Economics of tillage practices and spring wheat and barley crop sequence in the Northern Great Plains

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*ABSTRACT: Our objective was to analyze economics of spring wheat (*Triticum aestivum *L.) and barley (*Hordeum vulgare *L.) cropping and tillage practices after 10 years of evaluation. We initiated the study in 1983 on a Dooley sandy loam (fine-loamy, mixed Typic Argiboroll) 11 km (7 mi) north of Culbertson, Montana. Annually cropped tillage treatments included sweep tillage in fall with spring disking, sweep tillage in spring, and no-till. A conventional fallow-crop rotation was included. Spring wheat yields ranged from 74 kg/ha (1.1 bu/acre) to 3,465 kg/ha (51.5 bu/acre). Net return was highest for no-till annually cropped wheat at $19.04/ha ($7.71/acre) and lowest for barley-spring wheat rotation at –$23.74/ha (–$9.61/acre). Under conditions of this 10-year study, in a 356 mm (14 in.) precipitation zone, we conclude that annually cropped no-till wheat production was the most profitable cropping practice.*

Soil water deficiency is the most ubiquitous factor affecting crop production in the semiarid Great Plains. That, along with extreme fluctuations in weather conditions, limit the choice of crops available for cultivation. Although it is possible to grow winter wheat (*Triticum aestivum* L.) in the northern Great Plains (Aase and Siddoway 1980), the major crop, especially in the eastern portion, remains spring wheat.

Yearly cropping, when conditions permit, is encouraged to prevent excessive water from passing through the root zone. (Brown et al. 1983; Schneider et al. 1980; Deibert et al. 1986). To successfully grow a crop every year it is necessary to conserve as much soil water as possible from rain and snow between harvest and seeding. Stubble management for snow trapping and uniform snow distribution and for evaporation suppression is important for soil water conservation. (Aase and Siddoway 1976, 1980; Aase and Tanaka 1987; Tanaka and Aase 1987). A conservation practice gaining in popularity is to seed "no-till" into the undisturbed residue of the previous crop.

Because of the importance of the high quality hard red spring wheat grown in the northern Great Plains, our study was confined to spring wheat, with only one spring wheat-barley (*Hordeum vulgare* L.) rotation included. The economics of continuous cropping, including variants of tillage practices, as compared with conventional fallow-crop sequence have not been seriously considered. In an earlier report, following the first five years of the current study, Aase and Reitz (1989) reported on simple "out-of-pocket" expenses and returns. The objective of our current effort was to take a more in-depth look at the economics following 10 years of cropping and tillage comparisons.

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Materials and methods

The study was conducted on a Dooley sandy loam (fine-loamy, mixed Typic Argiboroll) 11 km (7 mi) north of Culbertson, Montana. The study, initiated in 1983, was designed as a randomized complete block with four replications. Each plot was 30 × 12 m (100 × 40 ft). The treatments were as follows: (1) sweep tillage in the fall and disk tillage in the spring to prepare a seedbed and cropped yearly to spring wheat (cv. 'Lew'); (2) no fall tillage (fall weed control with herbicides when needed), sweep tillage prior to seeding to maintain residue and cropped yearly to spring wheat; (3) no-till, cropped yearly to spring wheat; (4) and (5) annually cropped with same tillage practices as Treatment 1, Treatment 4 was cropped to barley (cv. 'Hector') in odd years and to spring wheat in even years, Treatment 5 was cropped to barley in even years and to spring wheat in odd years; (6) and (7) alternate years fallow-spring wheat rotations with no after-harvest tillage and with a disking operation in the spring for seedbed preparation. Treatment 6 was fallowed in even years and Treatment 7 in odd years. Glyphosate (Roundup)[1], bromoxynil (Buctril), diclofop-methyl (hoelon), and 2,4-D were used as necessary on all plots for weed control. In 1985, 1987, and 1991, parathion and in 1985 also malathion, were used to control grasshoppers. All chemicals were used according to label directions. Because the experimental location is in an area where sawfly (*Cephus cinctus* Norton) outbreaks are common, the sawfly resistant, solid-stem spring wheat cultivar "Lew" was used. We used certified seed in all years. A Versatile 2200[2] double-disk opener drill with a 20.3 cm (8 in) row spacing was used to seed both wheat and barley in north-south rows at 74 kg/ha (66 lbs/acre) for wheat and 84 kg/ha (75 lbs/acre) for barley, except in the first two years when a Noble DK4 hoe-drill with 25.4 cm (10 in) row spacing was used on Treatments 2 and 3 and a modified Versatile 2000 drill with double disk openers and 22.9 cm (9 in) row spacing was used on the other treatments. All plots except fallow received 56 kg N/ha (50 lbs/acre) as ammonium nitrate (34-0-0) broadcast at time of seeding in 1983, 1984, and 1985. In 1986 the rate was changed to 34 kg/ha (30 lbs/acre). Wheat on fallow received 34 kg N/ha (30 lbs/acre) in all years. Phosphorus requirements were met by broadcast applications of 640 kg/ha (570 lbs/acre) of diammonium phosphate (18-46-0) prior to the establishment of the study. The phosphorus fertilizer was incorporated into the surface 5 cm (2 in.) of soil.

