AN ECONOMIC COMPARISON OF REDUCED-INPUT AND INTENSIVE CROP ROTATIONS IN THE RED RIVER VALLEY

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ABSTRACT

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Alternative cropping systems may lead to reduced operating costs and provide long-term soil and water conservation. However, few economic studies substantiating these benefits are available. Using eight years of cropping data from the Red River Valley near Fargo, North Dakota, three cropping systems were compared: a hard red spring wheat and soybean rotation under conventional tillage; a hard red spring wheat and soybean rotation under no-till; and a reduced-input hard red spring wheat, winter annual rye, yellow sweet clover, and soybean rotation. The reduced-input rotation generated lower operating costs as well as lower yields than conventional systems but had more stable returns over the period of study.

A sweet clover break-even yield was found for the reduced-input rotation both with and without government subsidies. Results compared to historic yields in Cass County, North Dakota, showed a 0.38 and 0.25 probability that the reduced-input system was as profitable as conventional systems with and without federal payments, respectively. In all cases, the reduced-input system was as profitable as the two no-till alternatives.

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INTRODUCTION

Traditional cropping systems in North Dakota have been intensively tilled (DeVuyst and Halvorson 2004). While controlling weeds, intensive tillage contributes to extensive soil erosion and loss of soil quality. In addition, weed control represents 20 to 30% of farm input costs, and herbicides represent 85% of the pesticides applied to North Dakota fields annually (Derksen et al. 2002). In order to maintain farm profitability, enhance environmental conservation, and control weeds, reduced tillage and reduced-input rotations are being adopted. Conservation tillage hectareages throughout the United States have increased from 5.1% of total cropland in 1989 to 16.3% in 1998. In 2002, 33% of soybean and 18% of corn hectares in the United States were grown using reduced tillage practices (Yin and Al-Khaisi 2004).

The purpose of the current research reported here is to investigate the economic consequences of switching from a low diversity, traditional cropping system to a more diversified and reduced-input system. This analysis tests the hypothesis that break-even sweet clover yield can be obtained regularly. Sweet clover yields were not recorded during the time period of the experiment. Therefore, a break-even analysis is computed to find a sweet clover yield that makes reduced-input rotation as profitable as conventional and no-till systems. Three different tillage practices and weed control methods are involved, depending on the cropping system. Operating costs, revenues, and net returns are computed for each rotation with or without government programs, and a break-even sweet clover yield is obtained using linear programming. Finally, historical Cass County, North Dakota, sweet clover yields are compared to the results during the period of experiment.

Profitability of reduced-input rotation versus conventional and no-till practices is then described.

Experimental plots were established in the fall of 1993 in Cass County, near Fargo, North Dakota to observe the impact of three cropping systems on weed control. The three cropping systems were a hard red spring wheat-soybean rotation under conventional tillage, a hard red spring wheat-soybean rotation under no-till, and a reduced-input system including hard red spring wheat, yellow sweet clover, winter annual rye and soybeans.

LITERATURE REVIEW

Switching from high input conventional tillage systems to reduced tillage or reduced-input rotations have agronomic and economic impacts on farm profitability (Brown et al. 1996). Adopting conservation tillage improves soil conservation and water storage and maintains long-term soil productivity (Campbell et al. 1988, Smith et al. 2000). Doster et al. (1983) reported that no-till and other conservation tillage practices were more profitable for well-drained sandy soils than conventional systems. Moreover, yield potential for various crops with conservation tillage is higher, or at least no lower, because of higher soil moisture and reduced evaporation losses (Lafond et al. 1996).

Reduced-input rotations and crop diversification can break disease and weed cycles (Lindwall and Larney 1993). Moreover, crop rotations improve soil structure, increase soil organic matter, and improve water percolation. Further, introducing into the rotation legumes helps to fix nitrogen after harvest (Jones 1996). Studies in Saskatchewan report that weed seedling and seed bank densities are similar or lower in reduced-input rotations compared with high-input rotations (Derksen et al. 2002). Ramsdale et al. (unpublished) reported that total weed density in wheat and soybeans from 1994 to 1997 was generally highest in the reduced-input system. However, weed density was lower in the reduced-input system than conventional and no-till rotations between 1998 and 2001.

Winter wheat residues reduce weed seedling emergence by 45% and biomass by 60% on soybeans (Derksen et al. 2002). Introducing forage crops in a rotation has been shown to significantly improve yields of subsequent crops (Stoa and Zubriski 1969). Hoyt (1990) indicates that for the first eight years after forage termination, wheat yields were 66% to 114% greater after a forage crop relative to continuous wheat.

Adopting reduced tillage or reduced-input rotations in the northern Great Plains may improve the economics of farming systems. Studies show that production costs are higher as the system becomes more intensive (Zentner et al. 2002a). In contrast, in reduced-input systems, farmers often reduce machine-related operating costs (fuel, oil, and repairs) by reducing the number of field operations, combining two or more operations at the same time (e.g. seeding and fertilizing), and using machines with greater capacity and lower draft (Zentner et al. 2002a).

According to Parch et al. (2001), conservation tillage practices have higher economic returns than intensive tillage. The difference in returns is even higher with crop diversification. DeVuyst and Halvorson (2004) reported that under intensive cropping systems including spring wheat, winter wheat, and sunflowers, conservation tillage generates the highest expected profits, yet does increase the variability of profits.

Crop diversification is an efficient means to reduce operating costs. Zentner et al. (1996) reported that costs of production of forage-based systems are lower than continuous grain production but higher than wheat-fallow systems. Stability of net returns over time is also enhanced and may reduce income variability and business risk (Zentner et al. 1986).

However, conservation practices and crop diversification may require increased management effort to manage pest problems, fertilization and marketing. The learning process associated with adopting a new cropping system may increase business risk and require adjustment costs because of the new use of technology and purchase of new equipment (Wall and Zentner 1999). Zentner et al. (1996) report that conservation tillage may increase expenditures for herbicides by \$11 ha^{-1} with minimum tillage and \$31 ha^{-1} with no-till fallow-wheat systems.

MATERIALS AND METHODS

Experimental plan

The field study was established on a Fargo silty clay soil (fine, smectitic, and frigid type nitraquerts) with a pH of 7.5 and 5.5% organic matter (Ramsdale et al. unpublished). Fargo receives an average precipitation of 540 mm per year with an average growing season of 133 days, running roughly from May 14th until September 24th. During the study period (1994-2001), growing season temperatures were close to the 30-year average. The experimental site was managed using conventional tillage prior to the experiment and was fallowed the year prior to the study. The experimental design used a completely randomized block design with three replicates. Plots were 14 m x 30.5 m and separated by 2 m alleys within each replicate. A 9m wide border surrounded the study site and separated the replicates.

