

Table 2. Net benefits, by individual tests, of ecofallow compared with conventional spring tillage fallow in a winter wheat-fallow rotation at Akron, Colorado.

Fallow Year	Crop Year	Post-harvest Weeds Suppressed (kg/ha)	(%)	*Increase in* Soil Water at End of Fallow (cm)	Soil NO_3-N at End of Fallow (kg/ha)	Fewer Tillages (number)	*Increase in Wheat Yield Components* Grain (kg/ha)	Straw (kg/ha)	TDM* (kg/ha)	Protein Grain (%)
				Ecofallow using Amitrole + Atrazine						
1968	1969	550	51	2.3	17	2	255	610	865	0.3†
1969	1970	1,165	85	5.9	51	2	920	1,320	2,240	1.7
1970	1971	660	61	4.3	44	2	370	1,105	1,475	1.2
1971	1972	570	70	3.5	11†	2	315	575	890	0.0†
1972	1973	650	75	1.8	30	2	460	630	1,090	0.8
Average		720	68	3.6	31	2	465	850	1,315	0.8
				Ecofallow using Glyphosate + Atrazine or Paraquat + Atrazine (results pooled)						
1973	1974	1,030	73	3.6	46	1	560	1,095	1,655	1.9
1974	1975	615	65	4.5	28	2	740	895	1,635	0.6
1975	1976	580	62	3.9	16†	1	375	850	1,225	0.0†
1976	1977	1,110	82	4.6	28	2	275‡	265†‡	540†	1.1
1977	1978	1,055	73	4.2	22	2	660	870	1,530	0.7
Average		880	71	4.2	28	1.6	520	795	1,315	0.9
Coefficient of varieties % of All Tests		31	13	28	44		41	36	36	

*Total dry matter.
†Not significantly better than conventional spring tillage at the 95% level of probability (Duncan's multiple range test).
‡30% estimates hail damage.

June 5 during all years except 1977. That year new weeds emerged in early May.

Ecofallow plots stored significantly more soil water by the end of fallow than the conventional spring tillage fallow plots in all tests. This increased water storage ranged from 1.8 to 5.9 centimeters (0.7 to 2.3 in) per season. In comparison with conventional spring tillage fallow, ecofallow also increased the level of soil nitrate nitrogen significantly by the end of fallow in 8 of its 10 years.

The higher amounts of stored soil water and soil nitrate nitrogen available at the end of fallow as the result of the fall and early spring weed suppression by herbicides with ecofallow significantly improved grain yields as compared with conventional spring tillage fallow in all tests. Straw yields also increased significantly in all tests except 1977, when hail destroyed about 30 percent of the foliage. The combined extra yield of grain and straw exceeded the weight of weeds suppressed by a ratio of 1.6 to 1.

Briggs and Shantz (*1*) and Shantz and Piemeisel (*7*) showed similar water requirement values of about 232 kilograms (510 lb) of water per kilogram (2.2 lb) of dry matter produced for both winter wheat and 10 broadleaf weeds common to the area when grown separately. It could be assumed from their data that a given weight of weeds would inhibit an equal weight of wheat in the field. Nevertheless, our results suggest that weeds have an inhibiting effect on wheat greater than a 1:1 ratio. This interaction should probably be tested further with other crop and weed situations.

Grain protein also increased significantly with ecofallow in 7 of the 10 years tested. Protein gains seemed to be associated with years in which soil nitrate nitrogen was also high—1970, 1971, and 1973.

As expected in an erratic, semiarid environment, the coefficient of variation for most measurements was high, ranging from 28 to 44 percent. The coefficient of variation for percentage of weeds suppressed, however, was low, 13 percent, indicating consistent control.

The net benefits from ecofallow were achieved with an average of 1.8 fewer tillage operations per fallow season.