Grain yield harvest samples were obtained by cutting bundle samples 5-rows × 1-m (39 in.) long from six areas in each plot from all replications. The bundle samples were later threshed, and grain yield determined.

For the economic analysis the following assumptions were made. Machinery size and hours of use each year were based on a typical 809 ha (2,000 acre) dryland farm in eastern Montana. Fixed and variable cost data for the machines were taken from a 1990 Machinery Cost Bulletin (Baquet and Johnson 1990), and updated to 1993 costs (Table 1). Local farm suppliers provided 1993 prices for purchased

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

[2] Mention of trade names is for the benefit of the reader and does not constitute an endorsement by the USDA over other products not mentioned.

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Table 1. Machinery cost data

Item	Size	Use: Annual	Use: Land unit	Treatment: Variable cost	Fixed costs	Total costs
	m (ft)	hrs	hrs/ha (hrs/acre)	$/ha ($/acre)		
Toolbar	7.6 (25)	200	0.205 (0.083)	4.84 (1.96)	3.34 (01.35)	8.18 (03.31)
Toolbar w/rod	7.6 (25)	200	0.205 (0.083)	5.02 (2.03)	3.51 (01.42)	8.53 (03.45)
Tandem disk	6.4 (21)	50	0.309 (0.125)	7.49 (3.03)	7.76 (03.14)	15.25 (06.17)
Noble blade	7.3 (24)	50	0.274 (0.111)	8.28 (3.35)	8.55 (03.46)	16.83 (06.81)
Drill	7.3 (24)	150	0.274 (0.111)	10.08 (4.08)	8.50 (03.44)	18.58 (07.52)
Sprayer	14.3 (47)	100	0.146 (0.059)	1.56 (0.63)	1.48 (00.60)	3.04 (01.23)
Combine	7.3 (24)	200	0.381 (0.154)	17.37 (7.03)	27.78 (11.24)	45.15 (18.27)

Note: Tractor cost is included with each item. Labor costs are not included.

Table 2. Grain yield each year, 10–year average and averages for five high and five low yielding years

