Economic Returns and Hauling Distance of Hog and Cattle Manure

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Problem

The increased specialization of farming operations resulting in more large livestock enterprises and fewer mixed farming operations creates a break in the link between livestock and crop production. The larger size of livestock operations requires that suitable land be available within the economic hauling distance of the collection site. The cost of disposal for the livestock operation and the value of manure in crop production becomes significant in the economic assessment of this problem.

Many factors will affect the value of manure as a substitute for commercial fertilizers. The quantity of nutrients in animal manure will be influenced by the type and maturity of the livestock; feed used; the collection, storage and disposal method, Stonehouse (1991). Therefore the relative net returns between manured and non-manured crops will capture all the benefits (i.e., yield response) and potential disadvantages (i.e., crop lodging) of manure application.

Model

Manure can be valued as a replacement to the equivalent nutrient value of commercial fertilizers, Freeze and Sommerfeldt (1985). The per hectare value of manure (P_M) at commercial fertilizer prices (P_i) for a specific manure application rate is given by

$$P_M = \sum(P_i * Q_i) \qquad \text{for } i = 1 \text{ to } n \qquad \textbf{(1)}$$

where the quantity of a nutrient Q_i is dependent on the crop requirements. The per hectare benefit of manure relative to a non-manured plot for a specific manure application rate is given by equation 2.

$$P_M = \sum(P_{m,ij} * Y_{m,ij} - P_{f,ij} * Y_{f,ij}) - (W_m - W_f) \qquad \text{for } i = 1 \text{ to } n \text{ , } j = 1 \text{ to } z \qquad \textbf{(2)}$$

where
P_M is the per hectare total benefit or net return ($/ha),
$P_{m,ij}$ is the price of the i^{th} crop in the j^{th} year on manured land ($/kg),
$P_{f,ij}$ is the price of the i^{th} crop in the j^{th} year on non-manured land ($/kg),
$Y_{m,ij}$ is the yield of the i^{th} crop in the j^{th} year on manured land (kg/ha),
$Y_{f,ij}$ is the yield of the i^{th} crop in the j^{th} year on non-manured land (kg/ha),

W_m is the cost of loading, hauling and application of manure ($/ha),
W_f is the cost of application of inorganic nitrogen fertilizer ($/ha),
n is the number of crops,
z is the number of years.

The economic hauling distance (K) of manure relative to a non-manured check plot is given by equation 3

$$K = \{\{ \sum (P_{m,ij} * Y_{m,ij} - P_{c,ij} * Y_{c\,ij}) - W_m \} / W_{h,j} \} \quad \text{for } i = 1 \text{ to } n,\ j = 1 \text{ to } z \qquad \textbf{(3)}$$

where
$P_{c,ij}$ is the price of the i^{th} crop in the j^{th} year for the check plot (kg/ha),
$Y_{c\,ij}$ is the yield of the i^{th} crop in the j^{th} year for the check plot (kg/ha),
W_m is the cost of loading, and application of manure ($/ha),
$W_{h,j}$ is the per hectare cost of hauling the manure an extra kilometer ($/ha/km),
n is the number of crops,
z is the number of years.

Research Trials

Field experiments were conducted at two sites Burr and Dixon in the Black soil zone, in east central Saskatchewan near Humboldt. The treatments for the hog manure trials were a check, three rates injected with sweeps on 30 cm spacing, low rate injected with sweeps on 60 cm spacing, low rate injected with spikes on 60 cm spacing, broadcast and incorporated and three rates of deep banded urea. The treatments involving cattle manure trials were a check, three rates of broadcast and incorporated, broadcast with delayed incorporation and three rates of deep banded urea.

The cost of inorganic fertilizers used in this study is presented in Table 1. Nitrogen that becomes available next year and the year after is valued at the price of inorganic N adjusted for inflation at 2% and discounted at 7%.

Table 1: Cost of Nutrients $/kg

Nutrient	N1	N2	N3	P	K	S	Cu	Mn	Zn	Fe
$/kg	.52	.527	.54	.613	.267	.351	.220	.242	.265	.242

Source: Saskatchewan Wheat Pool

The main problem in valuing manure is that the nutrient content can be inconsistent. Ammonium and potassium have been shown to be very consistent between loads and when unloading, Schoenau (1997). However, the phosphorus and micro-nutrient content of manure has been very inconsistent between loads and when unloading, PAMI (1997). The value of manure at the Dixon and Burr research sites for hog and cattle manure is presented in Tables 2 and 3, respectively.

