WHEAT FARMERS ADOPT THE UNDERCUTTER FALLOW METHOD TO REDUCE WIND EROSION AND SUSTAIN PROFITS

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Abstract

Blowing dust from excessively tilled fallow fields is a major soil loss and air quality concern in the low precipitation (<12 inches annually) wheat production region of the Inland Pacific Northwest (PNW). A 2-year, tillage-based winter wheat-summer fallow (WW-SF) rotation is practiced on more than 90% of rainfed cropland in the region. Earlier research proved that the undercutter method for non-soil inversion primary spring tillage is not only environmentally superior but also agronomically and economically equivalent to high-soil disturbance conventional tillage. In this study, we conducted comprehensive surveys of 47 wheat farmers who purchased undercutters through the USDA-Natural Resources Conservation Service (NRCS). Farmers received 50% cost shares on the condition that they use the undercutter as prescribed by university scientists on at least 160 acres of land for three consecutive years. Participating farmers were interviewed each year from 2008 to 2010 regarding the agronomic and economic performance of the undercutter versus conventional fallow on their farms. The survey revealed equivalent average winter wheat grain yields and profitability for the two systems from 104 paired comparisons. Survey results also showed that 90% of farmer participants were satisfied with the undercutter system. We conclude that the undercutter system offers a costless air quality gain to society and soil conservation benefit for farmers.

Introduction

This study focuses on the low-precipitation (<12 inches annually) zone of east-central Washington and north-central Oregon that encompasses 3.7 million acres of non-irrigated cropland. Essentially, all this cropland is in a tillage-based WW-SF rotation. Excessive tillage during summer fallow causes recurrent wind erosion, which seriously degrades soil, and blowing dust, which poses a hazard for human health. Urban locations within this region frequently fail to meet federal clean air standards for PM10 emissions during windstorms (Sharratt and Lauer 2006). The sandy silt loam soils found throughout the WW-SF region have a greater potential to emit PM10 even though these soils are composed of a smaller percentage of PM10 compared to the finer-textured silt loam soils found in the intermediate- and high-precipitation zones of the PNW (Feng et al. 2011).

Long-term cropping systems studies in the low-precipitation zone have examined the feasibility of direct seeding spring-sown wheat, barley, and numerous other crops as well as the practice of no-till summer fallow where herbicides are used as a substitute for all tillage operations. Studies have shown that no alternative crop or cropping system tested so far can compete with WW-SF for average and stable profitability (Schillinger and Young 2004; Schillinger et al. 2007). The absence of significant summer rainfall in the PNW penalizes yields and returns of spring crops and increases their riskiness. Other studies have shown that no-till summer fallow, although ideal for wind erosion control (Sharratt et al. 2010), loses seed-zone water at a faster evaporative rate than tilled summer fallow during the hot, dry summer (Hammel et al. 1981; Wuest 2010). This loss often makes it difficult or impossible for farmers to plant winter wheat into carryover soil moisture in late summer with no-till summer fallow. However, with tilled summer fallow, adequate seed-zone moisture for planting in late summer can generally be achieved. The physics of water loss in tilled versus no-till summer fallow and the grain yield penalties associated with delayed planting of winter wheat are described by Wuest and Schillinger (2011) and Higginbotham et al. (2011).

Research conducted in the past two decades indicates that the most realistic method for farmers to mitigate wind erosion and achieve stable and profitable yields in the low-precipitation zone is to practice conservation tillage in a WW-SF rotation. The undercutter system of WW-SF farming was developed for this purpose. The undercutter is a primary tillage implement used in the spring to sever capillary pores and channels to halt liquid flow of water to the soil surface as required to retain seed-zone water in summer fallow. Undercutter implements are equipped with 32-inch-wide blades with 28-inch spacing between blades on two tiers. Blades have a narrow pitch to allow slicing below the soil surface with minimum soil lifting or disturbance of surface residue (Figures 1 and 2). With this system, a tank cart is pulled in front of the undercutter (Figure 1) to deliver nitrogen, and often sulfur fertilizer, through a manifold and tubing plumbed beneath both wings of individual undercutter blades. The optimal operating depth for the blades is about five inches to provide a relatively thick, dry surface soil mulch to retard evaporation during the summer (Wuest 2010).