In order to grow each crop every year in each rotation, eight plots were used in the rotation study, four for the reduced-input system and two for the other two systems. Consequently, two sequences of the reduced-input system and four sequences of the no-till and conventional tillage systems were completed. (See Table 1.)

Hard red spring wheat was seeded in late April or May each year under each rotation depending on weather with a Haybuster no-till drill at an 18-cm row spacing and with a density of 112 kg ha^{-1}. Cultivars were ‘Grandin’ in 1994, NDSU ‘2371’ in 1995, Pioneer ‘2375’ in 1996 and 1997, ‘Oxen’ in 1998 to 2000 and ‘Alsen’ in 2001.

Conventional and no-till soybeans were seeded with a Haybuster no-till drill in 18-cm rows. Reduced-input soybeans were seeded with a Hiniker no-till planter at 76-cm row spacing in order to allow inter-row cultivation. Two different soybean varieties, ‘Ozzie’

(1994 to 1997) and ‘Trail’ (1998 to 2001), were seeded in late May at 67 kg ha^{-1} for all systems.

Table 1. Experimental plan

	Conventional		No-till	
1994	Soybeans	Wheat	Soybeans	Wheat
1995	Wheat	Soybeans	Wheat	Soybeans
1996	Soybeans	Wheat	Soybeans	Wheat
1997	Wheat	Soybeans	Wheat	Soybeans
1998	Soybeans	Wheat	Soybeans	Wheat
1999	Wheat	Soybeans	Wheat	Soybeans
2000	Soybeans	Wheat	Soybeans	Wheat
2001	Wheat	Soybeans	Wheat	Soybeans
		Reduced-input		
1994	Sweet clover	Rye	Soybeans	Wheat
1995	Rye	Soybeans	Wheat	Sweet clover
1996	Soybeans	Wheat	Sweet clover	Rye
1997	Wheat	Sweet clover	Rye	Soybeans
1998	Sweet clover	Rye	Soybeans	Wheat
1999	Rye	Soybeans	Wheat	Sweet clover
2000	Soybeans	Wheat	Sweet clover	Rye
2001	Wheat	Sweet clover	Rye	Soybeans

Yellow sweet clover was seeded every year with a Melroe Kirchman small grain drill (15-cm row spacing) at 11 kg ha^{-1}. In the two first years (1993 and 1994), fall-seeded yellow sweet clover did not survive the winter. Therefore, from 1995 to 2001, planting was completed during the spring. Sweet clover was harvested two to three times a year depending on the weather.

Winter annual rye was seeded in September at a rate of 84 kg ha^{-1} each year following yellow sweet clover. Rye was seeded with a Melroe Kirschman small-grain drill from 1994 to 1998 and a Haybuster no-till drill from 1999 to 2001. Two varieties were planted, ‘Dacold’ in 1994 and 1995 and ‘Musketeer’ from 1996 to 2001.

Fertilizers were applied depending on soil sample analyses and yield goals for each crop. Samples were taken at a 15-cm depth in the fall of each year to determine nitrogen (N), potassium (K), phosphorous (P), soil organic matter, and pH. Granular fertilizer was applied in the spring before the seeding of yellow sweet clover, wheat, soybeans and rye (Ramsdale et al. unpublished).

Weed management varied between systems. In the conventional tillage system, pre- and post-emergence herbicides and pre-plant and post-harvest tillage were employed. In the no-till system, weed management included only foliar herbicides applied post-emergence or post harvest. As the reduced-input system was more diversified, so were the methods to control weeds. Management included pre-plant and post-harvest tillage, inter-row cultivation in soybeans, mowing in yellow sweet clover, and minimal use of non-residual herbicides as weed management options for wheat. No weed control was used in rye. This guideline to control weeds was followed as often as possible although adjustments were necessary every year due to weed pressures and weather conditions. All post-emergence herbicides were applied using an adjuvant.

The three tillage systems used in the study were intensive tillage in the conventional rotation, reduced tillage in the reduced-input rotation, and no-till in the no-till rotation. When used, tillage consisted of a tandem disk, field cultivator with harrow, chisel plow, V-blade sweep (76 cm) undercutter, and an inter-row cultivator with a 60 cm V-blade sweep. The depth of cultivation with either a tandem disk or a field cultivator was generally between 5 and 10 cm. The depth of cultivation when using an inter-row cultivator and V-blade sweep undercutter tillage was 2.5 to 5 cm deep. Chisel plow treatments were 15 to 20 cm deep.

Prices and costs

Yields of every crop, except sweet clover, were reported annually. Prices were obtained from the North Dakota Agricultural Statistics Service (1994-2001). Prices for all baled hay were used to represent sweet clover prices. Fertilizer prices were from North Dakota projected crops budget for 2004. Annual costs and prices were deflated to 2001 dollars using a PPI (reported in Table 2). The prices for nitrogen, phosphorus, and potassium were \$0.39 kg^{-1}, \$0.441 kg^{-1}, and \$0.265 kg^{-1}, respectively. Herbicides prices were obtained from the North Dakota State University Crop Production Guide (Zollinger et al. various years).

Actual seeding, harvest, pesticide application costs and tillage operations were recorded annually. Equipment costs were taken from the Farm Machinery Economic Cost Estimates for 2002 (Lazarus and Selley 2002).

Government program payments

Break-even returns to sweet clover are computed with and without government payments. When considered, loan deficiency payments were used for soybeans and wheat. Loan rate data for Cass County, North Dakota, were taken from USDA ERS (2004).

Economic analysis

Revenues were computed per hectare by multiplying each crop yield by its corresponding price. Returns per hectare by year and crop were computed by subtracting per hectare costs from revenues. To obtain returns to rotations, per hectare annual crop returns were weighted by the inverse of rotation length and summed.

Break-even yields for sweet clover in the reduced-input system were computed as the difference between the average return of the conventional or no-till rotation returns and the reduced-input rotation returns (without a return for sweet clover). Break-even sweet clover yield was obtained by dividing the break-even return by annual average hay prices.

Finally, the break-even sweet clover yield was compared to published county yields for Cass County, North Dakota, between 1995 and 2002 (USDA NASS, 1995-2002). A t-test was used to compare the means of the historical Cass County sweet clover yields and break-even yield using a 90% level of confidence.