Table 2: Value of Hog Manure $/ha for Application Rates Used

Year	Treatment[1]	L/ha	All[2]	N-P[3]
1997	**Dixon 1xI, S, N, BI**	38138	52.42	39.88
	Burr 1xI	69391	208.04	151.74
	Dixon 2xI	76287	104.85	79.76
	Burr 1xS, N, BI	80055	240.10	175.09
	Burr 2xI	134083	402.15	293.42
	Dixon 4xI	149539	209.69	159.51
	Burr 4xI	268156	814.91	596.93
1998	**Dixon & Burr 1xI, S, N,**	37006	55.10	34.89
	Dixon & Burr 2xI	74011	110.20	69.78
	Dixon & Burr 4xI	148033	219.08	139.59

1. Treatments (RxA) by year are the rate x type of application where rate = 1 - low rate, 2 - medium rate and 4 - High rate. Application = I - injection @ 30 cm spacing, S -sweep @60 cm spacing, N - spike @60 cm spacing, BI -broadcast and incorporated.
2. Value of manure in terms total nutrient content at the point of application.
3. Value of manure in terms of nitrogen and phosphorus content.

Table 3: Value of Cattle Manure $/ha for Application Rates Used

Year	Treatments[1]	t/ha	All[2]	N-P[3]
1997	**Dixon 1xBI, BD**	9.7	209.20	83.39
	Burr 1xBI, BD	18.3	392.28	156.44
	Dixon 2xBI	19.5	418.40	166.78
	Burr 2xBI	36.6	784.57	312.88
	Dixon 4xBI	39.1	836.79	333.56
	Burr 4xBI	73.2	1569.14	625.75
1998	**Dixon & Burr 1xBI, BD**	7.6	206.11	109.79
	Dixon & Burr 2xBI	15.1	412.22	219.56
	Dixon & Burr 4xBI	30.2	824.43	439.09

1. Treatments (RxA) are the rate x type of application where rate =1 - low rate, 2 - medium rate and 4 - High rate. Application is BI -broadcast and incorporated, BD - broadcast with delayed incorporation.
2. Value of manure in terms total nutrient content at the point of application.
3. Value of manure in terms of nitrogen and phosphorus content.

Manure Handling Costs

Loading, application and hauling costs were calculated for a large (19,749,000 litre) manure lagoon. Tractor, pump, injector and tank costs were used in constructing budgets for hauling liquid manure based on a worksheet developed by PAMI[1]. The machinery complement was sized to the lagoon capacity and application rate. Solid manure handling equipment was sized to a cattle enterprise producing 9490 tonnes of manure per year. Hauling costs are based on the average kilometer per hectare hauling distance to the available land base at a specific application rate for a one in two year frequency. The incorporation costs of liquid broadcast and solid manure and banding of urea fertilizer were calculated.

[1] PAMI report # 729 Pipeline Manure Injection Systems

Custom liquid manure hauling rates are $1.65/1000 litres for surface applied and $1.87/1000 litres for injection within a 2.4 km hauling distance plus the cost of two tractors and labour to run the pumps. Custom solid manure handling rates are on average $1.75/ tonne for short hauling distances.

The manure handling costs for liquid swine manure based on the application rates used at the Dixon and Burr sites are in Table 4. Custom application is cost effective at the lower application rates for the large hog enterprise. Ownership of manure handling equipment is economical for the large enterprise at high application rates.

Table 4: Manure Handling Costs for 19,749,000 litre Lagoon

	Rate	Own[1]	Custom[2]
Site	**L/ha**	**$/ha**	**$/ha**
Dixon	38138	94.69	79.75
Burr	69391	147.44	145.10
Dixon	76287	159.91	159.52
Burr	80055	167.63	167.40
Burr	134083	242.02	280.38
Dixon	152564	275.37	319.02
Burr	268156	484.01	560.73

1. All manure handling equipment is owned by the hog enterprise.
2. Custom application of the manure.

Cattle manure handling costs for the Dixon and Burr sites is presented in Table 5. Custom application is feasible at the lower rates and self applied at the higher rates.