Figure 1. A 375-horsepower crawler tractor pulls a 1,000-gallon tank cart filled with aqua NH3-N and a 32-foot-wide undercutter implement during primary spring tillage plus nitrogen and sulfur fertilizer injection in April. Photo by W.F. Schillinger.

Figure 2. The undercutter's narrow-pitched and overlapping 32-inch-wide V blades slice beneath the soil at a depth of five inches to completely sever capillary channels and halt the upward movement of liquid water to retain seed-zone water in summer fallow for late-summer planting of winter wheat. Most of the winter wheat residue from the previous crop is retained on the surface to control wind erosion. Photo by W.F. Schillinger.

A 6-year field experiment conducted in Lind, WA (9.52 inches average annual precipitation) showed the undercutter fallow system to be statistically equivalent agronomically and economically to conventional fallow (Schillinger 2001; Janosky et al. 2002). There were never any differences between undercutter and conventional tillage treatments in precipitation storage efficiency in the soil or in winter wheat grain yield. However, the undercutter method consistently increased surface residue, surface clod mass, and surface roughness compared to conventional tillage (Schillinger 2001). Wind tunnel tests have shown that the undercutter method reduces soil loss during high winds by up to 70% compared to conventional tillage fallow (Sharratt and Feng 2009).

The question is whether these promising experimental results could be duplicated on farmers' fields. To answer this question, the NRCS awarded a $905,000 Conservation Innovation Grant to the Washington Association of Wheat Growers (WAWG) to 50% cost share the purchase of undercutter implements with farmers. Forty-seven farmers located in ten counties in Washington and Oregon purchased undercutters through this program. Individual cost-share payments averaged $15,320, including $980 for the manifold apparatus and tubing to allow fertilizer application with the undercutter during primary spring tillage. Total payments to farmers equaled $720,040, with administrative costs absorbing the remainder. As part of the project, participating farmers consented to personal interviews in 2008, 2009, and 2010 about their experience and opinions regarding the undercutter method of farming. The objective of this paper is to report the results of the farmer survey and to discuss the implications for the economic viability of the undercutter system of WW-SF farming in the Inland PNW. This study provides a relatively rare multi-year, on-farm statistical test of promising field results.

Materials and Methods

Overview

The NRCS-WAWG project provided undercutter implements up to 32 feet in width that were fitted to apply aqua or anhydrous NH3-N at the time of primary spring tillage. Undercutter implements determined as suitable for the project were manufactured by Duratech Industries, Great Plains Manufacturing, and Orthman Manufacturing. All 47 participants accepted into the program farmed in the WW-SF region of south-central Washington and north-central Oregon, where average annual precipitation on their farms ranged from 6 to 12 inches.

All participant farmers agreed to (i) leave winter wheat stubble standing and undisturbed from the time of grain harvest in late July-early August until the time of primary spring tillage; (ii) apply glyphosate herbicide at a rate no less than 16 oz/acre in late March or April prior to primary spring tillage to control weeds; (iii) use the undercutter implement for primary spring tillage on at least 160 acres per year for three consecutive years, (iv) apply all nitrogen and sulfur fertilizer needed for the subsequent winter wheat crop with the undercutter during the primary spring tillage operation; (v) operate the undercutter blades at a depth of about five inches below the soil surface to optimize seed-zone water retention; (vi) rodweed only as required to control weeds during late spring and summer,

(vii) keep accurate records of dates of field operations, rates of fertilizer and herbicides applied, and grain yields; and (viii) participate in twice-annual surveys to provide information on their production practices and grain yields as well as their perceptions of the undercutter method for WW-SF farming.

Economic Assessment

Survey results revealed that most machine operations and input applications by individual farmers were similar for the undercutter and conventional fallow systems. Consequently, partial budgeting procedures were used as they provide an efficient method for comparing profitability of the two systems by measuring only changes in gross revenue and changes in costs for the undercutter system relative to the conventional system. The profitability comparison includes variable costs for fertilizer, herbicides, seed, labor, and diesel fuel, which increase with the number of acres farmed. Fixed costs (including depreciation, interest, taxes, and insurance for machinery and buildings) do not vary over fallow tillage systems because these fixed assets remain the same. Also, the land base remains equal under both systems, so land costs do not change. Farmers indicated they would keep their conventional primary fallow tillage machinery (e.g., tandem disks and field cultivators) for special conditions, or for part of their land, even after acquiring an undercutter.

