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Hayland conversion to wheat production in semiarid eastern Montana: tillage, yield and hay production comparisons

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Abstract

When converting grass- and haylands to cultivated crop production, care must be taken to conserve and maintain soil resources while considering economic issues. Methods of breaking sod can have a bearing on erosivity, physical and chemical properties of soils, and cost of production. Our objective was to compare three methods of converting crested wheatgrass [*Agropyron desertorum* (Fisch. ex Link) Schult.] hayland to wheat (*Triticum aestivum* L.) production vs. leaving the land for hay production. We initiated a study in 1990 on Dooley sandy loam (fine-loamy, mixed Typic Argiboroll) near Froid in semiarid eastern Montana, USA. Plots, replicated three times, were 12- by 30-m oriented east to west on a north-facing slope. We converted sod to cultivated crop production by: (1) moldboard plow, (2) toolbar with sweeps, (3) herbicides (no-till). Plots were fallowed until spring 1991 and then seeded to spring wheat each of the next four years. All wheat plots were fertilized with 224 kg ha^{-1} of 18-46-0 in 1991 and 1992, and 34 kg ha^{-1} nitrogen as 34-0-0 in 1993 and 1994. Grass was either fertilized same as wheat or not fertilized. Wheat yields averaged 2540 kg ha^{-1} on tilled treatments and 2674 kg ha^{-1} on no-till. Fertilized grass consistently out-yielded unfertilized, and averaged 3.2 Mg ha^{-1} vs. 1.8 Mg ha^{-1}. Toolbar with sweeps had highest economic return of US$169.48 ha^{-1} to pay for land,

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labor, and management. Moldboard plow had US\$162.05 ha^{-1}. Because of herbicide costs, no-till only returned US\$148.64 ha^{-1}. Unfertilized grass hay returned US\$67.68 ha^{-1} and fertilized grass hay, US\$97.95 ha^{-1}. Results may be tempered because our wheat yields were high: a 2016 kg ha^{-1} wheat yield would have returned the same as fertilized grass. Before converting grass- and hay-lands to small grains production, consideration must be given to such variables as sod conversion methods, management practices, labor requirements, market conditions, total precipitation and its temporal distribution, soil conditions, growth environment, soil conservation, and economics.

Keywords: Tillage; Sodbreaking; Hayland; Grassland; Wheat; Economics

1. Introduction

Some form of tillage is commonly used to convert grass- and haylands to cultivated crop land. Variable costs of tillage in converting to cultivated crop production are less than variable costs of using herbicides (Johnson et al., 1986). Many grass and haylands are susceptible to wind and water soil erosion. Therefore it is important to select appropriate tillage methods that conserve and sustain soil resources while considering economic issues.

Tillage and crop management practices influence many soil properties, such as bulk density (e.g., Mielke et al., 1986; Rhoton et al., 1993; Ismail et al., 1994; Pikul and Aase, 1995), pH (Blevins et al., 1977; Dick, 1983; Lal et al., 1994) and soil organic matter. Soil organic matter has been of great interest as it relates to tillage and cropping practices. Native grasslands can loose from about 30 to 50% of original organic carbon during 4 to 5 decades of cultivation (Campbell and Souster, 1982; Thiessen et al., 1982). When weather is favorable and crop yields are good, soil organic matter can increase or be maintained under well managed annual crop rotations (Campbell and Zentner, 1993; Aase and Pikul, 1995). Fallow-crop rotations on the other hand, tend to decrease soil organic matter (Rasmussen and Parton, 1994; Aase and Pikul, 1995).

Because of varying results from soil and crop management practices, the need for selecting appropriate management practices is apparent when converting grass-and haylands to cultivated crop production.

Our objectives were to examine effects of three tillage methods of converting crested wheatgrass to dryland wheat production on (a) subsequent wheat yields, (b) soil chemical and nutrient analyses and soil water, (c) cost and benefit comparisons between wheat and hay production.