Table 5: Cattle Manure Hauling Costs

Site	Rate	Own[1]	Custom[2]
	tonnes/ha	**$/ha**	**$/ha**
Dixon	9.7	82.29	29.01
Burr	18.3	74.75	73.97
Dixon	19.5	75.32	46.09
Burr	36.6	71.12	76.01
Dixon	39.1	71.79	80.27
Burr	73.2	88.10	140.11

1. All manure handling equipment is owned by the cattle enterprise.
2. Custom application of the manure.

Net Benefit and Marginal Rate of Return

The lowest cost method of handling manure from the large lagoon was used to arrive at the net benefit of hog manure for each manure treatment. Canola was grown in 1997 and Canadian Western Red Spring Wheat (CWRS) in 1998. The November 1997 street price was used for Canola and the October 1998-99 Pool Return Outlook for #1 CWRS was used for wheat less handling and freight to Humboldt. The revenue, net return and marginal rate of

return for each treatment at the Dixon hog manure site are presented in Table 6. The treatments are check, low rate injection at 30 cm spacing (1xI), medium rate injection (2xI), high rate injection (4xI), low rate injection at 60 cm spacing with sweeps (1xS), low rate injection at 60 cm spacing with spikes (1xN), low rate broadcast and incorporated (1xBI) and three rates of nitrogen 56, 112, 224 kg/ha (1xU, 2xU, 4xU) applied as urea. See Table 2 for rates of application of manure corresponding to the treatment descriptions. No cost is ascribed to the nutrients in the manure treatments but, it is included in the urea treatments. The 1xU treatment had the highest marginal rate of return (MRR) for 1997. The manure treatments producing the highest MRR for 1997 were the two 1xI and the 1xN with two of the 2xI (~76000 l/ha) being optimal. Over the two year trial the 1xI-0xI had the highest MRR as application of manure to spring wheat in 1998 did not produce an acceptable rate of return. The treatments, 1xI-0xI, 2xI-0xI, 4xI-0xI, where no manure was applied in 1998 had higher returns than the check plot. The 4xI-0xI treatment had the highest net return for 1998.

The revenue and cost of each treatment for the Burr hog manure site are presented in Table 7. A 1xI (~70000 l/ha) treatment had the highest net returns and MRR for 1997. The 1xS, 1xN and 1xBI treatments gave lower returns than the 1xI. The higher application rate of manure 4xI (~270000 l/ha) resulted in negative net returns due to crop damage. Manure and urea applications in 1998 resulted in lower returns than the check. The 2xI-0xI treatment gave the highest returns for 1998. The 1xI-0xI treatment had the highest MRR over the two years.

The treatments for the cattle manure trials were a check, low rate (1xBI), medium rate (2xBI), high rate (4xBI) all broadcast and incorporated, low rate broadcast with delayed incorporation (1xBD) and three rates of nitrogen 56, 112, 224 kg/ha(1xU, 2xU, 4xU). The revenue, net returns and marginal rate of return for each cattle manure treatment at the Dixon site are presented in Table 8. The 1xU treatment had the highest MRR for 1997. The 2xBI (~20 tonnes/ha) gave the highest return of the manure treatments. The 4xI-0xI treatment produced the highest return for 1998 with the 4xI-4xI trial having the highest MRR. Over the two years the two 2xBI-0xBI treatments had the highest MRR.

The revenue, net returns and marginal rate of return for each cattle manure treatment at the Burr site are presented in Table 9. The 1xBD (~18 tonnes/ha) treatment had the highest MRR for 1997 and the 2xI-2xI trial was the highest in 1998. The best net return at the Burr site was the 1xBD treatment for 1997 and the 4xI-0xI for 1998. Over the two years the 1xBD treatment resulted in the highest MRR.