Treatment	1984	1985	**1986**	**1987**	1988	1989	1990	**1991**	**1992**	**1993**	Ten–yr Avg.	Avg. five hi–yield years	Avg. five low–yield years
	kg/ha (bu/ac)												
1 Fall & sp.till/an.	727 (10.8)	854 (12.7)	**3410 (50.7)**	**2388 (35.5)**	128 (1.9)	854 (12.7)	666 (9.9)	**1783 (26.5)**	**2711 (40.3)**	**2180 (32.4)**	1567 (23.3)	2496 (37.1)	646 (9.6)
2 Sp. till/an.	807 (12.0)	1023 (15.2)	**3465 (51.5)**	**2449 (36.4)**	182 (2.7)	1097 (16.3)	1049 (15.6)	**2133 (31.7)**	**2731 (40.6)**	**2159 (32.1)**	(1709) (25.4)	2590 (38.5)	834 (12.4)
3 No-till/ an.	908 (13.5)	1144 (17.0)	**3316 (49.3)**	**2375 (35.3)**	316 (4.7)	1211 (18.0)	1251 (18.6)	**2052 (30.5)**	**2792 (41.5)**	**2328 (34.6)**	1769 (26.3)	2570 (38.2)	968 (14.4)
4 (W)Fall & sp.till/an.	767 (11.4)	760 (11.3)	**3310 (49.2)**	**2603 (38.7)**	74 (1.1)	922 (13.7)	498 (7.4)	**1857 (27.6)**	**2825 (42.0)**	**2220 (33.0)**	1581 (23.5)	2563 (38.1)	605 (9.0)
5 (B)Fall & sp.till/an.	866 (16.1)	280 (5.2)	**4445 (82.6)**	**3041 (56.5)**	124 (2.3)	1039 (19.3)	786 (14.6)	**2325 (43.2)**	**3810 (70.8)**	**2427 (45.1)**	1916 (35.6)	3208 (59.6)	619 (11.5)
6/7*crop/ fallow	868 (12.9)	636 (9.5)	**1783 (26.5)**	**1349 (20.0)**	296 (4.4)	730 (10.9)	750 (11.2)	**1406 (20.9)**	**1729 (25.7)**	**1628 (24.2)**	1117 (16.6)	1581 (23.5)	659 (9.8)
LSD(0.05) excl. barley	NS	176 (2.6)	**272 (4.0)**	**155 (2.3)**	141 (2.1)	226 (3.4)	269 (4.0)	**268 (4.0)**	**388 (5.8)**	**296 (4.4)**			

* Grain yields on summer fallow have been annualized by dividing by 2

Bold type refers to high-yield years

(Note: Barley and wheat in rotation have, for simplicity of presentation, been respectively designated as 4(B) and 5(W), and the fallow–crop rotation 6(7).)

materials such as certified seed, fertilizer, and chemicals. State-wide average yearly prices were collected for barley, excluding malt barley, and for spring wheat, excluding durum (Montana Agricultural Statistics Service 1993). The 10-year average cash price for spring wheat was $9.57/hl ($3.37/bu) and for barley $5.28/hl ($1.86/bu).

The commodity program provisions for the 1994 crop year were used. There were no Acreage Conservation Reserve requirements for wheat or barley. Both crops had Normal Flex Acres of 15% of the Crop Acreage Base. The Food, Agriculture, Conservation, and Trade Act of 1990 set target prices of $11.35/hl ($4.00/bu) for wheat and $6.70/hl ($2.36/bu) for barley. Deficiency payments are not made on Normal Flex Acres. This reduces the target price received on the crops by the formula: Actual Price = 0.85 × target price + 0.15 × cash price.

In the economic analysis we used actual prices of $11.10/hl ($3.91/bu) for spring wheat and $6.50/hl ($2.29/bu) for barley.

Results and discussion

The study was initiated in 1983 and all treatments followed barley grown in 1982. Therefore, we eliminated 1983 from the analysis. Since it takes two years (or two land units) to grow one crop unit in a fallow-crop rotation, yields on fallowed land were annualized (divided by 2). On summer fallowed land, grain yields during the 10-year period ranged from a low of 296 kg/ha (4.4 bu/acre) in 1988 to a high of 1,783 kg/ha (26.5 bu/acre) in 1986 (Table 2). On annually cropped no-till land, grain yields ranged from a low of 316 kg/ha (4.7 bu/acre) in 1988 to a high of 3,316 kg/ha (49.3 bu/acre) in 1986. When considering yield on fallow land (treatment 6 (7)) in the year it was produced (not annualized) then annual no-till (treatment 3) yield approached an average of 80% of fallow yield during the ten-year period.

Fallow operations were a mix of mechanical and chemical fallow weed control based on best judgement of soil, soil residue cover, and weather conditions at the time. Mechanical fallow operations averaged 2.7 times, and chemical weed control, 2.5 times during the 21-month fallow period. There were no mechanical fallow operations in 1990 and 1992, with a high of four chemical weed control operations in 1992. On the other hand there were no chemical weed control operations

Table 3. Ten-year average costs and returns for different tillage practices for spring wheat and barley crops in the northern Great Plains