2. Materials and methods

We initiated a study in April of 1990 on a Dooley sandy loam (fine-loamy, mixed Typic Argiboroll) (FAO: Kastanozem) about 6.4 km south of Froid, Roosevelt County, MT. The study area had been in crested wheatgrass for about 15 years prior to the study and was hayed every year. Study layout was randomized complete block with three replicates. Plots were 12- by 30-m oriented the long way east to west on a ca. 2%

north-facing slope. Prior to sod conversion we took one shallow-core and one deep-core sample from each plot area. The shallow-core sample was 15 cm deep and was divided into 0 to 8- and 8 to 15-cm segments for organic carbon analysis. Organic carbon was multiplied by 1.72 for conversion to organic matter. The deep-core sample was 122 cm deep and was divided into four 30-cm segments. The middle 15-cm increment from each deep-core sample segment was retained for nitrogen analysis, bulk density and soil water content determinations. The same sampling procedure was used in the spring of 1995, following the conclusion of the study, except two samples from each wheat plot were composited and three samples from each grass plot, for analysis. Bulk density was not determined.

Subsequent to converting from sod, three neutron probe access tubes to 1.2 m depths were installed in each plot. Soil water content at 30 cm increments was determined using neutron attenuation at the beginning and end of each growing season. Precipitation data were obtained at a research farm, about 4.8 km from the test site.

Sod conversion treatments prior to seeding spring wheat were accomplished with: (1) a five-bottom moldboard plow to a depth of ca. 17 cm; (2) a toolbar with 45.7-cm sweeps on 30.5-cm centers to a depth of ca. 9 cm; (3) herbicides (no-till) using tank mix of 2.5 l glyphosate [(*N*-phosphonomethyl)glycine] and 2.5 l of 2,4-D amine (2,4-dichlorophenoxyacetic acid) in 141 l of water per hectare to kill the sod. During the fallow period in 1990, to control weeds, there was one subsequent tillage operation with sweeps on each of treatments 1 and 2 and one application with a mix of glyphosate and 2,4-D on treatment 3. The plots were left fallow until the spring of 1991.

Beginning in 1991 mechanical tillage operations on treatments 1 and 2 were done with sweeps immediately prior to seeding. In 1992, it was necessary to use a tandem disk harrow before using sweeps. No-till treatment received a tankmix of 2.5-l glyphosate and 1.25-l 2,4-D each year prior to seeding. When deemed necessary, post-harvest weed control was done on all three sod conversion treatments using a mix of glyphosate and 2,4-D. Two post harvest weed control operations took place on each treatment in 1991, one in 1994 and none in 1992 and 1993.

The plots were seeded to 'Lew' spring wheat every year with a Versatile 2200 disk drill with 20-cm row spacing. We used the solid stem cultivar 'Lew' because the area of the study is at risk for wheat stem sawfly (*Cephus cinctus* Norton) infestations. Rate of seeding was the same among treatments within years but varied from about 2 to 2.5 million seeds per hectare among years. All plots were fertilized with 224 kg ha^{-1} of $(NH_4)_2HPO_4$ (18-46-0) in 1991 and 1992. In 1993 and 1994, we applied 34 kg ha^{-1} of nitrogen as NH_4NO_3 (34-0-0) to all plots. Weeds in the growing grain crop of all treatments were controlled as needed with a mix of bromoxynil (3,5-dibromo-4-hydroxybenzonitrile) and 2,4-D, except in 1994 when we used a mix of fenoxaprop-*P*-ethyl {(*R*)-2-[4-(6-chloro-1,3-benzoxazol-2-yloxy) phenoxy] propionic acid} and bromoxynil.

Comparison crested wheatgrass plots were on the north of, and adjacent to, the wheat plots and were replicated three times. One set of grass plots was unfertilized, the second set received 224 kg ha^{-1} of 18-46-0 fertilizer in 1991 and 1992, and 34 kg ha^{-1} of nitrogen as 34-0-0 in 1993 and 1994.