Table 2. Producer price index

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001
PPI	1.020	1.014	0.995	0.969	0.965	0.974	0.992	1.005	1.000

RESULTS

Yields

Yields summaries are reported in Table 3. Soybean yields were higher and less variable in conventional tillage than in the other cropping systems. Wheat yields were also higher under the conventional system than under the no-till and reduced-input systems and were more stable. Larger fluctuations and lower minimum wheat and soybean yields were observed in the reduced-input rotation. The lower average wheat yield under the reduced-input system was due largely to a yield of 0.25 tons ha^{-1} in 1995. Low rainfall from April to the end of June prevented optimal growth for wheat in 1995.

Table 3. Average annualized yields

	Yield (tons/ha)		
System	Soybean	Wheat	Rye
Reduced-input			
Average	1.47	1.87	3.11
Minimum	0.66	0.25	1.76
Maximum	1.99	3.17	4.51
Standard deviation	0.48	0.93	0.95
No-till			
Average	1.43	2.47	
Minimum	0.66	1.36	
Maximum	2.25	3.32	
Standard deviation	0.50	0.71	
Conventional			
Average	1.64	2.53	
Minimum	1.17	1.48	
Maximum	2.38	3.47	
Standard deviation	0.41	0.73	

Operating costs

Operating costs are presented in Table 4. The reduced-input system had the lowest average operating costs for soybeans and wheat (\$111.67 ha^{-1} and \$72.27 ha^{-1} respectively).

The smallest observed soybean operating cost was in the reduced-input system ($50.41 ha^{-1}) and the largest was in the conventional system ($231.32 ha^{-1}). Wheat operating costs followed a similar trend among cropping systems. Average wheat operating expenses for conventional and no-till systems account were $109.16 ha^{-1} and $162.32 ha^{-1}, respectively. Soybeans under the conventional tillage system had more stable operating costs. Average operating costs were highest in the no-till system and lowest in the reduced-input system.

Yellow sweet clover was the crop with the lowest average operating cost ($67.84 ha^{-1}). These results can be explained by fewer required field operations in sweet clover compared to all other crops. Average operating cost for rye ($120.10 ha^{-1}) was the largest of the crops grown in the reduced-input system.

Table 4. Average annualized operating costs

		Operating costs ($/ha)		
System	Soybean	Wheat	Sweet clover	Rye
Reduced-input				
Average	111.67	72.24	67.84	120.10
Minimum	50.41	40.71	43.80	114.51
Maximum	197.33	94.99	93.85	132.40
Standard deviation	43.65	16.15	19.07	6.44
No-till	Soybean	Wheat		
Average	149.88	162.32		
Minimum	70.06	88.17		
Maximum	226.53	265.74		
Standard deviation	45.56	60.42		
Conventional				
Average	150.37	109.16		
Minimum	101.79	80.28		
Standard deviation	38.80	31.88		

Revenues without government payments

Average annualized revenues are presented in Table 5. The highest average revenue from soybeans was obtained with the conventional tillage system ($308.84 ha^{-1}) followed by the reduced-input system (\$280.75 ha^{-1}) and the no-till system (\$269.32 ha^{-1}). In addition, the conventional system has the smallest standard deviation for soybean revenue. The coefficient of variation for soybeans is 0.28 with the conventional system, 0.36 with the no-till system and 0.43 with the reduced-input system. Even though the reduced-input system leads to larger soybean revenue fluctuations, it had the highest observed maximum soybean revenue (\$499.36 ha^{-1}). The lowest observed soybean revenue occurred in the no-till and reduced-input systems (\$109.44 ha^{-1}).

Table 5. Average annualized revenue

	Revenue (\$/ha)		
System	Soybean	Wheat	Rye
Reduced-input			
Average	280.75	180.44	233.11
Minimum	109.44	27.96	126.70
Maximum	499.66	321.90	384.63
Standard deviation	121.89	102.91	90.24
No-till			
Average	269.32	290.98	
Minimum	109.44	210.42	
Maximum	435.63	360.70	
Standard deviation	97.09	52.93	
Conventional			
Average	308.83	299.31	
Minimum	198.78	216.38	
Maximum	460.34	371.68	
Standard deviation	86.92	60.69	

The smallest observed average wheat revenue was under the reduced-input system (\$180.44 ha^{-1}). The largest observed average wheat revenue was under the conventional tillage system (\$299.31 ha^{-1}), whereas annualized average for the no-till system is \$290.98 ha^{-1}. The no-till and conventional tillage systems again showed less fluctuation in revenues than the reduced-input system. Average winter rye revenue under the reduced-input system is between wheat and soybean revenues ($233.11 ha^{-1}).

Returns by crops without government payments

Average annualized returns by crops are given in Table 6. Soybeans had the highest observed average returns within the reduced-input system ($137.89 ha^{-1}), followed by the conventional tillage system ($124.14 ha^{-1}). The combination of high yields and low operating costs led to higher returns in the reduced-input system. The maximum observed soybean return was under the reduced-input system ($423.74 ha^{-1}) and the lowest was under the no-till system ($-117.09 ha^{-1}). Soybean returns fluctuated greatly among years with a coefficient of variation of 1.06 for the reduced-input and conventional system and 1.57 for the no-till system.

Table 6. Average annualized returns by crop and system

	Returns ($/ha)		
System	Soybean	Wheat	Rye
Reduced-input			
Average	137.89	88.15	87.11
Minimum	-90.60	-69.41	-132.40
Maximum	423.74	281.19	270.12
Standard deviation	146.73	120.95	120.28
No-till			
Average	89.51	96.32	
Minimum	-117.09	-97.32	
Maximum	294.67	217.16	
Standard deviation	140.85	113.60	
Conventional			
Average	124.14	156.89	
Minimum	-101.79	-80.93	
Maximum	335.35	282.61	
Standard deviation	131.78	105.07	

Unlike soybeans, wheat was more profitable under the conventional system with an average return of $156.89 ha^{-1}, followed by the no-till ($96.32 ha^{-1}) and reduced-input systems ($88.15 ha^{-1}). In addition, largest maximum returns were from the reduced-input and conventional systems (around $281 ha^{-1}). The smallest minimum return was found under the no-till system ($-117.09 ha^{-1}). Similar to soybeans, returns for wheat are highly variable, and the coefficient of variation ranged between 0.67 for the conventional system to 1.37 for the reduced-input system. Sweet clover returns were not reported on this table, since returns could not be computed without yield data. Finally, rye average returns are similar to wheat returns ($87.11 ha^{-1}) and slightly less variable.