Table 6: Dixon Hog Manure Revenue, Net Return and Marginal Rate of Return

	1997				1998			Two Year	
Treatment[1]	**Revenue**	**Cost[2]**	**Net**	**MRR[3]**	**Revenue**	**Cost[2]**	**Net**	**Net**	**MRR**
	$/ha	**$/ha**	**$/ha**	**%**	**$/ha**	**$/ha**	**$/ha**	**$/ha**	**%**
Check	226.82	-	226.82		52.97		52.97	279.79	
1xI-0xI	524.21	79.75	444.46	278%	76.19		76.19	520.64	302%
1xI-1xI	494.23	79.75	414.48	235%	113.33	77.38	35.95	450.42	109%
2xI-0xI	659.35	159.52	499.83	67%	81.30		81.30	581.14	76%
2xI-0xI	653.28	159.52	493.76	60%	81.90		81.90	575.66	69%
2xI-2xI	597.48	159.52	437.96	-9%	215.22	154.76	60.46	498.42	31%
4xI-0xI	601.60	275.37	326.23	-288%	190.70		190.70	516.93	-55%
4xI-4xI	611.38	275.37	336.01	-279%	247.01	267.20	-20.19	315.82	-80%
1xS-1xS	391.72	79.75	311.97	107%	154.75	77.38	77.37	389.34	70%
1xN-1xN	531.63	79.75	451.88	282%	143.09	77.38	65.71	517.58	151%
1xBI-1xBI	452.14	82.65	369.49	173%	102.97	80.53	22.44	391.93	69%
1xU-1xU	476.57	47.34	429.23	428%	140.71	47.34	93.37	427.29	156%
2xU-2xU	538.52	74.06	464.46	132%	167.85	74.06	93.79	410.13	-33%
4xU-4xU	625.17	127.54	497.63	62%	208.08	127.54	80.54	323.10	-81%

1. Treatments (RxA) by year are the rate x type of application where rate = 0 - no manure, 1 - low rate, 2 - medium rate and 4 - High rate. Application = I - injection @ 30 cm spacing, S -sweep @60 cm spacing, N - spike @60 cm spacing, BI -broadcast and incorporated, U - urea.
2. The cost of application by the least cost method for manure and the cost of banding urea with an airseeder plus the cost of the urea.
3. The MRR is the marginal rate of return for each treatment for 1997.
4. The marginal rate of return for calculated over the two years of the experiment.

Table 7: Burr Hog Manure Revenue, Net Returns and Marginal Rate of Return

	1997				1998			Two Year	
Treatment[1]	**Revenue**	**Cost[2]**	**Net**	**MRR[3]**	**Revenue**	**Cost[2]**	**Net**	**Net**	**MRR[4]**
	$/ha	**$/ha**	**$/ha**		**$/ha**	**$/ha**	**$/ha**	**$/ha**	
Check	169.74	-	169.74		94.40		94.40	264.14	
1xI-0xI	401.84	145.10	256.74	60%	107.85		107.85	364.59	69%
1xI-1xI	476.35	145.10	331.25	111%	159.51	77.38	82.13	413.38	67%
2xI-0xI	284.53	242.02	42.51	-298%	198.56		198.56	241.07	-127%
2xI-0xI	424.82	242.02	182.80	-153%	152.13		152.13	334.93	-31%
2xI-2xI	409.94	242.02	167.92	-169%	186.30	154.76	31.54	199.45	-123%
4xI-0xI	219.92	484.01	-264.09	-176%	192.25		192.25	-71.84	-129%
4xI-4xI	209.77	484.01	-274.24	-179%	179.75	267.20	-87.45	-361.69	-147%
1xS-1xS	280.56	167.40	113.16	-34%	150.70	77.38	73.32	186.49	-32%
1xN-1xN	302.64	167.40	135.24	-21%	180.35	77.38	102.97	238.20	-11%
1xBI-1xBI	313.84	161.08	152.76	-11%	98.68	80.53	18.15	170.92	-39%
1xU-1xU	154.26	47.34	85.58	-133%	142.97	47.34	95.63	107.87	-165%
2xU-2xU	224.87	74.06	128.75	-26%	149.99	74.06	75.93	78.62	-125%
4xU-4xU	162.06	127.54	10.98	-217%	143.92	127.54	16.38	-204.18	-184%