We hand-cut, at the soil surface, six 5-row wide by 90 cm long wheat samples per plot each year to obtain grain yield samples. We also hand harvested four 90 by 90 cm

Table 1
Machinery cost data per field operation. Tractor cost is included with each item. Labor costs are not included

Item	Size (m)	Annual use (h)	Use per unit land (h ha^{-1})	Variable cost (US\$ ha^{-1})	Fixed cost (US\$ ha^{-1})	Total cost (US\$ ha^{-1})
Toolbar	7.6	200	0.205	4.27	3.83	8.10
Toolbar with rod	7.6	100	0.205	4.42	4.08	8.50
Tandem disk	6.4	50	0.309	6.13	8.62	15.25
Plow	5 bottom	50	0.823	16.70	20.78	37.48
Sprayer	14.3	100	0.146	1.70	1.73	3.43
Drill	7.3	150	0.274	9.27	9.51	18.78
Combine	7.3	200	0.381	17.22	27.87	45.10
Swather	6.1	100	0.413	9.27	13.32	22.58
Round baler		100	0.413	8.77	11.29	20.06
Loader		200	0.247	1.83	1.83	3.66

hay-yield samples per plot in 1991 and 1992. In 1993 and in 1994 we used a 3 m wide swather to lay the grass in wind rows, from which three 90-cm samples per plot were taken for hay yield samples. Hay yield was expressed on a 15% moisture basis.

We used the following assumptions for economic analysis. Machinery size and hours of use each year were based on a typical 809 ha dryland farm in eastern Montana. Fixed and variable cost data per field operation for the machines were taken from a 1990 Machinery Cost Bulletin (Baquet and Johnson, 1990) and updated to 1994 costs (Table 1). Local farm suppliers provided 1994 prices for purchased materials such as seed, fertilizer, and chemicals. State-wide average yearly prices were collected for non-alfalfa hay and for spring wheat, excluding durum, for the 1991 through 1994 evaluation period. The average price for hay was US\$61.48 Mg^{-1} (Montana Agricultural Statistics Service, 1993). The United States Department of Agriculture commodity program provisions for the 1994 crop year were used to calculate the price of US\$143.68 Mg^{-1} received for wheat.

Analysis of variance ($P = 0.05$) was used in data analysis.

3. Results and discussion

3.1. Soil chemical analyses

Soil analysis revealed that there was 11.4 kg NO_3–N ha^{-1} in the surface 30 cm of soil at the beginning of the study (data not shown). Phosphorus was deficient at 8.7 mg kg^{-1} in the surface 15 cm of soil and organic matter content was 16 g kg^{-1}. Since the field had been hayed every year prior to measurements little surface organic material was returned as a source of organic matter and nitrogen. Bulk density was consistent across the study area and averaged 1.55 g cm^{-3} in the surface 30 cm. At the end of the study, in the spring of 1995, there were no statistically significant differences in soil NO_3–N in the surface 30 cm of soil among wheat plots, nor between fertilized and unfertilized grass plots (data not shown). There was 12.3 kg NO_3–N ha^{-1} under wheat, 15.7 kg under fertilized grass, and 13.6 kg under unfertilized grass. Essentially all supplied and available nitrogen was used by the plants since little change was observed from beginning to end of study.

Soil organic matter on the plow treatment decreased from the original value of 16 g kg^{-1} to 13 g kg^{-1} in the surface 15 cm of soil, and was significantly less than on the sweep and no-till treatments which had 17 g kg^{-1} organic matter at the end of the study (data not shown). Some minor redistribution and dilution of organic matter may have occurred in the 0 to 15 cm soil layer on the plow treatment since plow depth averaged ca. 17 cm and organic matter was only measured to 15 cm. Our data are consistent with those of Reicosky and Lindstrom (1993) who showed that plowing caused a significant greater loss of carbon than conservation tillage. Organic matter decreased to 13 g kg^{-1} on the unfertilized grass plots and was significantly different from the fertilized grass plots, which increased to 18 g kg^{-1} organic matter. Thus, even during the short life of our experiment, conservative cultivation on wheat plots and addition of fertilizer on grass plots either maintained or increased soil organic matter in the surface 15 cm of soil.

3.2. Precipitation and soil water

Precipitation during the four years of the study is reported as monthly totals and compared against the 27-year average in Table 2. Precipitation amounts and distribution during the four years favored spring wheat production. In all years rain came in above average amounts some time during critical portions of the wheat growing season. The precipitation pattern did not favor cool season grass production in every year. Early season precipitation, through the month of May, was particularly unfavorable for grass production in 1993.