Returns per rotation without government payments

Annualized returns by rotation are reported in Table 7. The conventional system has an average return of $140.52 ha^{-1} followed by the no-till system ($92.92 ha^{-1}). The reduced-input system without sweet clover has annualized returns of $85.15 ha^{-1}. A note of caution is added here regarding average returns for the reduced-input system because of the absence of the sweet clover returns. Comparing the no-till and conventional systems, the latter leads to higher returns over the study period with more stable results as the coefficient of variation is lower (0.96 for no-till and 0.71 for conventional).

Table 7. Systems average annualized returns

	Returns ($/ha)		
System	Conventional	No-till	Reduced-input without sweet clover
Average	140.52	92.92	85.15
Minimum	-91.26	-106.49	-73.10
Maximum	261.57	193.14	177.90
Standard deviation	100.45	89.10	73.99

Economic results with government programs

Loan deficiency payments occurred in 1998, 1999 and 2001 for soybeans. Consequently, average soybean revenues and returns increase by \$13.07 ha^{-1} for the reduced-input system, \$14.19 ha^{-1} for no-till and \$15.76 ha^{-1} for the conventional system. Average returns by system also increase under government payments by \$7.00 ha^{-1}, \$6.31 ha^{-1}, and \$2.90 ha^{-1}, for the conventional, no-till and reduced-input systems, respectively.

Break-even yields and returns

Break-even yields and returns are for sweet clover are reported in Table 8.Without government program payments, for the reduced-input system to be as competitive as the conventional system, sweet clover needs an average return of \$249.18 ha^{-1} annually and \$34.94 ha^{-1} to be as competitive as the no-till system (Table 8). Sweet clover needs to yield 7.18 tons ha^{-1} for the reduced-input system to be as profitable as the conventional system and 1.01 tons ha^{-1} to be competitive with the no-till system. When compared to historic yields obtained by farmers in Cass County, North Dakota during the same period, the break-even yield of 7.18 tons ha^{-1} was obtained three out of the eight study years (Table 9). This implies that there is a 37.5% chance for farmers to obtain the sweet clover break-even yield. Similarly the break-even yield of 1.01 tons ha^{-1} was reached every year and the reduced-input system is therefore as profitable as no-till.

Table 8. Break-even results for sweet clover

Reduced-input system compared to		Break-even return without government programs	Break-even return with government programs
Return (\$/ha)	Conventional	249.18	267.63
	No-till	34.94	50.25
Yield (tons/ha)	Conventional	7.18	7.70
	No-till	1.01	1.45

Under government programs, the sweet clover break-even yield is 7.7 tons ha^{-1} as opposed to 7.18 tons ha^{-1} under conventional management and 1.45 tons ha^{-1} as opposed to 1.01 tons ha^{-1}under no-till. This is due to higher average revenues and returns under conventional tillage and no-till than the reduced-input system. Break-even yields were obtained 100% of the time when comparing reduced-input and no-till systems but only 25% (two years out eight years) of the time when comparing reduced-input and conventional rotations.

Table 9. Sweet clover historical yield results (1994-2001) (tons/ha)

		With government program		Without government program	
Year	Observed sweet clover yield	Conventional Target	No-till target	Conventional Target	No-till target
1994	8.10	7.7	1.45	7.18	1.01
1995	7.04	7.7	1.45	7.18	1.01
1996	6.38	7.7	1.45	7.18	1.01
1997	6.20	7.7	1.45	7.18	1.01
1998	7.36	7.7	1.45	7.18	1.01
1999	6.38	7.7	1.45	7.18	1.01
2000	9.41	7.7	1.45	7.18	1.01
2001	6.50	7.7	1.45	7.18	1.01

The results in Table 10 show that, between reduced-input and conventional systems, average yield differences are not significantly different than 0. However, between reduced input and no-till, the values obtained are 1.964 and 1.823 without and with government programs, respectively. As the sample size is small (eight observations), few conclusions can be enounced regarding statistical differences between means.

Table 10. T-test comparison between historical sweet clover yields and break-even sweet clover yields for each system

	Without government programs	With government programs	Without government programs	With government programs
	Conventional break-even yield	Conventional break-even yield	No-till break-even yield	No-till break-even yield
T-table value	1.860	1.860	1.860	1.860
T-value calculated	0.003	0.168	1.964	1.823

CONCLUSIONS AND IMPLICATIONS FOR PRODUCERS

The purpose of the study was to find the break-even sweet clover yield in the reduced-input system compared to conventional tillage and no-till systems. The break-even yield is obtained 37.5% of the time when compared to conventional tillage and 100% when compared to no-till rotation without government payments and 25% and 100%, respectively, when government programs are considered.

Switching from a conventional system to a reduced-input rotation has the following impacts for producers. First, wheat and soybean yields decline, mostly due to a lack of control weed in some years. Even though the difference is not large for soybeans (a loss of 0.17 tons ha^{-1}), wheat yield reduction is important (around 0.7 tons ha^{-1}) over the time period of the experiment (1994-2001). The lower yields result in lower revenues of \$28 ha^{-1} for the reduced-input system compared to conventional. In addition, revenues are less variable under the conventional cropping system.

Second, there is a significant reduction of operating costs, averaging \$39 ha^{-1} when moving to the reduced-input system. This difference can be explained by fewer trips across the field and a reduction in farm inputs.

Third, although not investigated in this study, there may be a potential for economies of scale under the reduced-input system. As fewer trips across the field are required, larger acreages can be covered with the same machinery. Consequently, producers may be able to produce at lower costs by spreading fixed cost on a greater acreage. Efficient use of labor and capital may also be a source of economies of size in the short-term and long-term.

Switching from conventional tillage system to no-till is not economically advisable. Reduced yields, increased operating costs and decreased profits make the no-till system less economically efficient than the conventional tillage system.

Government programs create disincentives for switching to reduced-input rotations. As the probability to reach the sweet clover break-even yield is reduced from 37.5% to 25% when federal subsidies are considered, producers prefer traditional rotations and tillage systems to the alternative system considered. Even though yields decline and new machinery investments may reduce short-term profits, long-run profitability and economies of scale may be obtained with the reduced-input system. In addition conservation practices and reduced input may preserve soil productivity and production potential in the longer term.