	Treatment*					
	1	2	3	4(W)	5(B)	6 & 7
	$/ha ($/ac)					
Gross return	225.02 (91.10)	245.30 (99.31)	253.99 (102.83)	226.97 (91.89)	201.35 (81.52)	320.63 (129.81)
Material cost	139.84 (56.59)	147.47 (59.68)	161.58 (65.39)	139.84 (56.56)	137.44 (55.62)	202.23 (81.84)
Machinery variable cost	45.00 (18.22)	37.25 (15.08)	33.30 (13.48)	45.25 (18.32)	45.42 (18.39)	52.56 (21.28)
Return over variable cost	40.24 (16.29)	60.64 (24.55)	59.18 (23.96)	42.01 (17.01)	18.55 (7.51)	65.92 (26.69)
Rotation avg.				30.28 (12.26)		32.97 (13.35)
Machinery fixed cost	53.50 (21.66)	44.61 (18.06)	40.14 (16.25)	53.94 (21.84)	54.09 (21.90)	58.19 (23.56)
Net return to land, labor, and management	−13.26 (−5.37)	16.03 (6.49)	19.04 (7.71)	−11.93 (−4.83)	−35.54 (−14.39)	7.73 (3.13)
Rotation avg.				−23.74 (−9.61)		3.88 (1.57)

*Treatments: 1) annual crop, fall and spring till; 2) annual crop; spring till; 3) annual crop, no-till; 4) and 5) annual crop, fall and spring till, spring wheat-barley rotations; 6) and 7) fallow-spring wheat rotations.

Table 4. Five-year average costs and returns for low yield years for different tillage practices for spring wheat and barley crops in the northern Great Plains

	Treatment*					
	1	2	3	4(W)	5(B)	6 & 7
	$/ha ($/ac)					
Gross return	92.72 (37.54)	119.75 (48.48)	139.06 (56.30)	86.92 (35.19)	65.06 (26.34)	188.34 (76.25)
Material cost	139.78 (56.59)	147.41 (59.68)	161.51 (65.39)	139.70 (56.56)	137.38 (55.62)	202.14 (81.84)
Machinery variable cost	46.83 (18.96)	39.00 (15.79)	34.46 (13.95)	46.83 (18.96)	47.13 (19.08)	57.03 (23.09)
Return over variable cost	−93.88 (−38.01)	−66.67 (−26.99)	−56.91 (−23.04)	−99.62 (−40.33)	−119.45 (−48.36)	−70.84 (−28.68)
Rotation avg.				−109.54 (−44.35)		−35.42 (−14.34)
Machinery fixed cost	55.38 (22.42)	46.53 (18.84)	39.57 (16.02)	55.38 (22.42)	55.67 (22.54)	61.65 (24.96)
Net return to land, labor, and management	−149.26 (−60.43)	−113.20 (−45.83)	−96.48 (−39.06)	−154.99 (−62.75)	−175.12 (−70.90)	−132.49 (−53.64)
Rotation avg.				−165.07 (−66.83)		−66.25 (−26.82)

*Treatments: 1) annual crop, fall and spring till; 2) annual crop; spring till; 3) annual crop, no-till; 4) and 5) annual crop, fall and spring till, spring wheat-barley rotations; 6) and 7) fallow-spring wheat rotations.

Table 5. Five-year average costs and returns for high yield years for different tillage practices for spring wheat and barley crops in the northern Great Plains

	Treatment*					
	1	2	3	4(W)	5(B)	6 & 7
	$/ha ($/ac)					
Gross return	358.30 (145.06)	371.83 (150.54)	368.92 (149.36)	367.96 (148.97)	337.11 (136.48)	452.95 (183.38)
Material cost	139.78 (56.59)	147.41 (59.68)	161.51 (65.39)	139.70 (56.56)	137.38 (55.62)	202.14 (81.84)
Machinery variable cost	43.18 (17.48)	35.49 (14.37)	32.11 (13.00)	43.69 (17.69)	43.69 (17.69)	48.07 (19.46)
Return over variable cost	175.35 (70.99)	188.93 (76.49)	175.30 (70.97)	184.56 (74.72)	156.03 (63.17)	202.74 (82.08)
Rotation avg.				170.31 (68.95)		101.37 (41.04)
Machinery fixed cost	51.62 (20.90)	42.66 (17.27)	40.71 (16.48)	52.51 (21.26)	52.51 (21.26)	54.76 (22.17)
Net return to land, labor, and management	123.72 (50.09)	146.27 (59.22)	134.59 (54.49)	132.05 (53.46)	103.52 (41.91)	147.98 (59.91)
Rotation avg.				117.79 (47.69)		74.00 (29.96)

*Treatments: 1) annual crop, fall and spring till; 2) annual crop; spring till; 3) annual crop, no-till; 4) and 5) annual crop, fall and spring till, spring wheat-barley rotations; 6) and 7) fallow-spring wheat rotations.

on fallowed land in 1984 and 1993, with a high of four mechanical fallow operations in 1984.