Straw mulch at the end of fallow in the surface 7.6 centimeters (3 in) of soil averaged 3,600 kilograms per hectare (3,270 lb/a) with ecofallow (Figure 2). This compared with 2,400 kilograms per hectare (2,140 lb/a) for conventional spring tillage fallow. This extra mulch provides better soil erosion protection (*5*, *6*). In addition, the higher volume of straw mulch improves soil water content in the seed zone (*8*).

The cost per hectare of ecofallow is only slightly higher than conventional spring tillage fallow, but the net profit is significantly higher because of the 15 to 25 percent higher grain yield.

Commercial adaptation

Several contact and pre-emergence herbicides have recently been approved by the Environmental Protection Agency (EPA) for ecofallow. The EPA labels also give time and rate of herbicide application for various soil types and crop rotations. These recent approvals triggered a rapid expansion of minimum tillage in the fallow-winter wheat area of eastern Colorado, western Nebraska, and western Kansas. Chemical manufacturers and herbicide application companies estimate that ecofallow in this region increased from essentially nothing in the fall of 1976 to 40,000 hectares in 1977 and 344,000 hectares in 1978. The 1978 hectarage represents about 10 percent of total fallow hectares in the region. A further increase was expected in 1979 because of cost-sharing programs for this practice available through the Soil Conservation Service and Agricultural Stabilization and Conservation Service.


Soil Conservation Service photo

Figure 1. Weed-free wheat stubble in an ecofallow system. Time is mid-May after herbicide application the previous July.

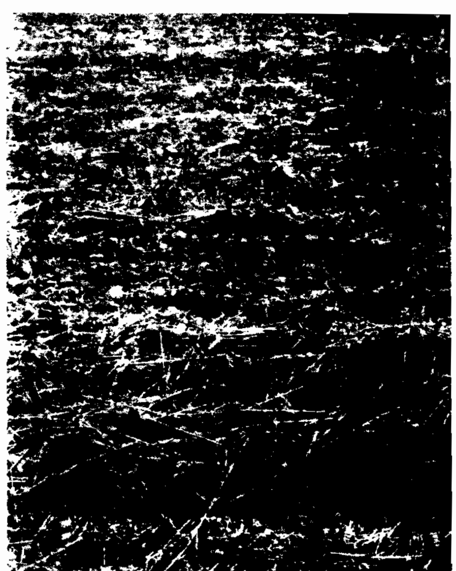
Soil Conservation Service photo

Figure 2. Ecofallow in late August, before seeding winter wheat. Note erosion-resistant soil clods and abundant soil-protective straw mulch.

Some problems with ecofallow remain to be refined in the field. One is determination of lower applications rates for atrazine or use of shorter term pre-emergence herbicides on sandy soils that are low in organic matter and on soils high in lime content. Greater refinement is also needed to avoid overlap and underlap of herbicide applications in wheat stubble. Overlap can cause harmful herbicide carryover, thereby damaging the succeeding crop. Underlap can be a source of weeds and weed seeds. In general, water pressures and amounts of water carrier also need to be worked out for various quantities and types of stubble, such as wheat, sorghum, and millet.

Conclusions

Winter wheat yields in the Central Great Plains have increased remarkably in the last two decades because of such technological advances as improved water storage in fallow with stubble mulching, better planting and harvesting equipment, and higher yielding and better quality wheat varieties (*5*). The advent of ecofallow is a continuation of these technological systems, and it may be a significant breakthrough in dryland agriculture. The advantages include 15 to 25 percent higher yields, some reduction in the energy required for field work, and reduced soil erosion (*5*, *6*). Considering possible fuel shortages, ecofallow may be the new standard system for raising dryland wheat in the Central Great Plains.