Soil water content at time of spring wheat seeding and harvest, to a depth of 1.2 m, for the wheat and grass plots are shown in Fig. 1. Total precipitation for the spring

Table 2
Monthly and long-term average precipitation

Month	Monthly precipitation (Year)				
	1991 (mm)	1992 (mm)	1993 (mm)	1994 (mm)	27-yr average (mm)
January	5.3	11.9	6.6	13.0	10.9
February	8.9	4.3	5.3	19.6	7.6
March	10.4	10.2	15.0	2.5	14.2
April	68.1	72.6	5.1	22.1	30.5
May	66.5	29.7	25.9	53.1	52.8
June	112.5	103.1	59.7	97.3	74.7
July	40.6	47.5	130.6	18.5	52.1
August	11.7	62.5	93.7	17.3	37.3
September	65.0	17.0	3.8	15.7	37.8
October	6.6	15.2	2.5	23.6	18.8
November	12.2	17.3	23.4	4.6	11.2
December	4.3	9.1	5.8	17.8	10.9
Total	412.1	400.4	377.4	305.1	358.8

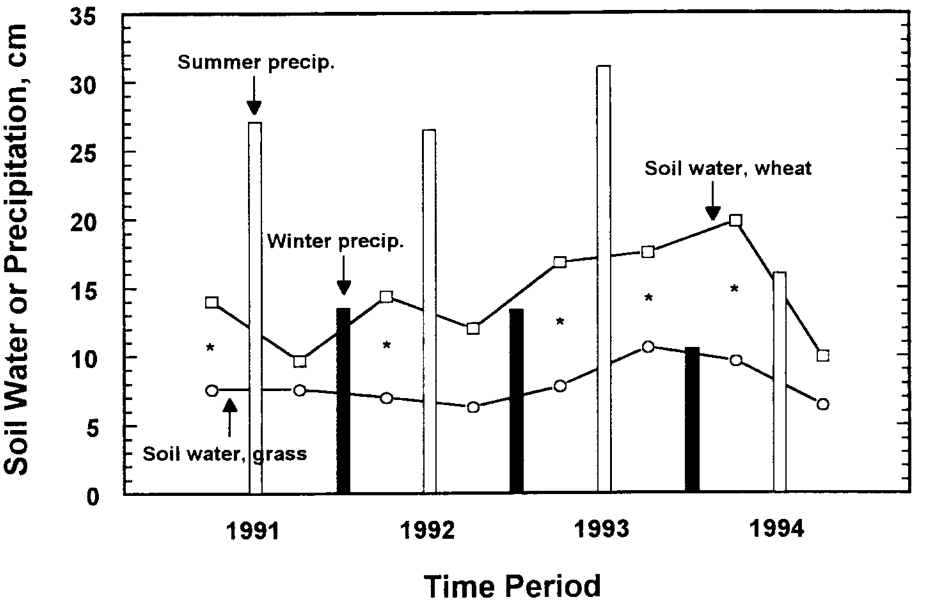

Fig. 1. Periodic soil water content to 1.2-m depth and precipitation. There were no statistical differences among sod conversion treatments nor between fertilized and unfertilized grass treatments, therefore all sod conversion treatments are combined as are the two grass fertilizer treatments. Asterisk (*) indicates statistically significant difference ($P = 0.05$) between wheat and grass plots.

wheat growing season and between harvest and the next spring are also shown. Soil water measurements did not coincide exactly with initiation of crested wheatgrass growth and grass harvest. Nevertheless, the data show the pattern of soil water extraction for wheat and crested wheatgrass. There were no statistically significant differences in soil water contents among sod conversion treatments, nor between fertilized and unfertilized crested wheatgrass treatments. Therefore soil water content data from all sod conversion treatments were combined as were the data from the two grass fertilizer treatments.

During the 1990 to spring 1991 fallow season spring wheat plots gained water and had significantly higher soil water content than grass plots at the beginning of the growing season in 1991 (data not shown).

Crested wheatgrass treatments accumulated little, if any, soil water from any precipitation, except some gain (2.8 cm) between spring and fall in 1993. By the time the rains came in that year, crested wheatgrass had finished its growth cycle and was mature, therefore it used little water the rest of the season. Generally, the grass appears to have used all water available and was somewhat opportunistic in being able to take advantage of all precipitation that fell prior to its maturation. The wheat plots also gained some water from late spring rains in 1993, and every year the spring wheat plots gained water from overwinter precipitation.