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APPENDIX. LITERATURE REVIEW

Choosing a cropping system is a process that has to take into account many different factors influencing short-term and long-term operatings. Campbell et al. (1995) and Young et al. (1999) reported that for a cropping system to be sustainable in the long term, it must: (i) be technically or agronomically feasible (i.e., suited to the soil and climatic conditions of the area, practical to implement, and capable of producing acceptable grain yields and quality); (ii) ensure that the quality of the soil, water, and air resources are maintained or enhanced; and (iii) be economically viable. Moreover, according to Brown et al. (1996), key factors that have been identified include: long-term agronomic benefits, yield differential, soil conservation, herbicide requirements, fuel use, machinery use, investment requirements, and knowledge and management requirements.

This appendix discusses previous studies addressing the economic benefits of reduced-input rotations, tillage method impacts on farm productivity, and crop diversification consequences.

From a producer’s perspective, there is an economic incentive to use crop rotations and soil tillage methods that provide the greatest net return to management, risk taking in the short term and to land equity and other fixed assets of production in the long term (Zentner et al. 2002a). Profit-maximizing producers will switch to a new cropping system if it provides more economic return in terms of one or more lower production costs, higher net returns and lower business risks.

Tillage operations

Intensive cropping

Conventional tillage systems have been used for many years for practical reasons including farmer familiarity with production management. Nevertheless, economic as well as environmental factors may offset those advantages.

Studies show that production costs may be higher as the conventional system is more input intensive. This increase is due to higher expenditures for seed, fertilizers, pesticides, machinery operating and ownership as more of the land area is occupied by crop production instead of summer fallow (Zentner et al. 2002b). Intensive cropping is favored when the price of grain is relatively high because of the opportunity cost of fallowing a field.

Zentner et al. (1996) show that conventional tillage cropping systems on the Canadian Prairies provides higher returns than conservation and zero tillage systems on both fallow-wheat and continuous-wheat rotations on silt loam and clay soils; however on highly erodible sandy loam soil, the opposite was observed. McConkey et al. (1998) report that changes in wheat market prices have little influence on the economic rankings of the tillage methods because of the absence of yield differences between the different tillage systems. Also, differences are smaller in the case of diversified cropping systems compared to monoculture wheat systems because of the advantage of minimum tillage management for the new introduced crops. However, a reduction in herbicide costs by more than 50% would make conservation tillage as profitable as conventional tillage in monoculture wheat systems (Gerowitt 2003).

Reduced and conservation tillage

Reduced and conservation tillage practices are an alternative to conventional tillage systems. Over the past decade, U.S. farmers have continued to adopt conservation tillage practices. According to the Conservation Technology Information Center (1999), the area planted using conservation tillage practices increased from 5.1% in 1989 to 16.3% in 1998. According to Lafond et al. (1996), Lindwall and Larney (1993), and Johnston et al. (1983), the yield potential with conservation tillage is similar or higher than with conventional tillage because of higher soil moisture and reduced evaporation losses.

No-tillage farming involves planting seeds in a narrow slot that is opened by the planter with minimal disturbance of the surface crop residue. No additional tillage is done for seedbed preparation. Additional soil and residue disturbance is limited to fertilizer and pesticide placement (Hanna 1995). According to Yin and Al-Kaisi (2004), 33% of soybean and 18% of corn acres were grown under no-till practices in 2002 and the acreage in no-till is increasing. The potential still exists to increase no-till acres throughout the country.

The reduced machine and labor requirements associated with using reduced or conservation tillage also permits more timely seeding operatings during optimal weather conditions, so that it improves the potential for higher and more stable crop yields with improved grain quality (Zentner et al. 2002a). Moreover, the benefits of using conservation tillage practices for reducing soil losses and maintaining or improving long-term soil productivity are widely reported (Campbell et al. 1988; Acton and Gregorich 1995; Smith et al. 2000). With reduced tillage, less organic matter is oxidized and lost than with frequent moldboard and chisel tillage (Bremer et al. 2001). Consequently, long-range benefits include increases in soil organic matter and favorable types of microbes and earthworms. The latter are soil builders that improve soil structure and increase its capacity to hold moisture and nutrients, enabling root proliferation, greater plant growth and therefore greater yield potential (Bremer et al. 2001).

Hairston et al. (1990) compared soybean yield differences between conservation tillage and conventional tillage. Results were similar on sandy soils during a three-year experiment. However, on silt loam and clay soils, yields under conventional tillage were higher than under the no-till practice. This loss of yield on finer textured soils has also been observed in previous studies by Hairston et al. (1984) and Dick et al. (1986a, b) in Ohio. No-till practices led to higher corn and soybean yields in North Carolina on sandy loam soils (Wagger and Denton 1989). Similarly, no-till increased soil water storage during the fallow period in north central Texas, resulting in increased sorghum yield compared to conventional tillage practices (Wiese et al. 1998). Liu and Duffy (1996) showed that no-till practices resulted in greater economic returns than conventional tillage on soybeans, mostly because of lower operating costs. No-till and reduced tillage have similar economic returns (Liu and Duffy 1996).

Farmers can reduce machine-related operating costs (fuel, oil and repair) by reducing the number of field operations, combining two or more operations at the same time (e.g., seeding and fertilizing), or using machines with greater capacity and lower draft equipment (Zentner et al. 2002a).

Labor cost savings may also be enhanced. By reducing the number of trips across the field, conservation tillage practices allow farmers to spend less time on field operations and save the cost of hiring labor, an important consideration given the low supply of farm labor (Zentner et al. 2002a). Alternatively, the additional free time may permit farm operators to expand their land base, thereby taking advantage of economies of scale and helping to spread the fixed costs of machinery ownership over a larger area, complete production tasks or activities in a more timely fashion, undertake new or additional on-farm value-added activities, perform custom work for neighbors, work off the farm or spend more time on leisure and family activities (Brown et al. 1996; Gray et al. 1996).

Several studies evaluated the long-term impact of conservation tillage on soil conservation regarding erosion, organic matter loss, and salinization (Sparrow 1984). Van Kooten et al. (1989) estimated that the annual cost of erosion in the Canadian Prairies Brown soil zone was between \$2.38 ha^{-1} and \$5.63 ha^{-1}. Reduced tillage was found to be preferable than conventional tillage or no-till regarding erosion and organic matter (Smith and Shaykewich 1990).