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Costs and benefits of terraces for erosion control

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ABSTRACT: To determine if terrace systems are economically justified from the farmer's standpoint, terrace construction costs were estimated using 1978 data. Terraces of both the gradient and tile-outlet-storage type were investigated on field slopes between 1 and 15 percent. Government cost-sharing for terrace construction was accounted for in the analysis. Two management levels and two subsoil types were considered as variables. A number of common soils in Illinois were selected on the basis of their initial productivity, erodibility, kind of subsoil, and range of slopes. Soil losses for various conditions were estimated using the universal soil loss equation. Corn and soybean prices for 1978 were used in the economic evaluation. The analysis showed that, except in a few situations, the farmer will sacrifice income to control erosion by constructing terraces. Although this finding contradicts the view that soil conservation pays, the study evaluated only the direct benefits of terracing. If other costs of erosion are considered, the benefits from terracing may offset the costs. The future costs of soil erosion to society in the form of reduced agricultural productivity may justify additional expenditures by governmental agencies to promote soil conservation.

SOIL is removed by erosion in many areas every year. More than 12 million tons of sediment contribute daily to surface water pollution in the 48 contiguous states (*1*). This sediment damages engineering works, agronomic activities, and wildlife. Gross erosion from agricultural areas in Illinois exceeds 181 million tons annually (*5*). Only 14 percent of the state's 9.7 million acres of sloping cropland is adequately protected from erosion (*7*).

There are several methods to control erosion, including tillage practices or crop rotations that reduce the potential for erosion. Terracing also is an effective erosion control practice, but terracing is expensive, even when the gorvernment shares the cost. The expense deters some landowners from installing terraces.

Allowing erosion to go unchecked, however, also can be costly. Soil erosion ultimately reduces crop yields and causes downstream sediment damages.

Our study was conducted to determine if terrace systems could be economically justified from the farmer's standpoint solely. We investigated this economic justification on several sloping soils in Illinois by considering soil productivity, erosion potential, kind of subsoil, reduced productivity from the loss of topsoil, management levels, and terrace installation costs.

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Study methods

Evaluating the economic impact of initiating a conservation practice, such as terracing, involves several variables. We looked at a number of these to determine their effects on the income consequences of terracing.

Range of soils. The soils examined in our study represent a range of initial productivities, erodibilities, kinds of subsoil, and slopes. Table 1 describes the properties of these soils (*3*). Subsoil was classified as favorable or unfavorable depending on whether or not it has characteristics that are favorable to plant growth such as structure and soil type, but lacks nutrients.

Soil loss calculations. We used the universal soil loss equation, A = RKLSCP, to predict soil erosion rates (*9*). We held the rainfall factor, R, cropping management factor, C, and erosion control practice factor, P, constant throughout the study. The R factor varies in Illinois from 160 in the north to 220 in the south. We used a value of 180, the accepted figure for most of central Illinois.

We assumed the tillage system without terraces to be fall plowing, up-and-down slope. This system used a P factor of 1.0 and a C factor of 0.51. We used the same C factor for the two crop rotations considered, continuous corn and corn-corn-soybeans. To obtain the slope length and slope factor, LS, we used a slope length of 400 feet.

To calculate the percentage yield reductions due to erosion, we computed the total inches of soil eroded each year. We converted this soil loss to volume using a bulk density of 84 pounds per cubic foot, an average value for the plow layer of several silt loam soils (*2*).

We assumed that the terrace system was planned and maintained properly and that the annual soil loss would be equal to or less than the soil loss tolerance level. That is, the terrace spacing was adequate to provide an LS factor in combination with a P factor for contouring so that the soil loss tolerance was not exceeded. Thus, we did not compute the soil loss for the terraced situation.

Calculating yield reductions. The extent to which soil erosion reduces yields depends upon the level of farm management and the subsoil's ability to support plant growth. Level of management can substantially change the initial soil productivity. Table 2 lists some representative characteristics of basic and high levels of management.

Table 3 shows the relationships of level of crop management, slope, subsoil, and degree of erosion to crop yields. Our analysis included the adjustment of yields to account for slope and kind of subsoil. Because favorable and unfavorable subsoils have different effects on yield, we evaluated the subsoils separately.

We assumed that moderate erosion had occurred on the soils before the study.