All cost and revenue figures are presented on a rotational acre basis. For example, a rotational acre of WW-SF contains 0.5 acre of winter wheat and 0.5 acre of fallow. Crop prices are averages over the experiment era, while input prices are near-term projections.

Results and Discussion

Table 1 displays the average land use reported by participating farmers from 2008 to 2010. Adjustments in leased and owned land caused farm size to change over time. The areas listed under undercutter and conventional include both harvested and fallow acres on which these systems were used. Farmers used the undercutter on an average of 790 acres of “other” land; 392% above their contractual level of 160 acres, and this use grew from 2008 to 2010 (Table 1). Over the three years, participant farmers used the undercutter method on an average of 21% of their cultivated acres while using conventional tillage on the remaining 79%. This excludes an average of 1,114 acres of non-cropped land enrolled in the Conservation Reserve Program (CRP), 19% of the average farm size of 5,738 acres.

Table 2 presents averages and standard deviations of winter wheat grain yields using the undercutter and conventional tillage methods for individual farm sites within the same year as well as averaged over the three years. Matching grain yields by farm site and year is appropriate because agro-climatic factors and management associated with individual farms and years is held constant. For example, if a farmer reported yields in 2008 for only one system, that pair was not included in the sample. The total sample includes 104 complete pairs over the two systems. This sample over a three-year period and across ten counties in two states provides an excellent comparison of the performance of the two fallow systems. The sample size for the undercutter system in 2008 was reduced by delivery delays of undercutters to some farmers during the 2007 fallow

Table 1. Average land use on participating farms by year.

Category	**2008**	**2009**	**2010**
		acres	
Undercutter: contract	195	203	160
Undercutter: other land	669	768	936
CRP	1,000	1,010	1,329
Conventional WW-SF	3,959	3,171	3,814
Total farm	5,824	5,152	6,239

Table 2. Winter wheat grain yields matched by farm and year for conventional (Conv.) and undercutter (U.C.) tillage from 2008 to 2010 as well as the three-year average.

	Year							
	2008		2009		2010		Average	
	Conv.	U.C.	Conv.	U.C.	Conv.	U.C.	Conv.	U.C.
Number of farms	14		47		43		104	
Average yield (bu/acre)	34.4	32.9	34.4	32.9	44.2	44.0	36.5	36.0
Paired T P-Value[1]	0.40		0.78		0.89		0.62	

[1] Values greater than 0.05 indicate no statistical differences between conventional and undercutter tillage treatments.

year, which caused unavailability of yields for a full WW-SF cycle for these farmers. Responses for data decreased slightly in 2010 because that year fell beyond the required reporting period for the project.

Farmers achieved very similar grain yields using the undercutter and conventional systems both in individual years and over all three years (Table 2). The most robust statistical comparison of mean yields is that for all three years, which compares the two systems over varying weather conditions. Over 2008–2010 with complete paired data, average yields between undercutter and conventional differed by only 0.5 bu/acre, or by 1%.

Some farmers were initially concerned that less aggressive primary tillage (e.g., undercutter versus tandem disk) might increase the number of subsequent required rodweedings. In fact, farmers rodweeded 0.14 fewer times per year on undercutter ground.

Glyphosate is the dominant herbicide for controlling weeds prior to primary spring tillage regardless of tillage system. The survey results showed that farmers used statistically equivalent rates of glyphosate regardless of fallow tillage treatment. Participants in the WAWG-NRCS project were contractually required to apply glyphosate at a minimum of 16 oz/acre. They applied slightly more than required, averaging 16.7 oz/acre for both their undercutter and conventional fields. As with glyphosate, individual farmers generally applied in-crop broadleaf weed herbicides identically on both undercutter and conventional fields.

Nitrogen fertilizer application rates by individual farmers were statistically equivalent for the two fallow systems, averaging 46, 43, and 49 lb/acre in 2008, 2009, and 2010, respectively. About half the farmers applied sulfur at an average rate of 9 lb/acre tank mixed with their aqua NH_3-N, and this did not differ significantly between tillage systems. Winter wheat seeding rate averaged 54 to 60 lb/acre depending on the year and were identical for individual farmers within the year over fallow systems.