In Indiana, Doster et al. (1983) found that no-till and reduced tillage practices were more profitable for well-drained sandy soils than a conventional tillage system, but the opposite was reported for poorly drained clay soils. Klemme (1982) showed that, if equal yields could be produced by each tillage system, then the cost of production on a per-bushel basis is similar between conventional and conservative tillage systems.

Liu and Duffy (1996) compared the profitability of conventional and conservation tillage practices and reported that most conservation systems including no-till or reduced-till had higher profits than plowing and conventional tillage. According to Parsch et al. (2001), conservative tillage practices had higher yields and economic returns than conventional tillage practices, and the difference was even higher when crops are grown in rotation.

However, conservation practices and diversified crop rotations may require more time to manage pest problems, fertilization, and marketing. When switching to a new system, farmers go through a learning process, increasing risk and adjustment costs because of the new use of technology or choices of crops (Wall and Zentner 1999). Also, McConkey et al. (1998) report lower quality of grain from conservation tillage practices, thus lowering market price and eroding profits.

According to Zentner et al. (1996), adopting conservation tillage practices may increase expenditures for herbicides by \$11 ha^{-1} with minimum tillage and by \$31 ha^{-1} with no-till managed fallow-wheat (compared to conventional tillage), mainly reflecting the higher cost of controlling weeds on fallow areas with herbicides than with tillage. Also total costs are 6% higher on the fallow-wheat system when using minimum tillage versus conventional tillage and 29% higher when using no-tillage practices. Similarly, total costs for no-tillage managed continuous wheat average 13% higher than the comparable conventional tillage managed system, reflecting the increased expenditures for herbicides plus the need for somewhat higher rates of nitrogen fertilizer with zero tillage management (McConkey et al. 1998). Jolly et al. (1983) compared four tillage systems and their economic impact on a corn-soybean rotation. Using returns to land and management as a measure of economic performance, they report that on a short-term basis (1-2 years), lower residue systems such as moldboard and chisel plow are preferred whereas on a long-term basis (3-4 years) that allow for reallocation of labor and capital, high-residue systems such as strip-till and ridge-till are competitive.

Crop diversification

Diversified cropping systems and pulse crops

Cropping systems can be defined as the combination of crops grown and management applied. Crop rotation systems are a subset of cropping systems (Gebremedhin and Schwab 1998). Crop rotation systems are characterized by a defined sequence of crops produced on a particular parcel of cultivated land and the associated management practices (Gebremedhin and Schwab 1998). Numerous cropping systems can be employed and several factors have to be taken into consideration to choose among crop possibilities and management and monitoring of production.

Crop rotations and crop diversification offer economic advantages as well as agronomic and environmental benefits. Several advantages of crop rotations have been widely recognized (Bray and Schnittker 1956; Guertal 1997; Jones 1996; Christenson 1991). Crop rotations can break disease and weed cycles. Crop rotations can also effectively reduce soil erosion, thereby avoiding long-term declines in the productive capacity of the land and reducing non-point pollution that could occur (Gebremedhin et al. 1998). Crop rotations improve soil quality, enhance permeability and increase biological activity, water and nutrient storage capacity, and organic matter. Using cover crops enhances the benefit of crop rotations by improving soil structure, increasing soil organic matter, water percolation and beneficial insect population, suppressing or maintaining weeds, reducing soil erosion and fixing nitrogen after grain harvest (Jones 1996).

These benefits from cover crops may increase farm profitability by either reducing cost (e.g., by reducing the need for commercial fertilizer) or increasing yields through their effect on soil quality and fertility. Roberts and Swinton (1996) showed in Michigan that the use of cover crops in a corn-soybean-wheat rotation reduces nitrate leaching while maintaining profitability.

Miller et al. (2002) reported that in the Canadian Prairies the area sown with legumes has increased in the last two decades. The proportion of legumes is 35% of the total wheat area in the northern plains, due mostly to the growing presence of soybeans in the subhumid regions of the eastern Dakotas (Farm Service Agency, State Office, Fargo, ND, 1999). Unlike in adjacent Canadian prairies, legumes still have a minor role in the semi-arid regions of the Dakotas and Montana in 1999 (Farm Service Agency, State Office, Bozeman, MT).

According to Zentner et al. (2002), introduction of legumes (e.g., fava beans, field beans, field pea, lentils and soybeans) can decrease the need of nitrogen because of the natural fixation of nitrogen by the plant if inoculation is done at the time of planting. Moreover, rotational benefits of legumes may facilitate greater diversification of cropping (Miller et al. 1998; Angadi et al. 1999). Including legumes in the rotation may also provide cost savings for cereal and oilseed crops that may be grown on the pulse stubble, because of residual soil nitrogen and moisture (Miller et al. 1997).

Other benefits of using legumes include greater flexibility in herbicide choice because of the variety of crops and a break in the disease cycle with decomposition of host crop residues (Fernandez et al. 1998). The rotational effect of legumes on subsequent wheat yield seems to be the result of a series of complex interactions of the pulse crop on soil water (Angadi et al. 1999), soil nutrient supply (Grant et al. 2002; Beckie and Brandt 1997), and interruption of pest cycles (Derksen et al. 2002; Krupinsky et al. 2002). Miller et al. (2002), however, reported that legumes could have positive, neutral or negative effects on subsequent crop yield, depending how the previous pulse crop affects the pool of weed seed in the succeeding crop.

Miller et al. (1997) indicated that wheat production costs are not affected by the introduction of legumes into rotations. However grain yield and protein content are higher when wheat is grown on pulse stubble compared with oilseed or cereal stubble. Some of the legumes respond better in stubble cropping environments while others are better suited to a fallow environment (Miller et al. 1997). Yields of lentil, field pea and chickpea grown on stubble are about 85% of those grown on fallow whereas yields of mustard and wheat grown on stubble are only 70% of the comparable fallow-crop yields. As the climate varies in the northern plains, adaptation of these crops to particular environmental conditions is a concern for many researchers. Miller et al. (2002) relate that relative yield performance of different legumes due to climatic factors such as thermal conditions, adequate fertility and freedom from pests on a particular location is a useful indicator of the adaptation of those crops to that location.