Overwinter soil water gain on wheat plots, contrasted to no gain on grass plots, made up for soil water depletion during the growing season (Fig. 1). Thus the difference in

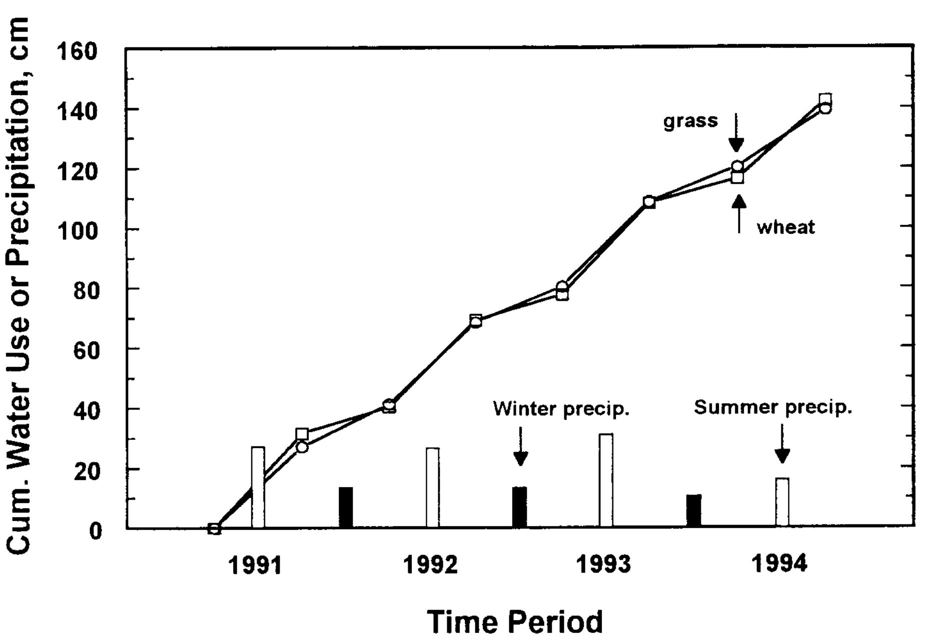

Fig. 2. Cumulative water use to 1.2-m soil depth for wheat and grass plots during summer and winter seasons. Water use is difference in soil water from beginning to end of each season, plus precipitation during same season.

soil water content between wheat and grass plots persisted during the study and end-of-study cumulative water use (soil water change plus precipitation) was the same for wheat and grass at ca. 140 cm (Fig. 2).

3.3. Crop yields

There were no statistically significant differences in wheat yields among sod conversion treatments within years (Table 3). However, there were statistically significant differences among years. That is probably what should be expected since the plots were fallowed for one year prior to seeding and because of favorable rainfall for wheat production. Yields in 1991, following fallow, averaged 2789 kg ha^{-1}. Yields in the three subsequent years were all 'recrop' yields and averaged 2517 kg ha^{-1}.

Consistency of yields during the years was not the case for the grass plots. Late fall and early spring precipitation is important for grass growth. The particularly low grass yield in 1993 (Table 3) can be attributed to lack of early season precipitation, especially during April and May (Table 2). Crested wheatgrass was opportunistic in the use of mineralized nitrogen. Fertilized grass made better use of available water, and in three years out of the four yielded about 1.6 times that of the unfertilized grass. In 1993 the fertilized grass responded with about 4.5 times the yield of unfertilized grass. Stands of crested wheatgrass six years old and older can have yields reduced by as much as 70% compared with a two to three year old stand (White, 1985). Obviously, fertilizer made up for some of the lost production of the old crested wheatgrass stand we worked with.