Having determined that grain yields and input rates were statistically equal for the two fallow tillage systems within farms and years, it is now necessary to assess if machinery operation costs differed. Project planners initially expected a cost saving with undercutter tillage because application of fertilizer in tandem with the undercutter during primary spring tillage was contractually specified. Indeed, as previously mentioned, participants received an average of $980 in cost sharing to set up their new undercutter with appropriate manifold and tubing to deliver either aqua or anhydrous NH_3 fertilizer. In practice, this expected saving did not materialize because some farmers were unable to inject fertilizer on their undercutter ground due to tractor power limitations, use of custom fertilizer application, and other reasons. Also, most farmers injected fertilizer during primary spring tillage with their conventional tillage implement. Over the three years, fertilizer was injected during primary spring tillage 76% of the time with the undercutter and 64% of the time with conventional tillage.

Another potential disparity in machinery costs could originate from differences in the cost of primary tillage with the undercutter versus other implements, such as the tandem disk or field cultivator, on the same farms. A subsample of nine farmers was interviewed about machinery costs in 2009 and 2010. These farmers covered an average of 21.4 and 20.0 acres of land per hour and consumed an average of 9.75 and 9.81 gallons of diesel with their undercutter and conventional primary tillage, respectively. Both the undercutter and conventional primary tillage implements had similar power requirements, and sampled farmers generally used the same tractor to pull both implements. Land area tilled and fuel consumption per hour were statistically equivalent.

While not statistically significant, point estimates from the survey showed farmers' subjective satisfaction with the undercutter improved over time. On a scale of 1 (very unsatisfied) to 5 (very satisfied), results for satisfaction with the undercutter method averaged 4.1 in 2008, 4.5 in 2009, and 4.7 in 2010. Table 3 shows surveyed farmers' subjective expectations from 2008 to 2010 regarding long-run profit changes using the undercutter method. In all years, 40% or more farmers expected greater profit with the undercutter method. Similarly, a plurality or equal percentage of farmers expected equal profitability with the two systems ranging from 45% in 2008 to 55% in 2010 (Table 3).

Table 3. Percentage of farmers expecting differing long-run profit changes with the undercutter compared to the conventional tillage system by year.[1]

Expected profit change	2008	2009	2010
Higher	45	43	40
Same/Unsure	45	50	55
Lower	10	7	5
Number of farms	47	47	33

[1] Farmer expectations were not statistically different over years at $P < 0.05$.

The partial budgeting comparison of the two fallow systems is clear and straightforward given the survey results. Statistically equivalent average grain yields on the same farms within years for the two systems implied equal economic gross returns. Similarly, statistically equivalent glyphosate, fertilizer, seed, and other input use implied equal costs for these inputs. Furthermore, there were no significant cost differences between systems in fertilizer application or primary spring tillage. Consequently, partial budgeting shows that the undercutter and conventional tillage systems averaged equal profitability. These results obtained from actual farms confirm data of equal profitability based on a six-year field experiment comparing undercutter and conventional tillage systems reported by Janosky et al. (2002).

Results validate the policy wisdom of the WAWG-NRCS program for evaluating the undercutter on actual farms. As further support for the undercutter system, some equipment dealers have reported selling more undercutters since 2007 outside the cost-sharing program than they sold under the program (Harry Schafer, pers. comm.).

On the other hand, farmers reported a “learning curve” with the undercutter and variable performance on different soils. Participants complained most frequently about maintaining depth control at speeds greater than 4.0 mph, blade wear, difficulty operating in heavy residue, shank kickbacks not setting properly, and problems with large soil clods leaving some air voids between the surface and the depth of tillage. Blade wear can be reduced by at least 50% by chrome plating, which also permits soil to more easily slide over the undercutter blade and thus reduces drag. Large clods can be readily sized, and air voids eliminated, with a lightweight rotary harrow-type implement that attaches directly to the back of the undercutter frame (Figure 3). Many of the farmer participants installed such an attachment on their undercutter.

Conclusion

This study provides promising economic results for the environmentally friendly undercutter tillage fallow system. With the demonstration of equal profitability through paired comparisons of undercutter and conventional systems within the same farms and years during this three-year study, we conclude the undercutter system offers a costless air quality gain to society and soil conservation benefit for farmers.

Figure 3. Undercutter implements have blades on two ranks to allow easy passage through high levels of residue without plugging. This unit is equipped with an attached skew treader to size soil clods. The angle of the skew treader attachment can be adjusted to achieve the desired size of surface soil clods. Photo by W.F. Schillinger.

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Resources

A more detailed version of this paper is available at:

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