The climate of the northern plains is continental with long, cold winters and short but warm summers; large diurnal ranges in temperatures; frequent strong winds and uncertain precipitation (Padbury et al. 2002). As a consequence, farmers change their crop management yearly (Stewart and Robinson 1997). Legumes, as all crops, have thermal requirements (cumulative degree days) for crop maturity. In a study on the adaptability of legumes in the northern plains, Miller et al. (2002) find that soybean adaptation is constrained by long maturity requirements and dry beans are relatively well adapted to warm, wet growing seasons or areas under irrigation, excluding dryland of the northern plains. Even if effects of tillage practices on legumes have not been studied in detail, the few results available are in favor of no-till practices to promote growth and potential yields of those crops. For instance, at Indian Head, Canada, increase of field pea yield with no-till practices is related to extra moisture conserved from leaving standing stubble over the winter, increasing snow trapping and promoting moisture conservation (McConkey et al. 1998). In addition, at Swift Current, Canada, legumes have improved yield when planted directly in the cereal stubble, due to reduced wind speed and evaporative demand for water. A study in southern Saskatchewan shows that chickpea provides about one half the amount of crop residue on the soil surface as spring wheat grown under the same conditions (McConkey 1998). Consequently, adopting no-till practices can help reduce exposure to highly-eroding conditions from wind or water.

Because of short growing seasons and unpredictable weather conditions, producers face several constraints regarding introduction of legumes in the rotation. Miller et al. (2002) show that legumes are more difficult to produce than wheat and a high expected benefit has to be perceived by farmers in order to switch to legumes. Moreover, legumes cost savings are offset by the cost of seeds and additional machinery needed. To minimize harvesting losses, additional machinery is needed (land rollers, flex-headers, and pick-up reels) increasing production costs as well as business risk.

Forage crops as a potential to diversify

Another means to diversify crop rotations in the northern plains is to introduce forage crops in the rotation (Entz et al. 2002). Forage crops include 7.8 million ha of cultivated hay and 3.8 million ha of cultivated pasture in Canada (Alberta Agric., Food, and Rural Dev. 1999; Manitoba Agric. and Food, 1999; Saskatchewan Agric. and Food 1999; Nass 1999). According to Small and McCaughey (1999), forage is produced and stored during the short growing season and fed during the rest of the year. The predominant winter-feed is hay followed by straw, silage, stockpiled perennial pasture and swathed annual pastures. Around 10% of the forage is used directly in the northern plains for dairy cows; some is exported to South America and importation happens only during dry years and low forage yield (Entz et al. 2002).

The most common forage crop grown is alfalfa, occupying about 61% of the total hay area in Canada (Entz et al. 2002). When alfalfa cannot be grown due to climatic or soil conditions, other legumes such as red clover, alsike clover or sainfoin are chosen by producers as a replacement (Entz et al. 2002). Unlike Australia or the humid U.S Midwest, forage crops have received less attention, and the drier conditions in the northern plains modify agronomic impacts of forages relative to wetter areas (Entz et al. 2002). In a long-term study (1912-1956) on perennial forages conducted at Fargo, North Dakota, Stoa and Zubriski (1969) reported that wheat yields were 50% higher from land cropped previously to alfalfa for three years than from land previously cropped to non-legumes. A survey conducted in Manitoba shows that 71% of producers had higher grain yields after a forage crop than in annual crop rotations (Entz et al. 2002). Hoyt (1990) reports that for the first eight years after forage termination, wheat yields were 66% to 114% greater compared to continuous wheat. In wet areas of the Northern Plains, water-depleting characteristics of alfalfa and other forage crops are beneficial and also play a great role in avoiding soil salinization (present on about 25% of the total land area) and maintaining soil fertility in the long term (Morrisson and Kraft, 1994). Hoyt and Leich (1983) report that the subsoil (60-135 cm) dewatering effect with perennial legumes lasted for at least two years after stand termination and that alfalfa provided greater dewatering benefits than red clover.

Concerning pest control, a survey of Canadian Prairie farmers relates that 83% of respondents find that fewer weeds are present after alfalfa than after conventional grain rotations with good suppression of wild oat, green foxtail, and Canada thistle (Entz et al. 2002). According to Ominski et al. (1999), wheat after perennial alfalfa or alfalfa-grass hay crops has significantly less weed infestation than wheat in a conventional grain rotation, and the pool of weed changes from traditional weeds to secondary ones. Regarding tillage practices, no-till or reduced-till seem to be preferable due to water conservation and available moisture for fragile forage crop seedlings helping germination (Entz et al. 2002).

The most important set of studies on the economic impact of forage crops was conducted by Zentner et al. (1986, 1988, 1991, 1992, 1996, 2002a, 2002b). They reported that costs of production for forage-based systems were lower than continuous grain production but higher than wheat-fallow systems. Another benefit is the stability of net returns across years compared to traditional systems Introducing two or three years of forage crops in a six-year rotation reduces income variability and business risk (Zentner et al. 1986).

Weed control

Controlling weeds is one of the prerequisites for any successful production system (Gerowitt 2003). Consequently, farmers can use different means to achieve this goal, in a long-term base with crop rotation and reduced-tillage practices, in a short-term base with fertilization influencing the competition of arable crops or in the very short-term via mechanical and/or chemical control. Overall, the goal is to reduce negative outputs of arable farming. Potential weed control benefits given by reduced-input rotations have been shown in different studies (Gerowittt 2003).

In a study in Saskatchewan, weed seedling and seed bank densities were reported to be similar or lower in reduced-input rotations compared with high-input rotations (Derksen et al. 2002). Best results were reported where delayed seeding is used in a rotation of spring wheat and annual legumes to reduce herbicide and fertilizer use. The highest weed seedling densities occurred in a fully fertilized conventional tillage rotation using a post-emergent herbicide strategy.

In a long-term crop rotation study, Ramsdale et al. (unpublished) report that total weed density in wheat and soybean from 1994 to 1997 was generally higher in the reduced-input rotation. However, between 1998 to 2001 weed densities for the reduced-input rotation were generally equal to or less than weed densities in the conventional and no-till systems for both wheat and soybeans.

Diversifying rotations to include both spring and winter crops helps control weeds (Moyer et al. 1994; Blackshaw et al. 1994). Crop diversification provides more control opportunities and disrupts life cycles of weeds that are crop mimics (Anderson 1997). The apparent success of crop rotation systems for weed suppression is based upon use of crop attributes, such as varying patterns of resource competition, allelopathic interference, soil disturbance, and mechanical damage, which are combined to create an inhospitable environment for weeds (Liebmann and Dyck 1993). Also diversifying the rotation can reduce weed seed production (Kegode et al. 1999). Moreover, weed communities become more diverse in diverse cropping systems, thus minimizing the predominance of any one weed (Froud-Williams 1988; Derksen et al. 1995). Excellent weed suppression has been shown with under-seeded biennial sweet clover. Similarly, weed control of perennial alfalfa lasts three years for wild oats and several others but not on all weed species (Froud-Williams 1988; Derksen et al. 1995).