Chemical weed control operations on the no-till treatment (treatment 3) averaged 1.5 between harvest and planting of next crop, with two in each of seven years, one in one of the years, and zero in two of the years. The other annual cropping treatments were intermediate in tillage and chemical operations. Herbicide weed control during the cropping season was on an as-need-basis on all treatments. During a heavy grasshopper infestation in 1985, the fields were sprayed once with malathion and twice with parathion. The plots were sprayed twice with parathion for grasshopper control in 1987 and once in 1991.

The 10-year average net return to land, labor and management was highest for the no-till treatment (Treatment 3) at $19.04/ha ($7.71/acre) (Table 3). The spring-till annually cropped treatment (Treatment 2) was next at $16.55/ha ($6.49/acre) followed by fallow-crop rotation (Treatment 6(7) at $3.88/ha ($1.57/acre). The wheat-barley rotation (Treatments 4 and 5) is considered as a rotation average and that treatment, as well as the fall and spring-tillage annually-cropped treatment (Treatment 1), had negative returns. Two units of land are needed to produce one unit of crop for the fallow-crop rotation; therefore, the costs of the 21-month fallow season were added to the costs and returns of the crop year.

The study encompassed five "good" years and five "bad" years. The rankings for the average net returns to land, labor and management for the five low yield-years differ from those of the 10-year average, and all treatments had large negative returns (Table 4). The lowest average loss for the five "bad" years was experienced on the fallow-crop treatment (Treatment 6(7)), with –\$66.25/ha (–\$26.82/acre). Net returns over variable costs were also negative for all treatments. The rankings change again when we compare net returns to land, labor and management for the five high yield years (Table 5). The annually cropped treatment with one tillage operation in the spring (Treatment 2) now had the highest return at \$146.27/ha (\$59.22/acre), followed by no-till (Treatment 3) at \$134.59/ha (\$54.49/acre).

During the five low yield years, when yields went as low as about 135 kg/ha (2 bu/acre), fallow-crop was the most advantageous, followed by no-till, although both had negative returns. Spring-till annual cropping had a slight advantage during the five high yield years, mainly because of lower material cost, followed once again by no-till. Fall- and spring- till annual cropping was the least advantageous of the three spring wheat annual cropping practices, mainly because of lower yields than the other two. Fall tillage disturbed the stubble and left it in more or less random positions, reducing snow catch and therefore reducing early spring soil water necessary for robust plant growth. There was also a loss of protection afforded by undisturbed stubble. Material and machinery costs were highest for the fallow-crop sequence. The annual no-till had the next highest material cost, but this was partially offset by having the lowest machinery costs of all treatments. The research site is classified as Highly Erodible. However, all treatments resulted in adequate cover for erosion control, albeit the cover was minimal during the second spring of the fallow-crop sequence.

Based on this study, conducted on a sandy loam soil in a 356 mm (14 in) precipitation zone, the conclusion is that annual no-till wheat production was the most effective, efficient, and profitable cropping practice during the 10-year period. No-till provided residue for added snow catch, increased wind protection for crop growth and added soil erosion control. We consider the study to have been conducted with intensive management, and individual farmer decisions will influence costs and net returns to some degree. Crop Acreage Base restrictions may limit the crop acreage that can be grown each year. Land in fallow could be seeded to soil building crops such as legumes. Since we used state-wide average yearly costs and prices received in the analysis, costs and prices received may also vary from location to location and from time to time. Despite the positive findings for annual no-till spring wheat, we do not necessarily advocate spring wheat monoculture. For example, plant diseases are recognized as having a greater potential in no-till situations, and although not a serious problem during the course of our study, we recognize that diversification and rotations, when possible, are beneficial for such things as breaking potential disease and insect cycles.

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