Table 3
Wheat grain yield and crested wheatgrass hay yield

	Yield				
	1991	1992	1993	1994	Average
Soil breaking treatment (kg ha^{-1})					
Plow	2755	2567	2405	2439	2540
Sweeps	2829	2399	2452	2473	2540
No-till	2782	2694	2439	2788	2674
Significance ($P = 0.05$)	NS	NS	NS	NS	
Average	2789a[a]	2553b	2432b	2567b	
Crested wheatgrass (Mg ha^{-1})					
Non fertilized	3.56	1.67	0.38	1.79	1.85
Fertilized	5.46	2.34	1.73	3.13	3.17
Significance ($P = 0.05$)	*	*	*	*	

[a]Means among years with same letter are not significantly different ($P = 0.05$).

3.4. Economics

Monetary return, based on our study, out of which to pay for land, labor, and management, was the highest for treatment 2 (sod conversion with sweeps) at US$169.48 ha^{-1} (Table 4). Treatment 1 (sod conversion with plow) was next at US$162.05 ha^{-1}, followed by treatment 3 (no-till) at US$148.64 ha^{-1}. Fertilized crested wheatgrass had a net return about 1.4 times that of non-fertilized crested wheatgrass. However, both crested wheatgrass treatments returned less than any of the wheat treatments. Rankings among treatments did not change when comparisons were made among 'Return Over Variable Cost' data. Return Over Variable Cost means income minus costs of all materials and machinery operating costs. Treatment 2 (sweeps) came in at US$217.49 ha^{-1}.

Table 4
Average costs and returns for the 1990–1994 evaluation period

	Treatment				
	Plow (US$ ha^{-1})	Sweeps (US$ ha^{-1})	No-till (US$ ha^{-1})	Grass, unfertilized (US$ ha^{-1})	Grass, fertilized (US35$ ha^{-1})
Gross return	365.21	365.21	384.53	113.99	194.66
Material cost	110.53	110.53	155.77	0.00	50.41
Machinery—Variable cost	40.33	37.19	34.35	19.87	19.87
Return over variable cost	214.36	217.49	194.41	94.12	124.39
Machinery—Fixed cost	52.31	48.01	45.77	26.44	26.44
Net return to land, labor, and management	162.05	169.48	148.64	67.68	97.95

Labor requirements for the initial plot preparation year (1990) were 3.5 times greater for the plow treatment as compared with the no-till treatment. This compares with results from a farm demonstration study in south central Montana that showed labor requirements for the sod breaking year were almost eight times greater for conventional tillage as compared with no-till (Remer, 1995).

Labor requirements for seedbed preparation and weed control were 33% greater for sweep treatment than for no-till treatment and 73% greater for plow treatment than for no-till treatment (0.76 h ha^{-1} vs. 0.44 h ha^{-1}). The sprayer was used twice as much on no-till treatment as compared with plow and sweep treatments, but there was no requirement on no-till treatment to invest in machinery costs for plow or disk. The toolbar was used 5 times during the study on plow treatment and 6 times on sweep treatment.

The yield advantage in our study of wheat on no-till treatment over that of wheat on sweep treatment would have needed to be 296 kg ha^{-1} to make up for higher costs associated with herbicides. Fertilized crested wheatgrass yield would have needed to be 4.3 Mg ha^{-1} rather than 3.2 Mg ha^{-1} for it to have equaled net return of the wheat sweep treatment. Or a wheat yield of 2016 kg ha^{-1} on tilled treatments would have resulted in the same monetary return as that from fertilized grass.

4. Conclusion

In contemplating converting grass/haylands to grain production in semiarid areas, careful consideration must be given to such things as methods of sod conversion, management practices, labor requirements, precipitation and its temporal distribution, soil conditions, and market conditions. We generally consider annual no-till wheat production to be more economically advantageous than other tillage practices (Aase and Schaefer, 1996). In the present study no-till wheat yields were similar to those on the other tillage practices. But because of herbicide costs, net economic return from no-till wheat production to land, labor, and management was less than that from the other practices. No-till is the better choice from standpoint of soil erosion control and organic matter maintenance and/or increase. Organic matter is important for soil structure and activities of soil microorganisms. Organic matter in the surface 15 cm of soil decreased under the plow treatment. It was maintained under sweep and no-till treatments and increased under fertilized grass. Hay production had less net monetary return to land, labor, and management than wheat production during the course of our study. However, one needs to consider potential benefits of leaving land in hay production, including reduced labor requirements, soil conservation, as well as economics.

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