Weed community composition and density varies depending on the frequency and strength of pressure applied to control it. Therefore, varying selection pressure to keep weed communities from equilibrium can minimize weed densities and reduce adverse selection. A diverse cropping system including different seeding date, crop life cycle, herbicide mode of action, herbicide timing, crop residue layers, and soil disturbance will provide an economical means of managing weeds by reducing weed densities and reliance on herbicides (Derksen et al. 2002). For instance, winter wheat residue reduces weed seedling emergence by 45% and biomass by 60 % in soybeans (Derksen et al. 2002).

Reduction in herbicide use is viewed as a risk to economic viability (Zoschke 1994). However, the need to reduce herbicide applications has been motivated by the widespread appearance of herbicide resistance (Powles et al. 1997), risks of environmental contamination, and negative perceptions of pesticides (Major 1992).

Impact on business risk

According to Schoney (1995), summer-fallowing has been employed in the northern plains as the main means used by producers to minimize or manage business risk. Results observed by Zentner et al. (1996), and Zentner and Campbell (1988) confirm that in wheat monoculture, producers would prefer two- or three-year fallow-type rotations compared with continuous cropping systems, particularly in the drier Brown soil zone. Also, conventional tillage is preferred to minimum tillage or no-till practices because of lower out-of-pocket production costs and the lack of significant yield benefits with no-tillage (Zentner et al. 1992). According to Zentner et al. (2002), conservation tillage practices increase production and market risk due to the higher cash outlays for inputs, the need for additional capital purchases and greater management skills.

No-till practices are a solution to stabilize yield in years when temperature are unusual or low or poorly distributed precipitation occurs during the growing season (Lafond et al. 1996). Planting crops directly into standing stubble improves the microclimate and allows better growth because of a reduction in evaporation loss from the soil and crop seed protection from wind and water erosion (Lafond and Derksen 1996; Cutforth and McConkey 1997). However DeVuyst and Halvorson (2004) report that under intensive cropping systems, minimum tillage generates the highest expected profits and the highest variability in profits.

As each crop has different water and nutrient requirements, diversifying is a way to reduce business risks (Zentner et al. 2002). Not only does a relationship exist between the crop sequence and crop yield but also between grain prices and grain yields. A high correlation between grain prices provides little advantage for the farmer to diversify (Zentner et al. 2002). However, if the correlation between two crop yields or prices is low, producing both of them will reduce market risk.

Impact of federal policies

According to Watts and Buschena (2000), northern plains agriculture has been buffeted by trade liberalization, major changes in government price support programs, high levels of crop production throughout the U.S. and the world, and a volatile U.S. and international economic situation. The 1973 Agriculture and Consumer Protection Act established the framework for agricultural price and income support programs of the 1980s and 1990s. Key elements for wheat, barley, and rice were target prices and deficiency payments and price supports for each crop through nonrecourse loan programs (Smith and Glauber 1997). Prior to the 1985 act, a farm's effective payment yield was set equal to the average yield for that county or a higher "proven" yield for the farm based on an Olympic average of the five previous crop years (calculated by dropping the lowest and highest years from the average). Then, under the 1990 act, target price maximums were fixed at the 1989 levels, but to meet federal budget targets, fifteen percent of all crop average bases became ineligible for deficiency payments.

According to Smith and Glauber (1997), the FAIR Act (Federal Agricultural Improvement and Reform), that became law on April 4, 1996, reflected one more step in a gradual evolution of U.S. agricultural policy towards greater market orientation. To receive payments and loans on program commodities, producers entered into a 'production flexibility contract' for the period 1996-2002, requiring participating producers to comply with conservation plans for the farm, wetland provisions, and planting flexibility provisions, and to keep the land in agricultural use (USDA ERS1996). Whereas the FACT Act (Food, Agriculture, Conservation and Trade) of 1990 had the purpose of freezing price and income-support rates at existing levels without reducing subsidy levels, the 1996 FAIR Act emphasized major reforms in the areas of target price, nonrecourse loans, production control and acreage reduction requirements. Most analyses of the 1996 Act suggest little change in acreage or prices for wheat and feed grain (USDA 1996; FAPRI 1996). Smith and Glauber (1997) suggest that increased planting variability qould allow producers to react more quickly to changing market conditions, hence acting to stabilize market prices.

Summary of literature

Previous studies show a difference in production costs between systems, including higher expenditures in the conventional and no-till systems compared to reduced-input rotations (Zentner et al. 2002a, 2002b). Conservation tillage and low input rotations allow better soil conservation as well as higher water storage, thus increasing yields in well-drained sandy soils (Doster et al. 1983). However better yields are reported under conventional systems on silt loam and clay soils (Hairston et al. 1990; Campbell et al. 1988). Reduced-input rotations help reduce machine and labor operating costs with a better reorganization of farm operations (Zentner et al. 2002). However, large investments and a learning process may be necessary and costly (Wall and Zentner 1999).

Crop diversification is one of the major changes when switching to a reduced-input system and has major agronomic advantages (Jones 1996). Reduced costs (low use of fertilizers and herbicides) and maintained or higher yields are reported when using diversified crops such as pulse or forage crops (Roberst and Swinton 1995). Wheat yields are reported to be 66% to 114 % greater when seeded after forage in a rotation (Hoyt 1990). Effects of legumes are even higher when grown with reduced tillage practices than with conventional tillage practices (McConkey 1998). However adaptation of some of those legumes to the northern plains climate is questionable and may have a negative economic impact on business (Miller at al. 2002).

Weed control is similar or improved when using reduced-input rotations (Derksen et al. 2002). In addition, no-till practices, crop residues and crop diversification help controlling the weed pool and limit negative impacts on crop yields (Kegode et al. 1999).

Reduced-input systems are preferred to conventional tillage systems regarding business risk because of lower out-of-pocket production costs. Reduced-input systems increase production and market risk and diversifying production may lower risk (Zentner et al. 2002).

Finally, government programs and regulations require producers to comply with conservation plans for the farm, wetland provisions, and planting flexibility provisions, and to keep the land in agricultural use (USDA ERS 1996) denoting increasing incentives toward reduced-input agriculture.