Table 8: Dixon Cattle Manure Revenue, Net Returns and Marginal Rate of Return

	1997				1998			Two Year	
Treatment[1]	**Revenu**	**Cost[2]**	**Net**	**MRR[3]**	**Revenue**	**Cost[2]**	**Net**	**Net**	**MRR**
	$/ha	**$/ha**	**$/ha**	**%**	**$/ha**	**$/ha**	**$/ha**	**$/ha**	**%**
Check	267.03	-	267.03		72.26	-	72.26	339.29	
1xBI-0xBI	299.26	29.01	270.25	11%	94.64		94.64	364.89	88%
1xBI-1xBI	322.42	29.01	293.41	91%	90.23	25.13	65.10	358.52	36%
2xBI-0xBI	380.55	46.09	334.46	240%	102.37		102.37	436.84	421%
2xBI-0xBI	360.05	46.09	313.96	120%	101.78		101.78	415.74	298%
2xBI-2xBI	302.49	46.09	256.40	-217%	119.04	38.35	80.69	337.09	-71%
4xBI-0xBI	379.80	80.27	299.53	-102%	132.37		132.37	431.91	-14%
4xBI-4xBI	381.94	80.27	301.67	-96%	179.39	64.77	114.62	416.29	-21%
1xBD-1xBD	238.62	29.01	209.61	-198%	99.16	25.13	74.03	283.64	-103%
1xU-1xU	464.84	47.34	417.50	318%	152.13	47.34	104.79	427.62	93%
2xU-2xU	473.76	74.06	399.70	-67%	182.37	74.06	108.31	359.89	-127%
4xU-4xU	484.14	127.544	356.60	-81%	200.94	127.5	73.40	174.92	-158%

1. Treatments (RxA) are the rate x type of application where rate = 0 - no manure, 1 - low rate, 2 - medium rate and 4 - High rate. Application is BI -broadcast and incorporated, BD - broadcast with delayed incorporation, U - urea.
2. The cost of application by the least cost method for manure and the cost of banding urea plus the cost of the urea.
3. The MRR is the marginal rate of return for each treatment for 1997.
4. The marginal rate of return calculated over the two years of the experiment.

Table 9: Burr Cattle Manure Revenue, Net Returns and Marginal Rate of Return

	1997				1998			Two year	
Treatment[1]	**Revenue**	**Cost[2]**	**Net**	**MRR**	**Revenue**	**Cost[2]**	**Net**	**Net**	**MRR**
	$/ha	**$/ha**	**$/ha**	**%**	**$/ha**	**$/ha**	**$/ha**	**$/ha**	**%**
Check	241.20	-	241.20		68.21			309.38	
1xBI-0xBI	313.88	43.97	269.91	65%	91.07		91.07	360.98	117%
1xBI-1xBI	278.84	43.97	234.87	-14%	97.97	25.13	72.84	307.71	-2%
2xBI-0xBI	344.84	76.01	268.83	-3%	108.33		108.3	377.15	50%
2xBI-0xBI	299.26	76.01	223.25	-146%	88.09		88.09	311.34	-155%
2xBI-2xBI	320.81	76.01	244.80	-78%	160.94	38.35	122.5	367.40	132%
4xBI-0xBI	394.50	140.11	254.39	-16%	127.02		127.0	381.40	7%
4xBI-4xBI	358.03	140.11	217.92	-54%	181.89	64.77	117.1	335.04	-36%
1xBD-1xBD	383.48	43.97	339.51	224%	112.49	25.13	87.36	426.87	170%
1xU-1xU	297.80	47.34	250.46	20%	129.52	47.34	82.18	237.96	-75%
2xU-2xU	252.90	74.06	178.84	-268%	180.11	74.06	106.0	136.77	-117%
4xU-4xU	203.21	127.54	75.67	-218%	166.42	127.50	38.88	-	-176%

1. Treatments (RxA) are the rate x type of application where rate = 0 - no manure, 1 - low rate, 2 - medium rate and 4 - High rate. Application is BI -broadcast and incorporated, BD - broadcast with delayed incorporation, U - urea.
2. The cost of application by the least cost method for manure and the cost of banding urea plus the cost of the urea.
3. The MRR is the marginal rate of return for each treatment for 1997.
4. The marginal rate of return calculated over the two years of the experiment.

Economic Hauling Distance

The net revenue for each treatment is calculated by subtracting the application costs from the gross revenue. The marginal revenue is then calculated by subtracting the net revenue of the check from each treatment. The economic hauling distance is then determined by dividing the marginal revenue by the cost of hauling. The hauling distance for treatments where no manure is applied in 1998 is calculated as the distance for 1997 plus the distance for 1998. The economic hauling distances for the two types of manure for the treatments with a positive marginal rate of return are presented in Tables 10 and 11 for hog and cattle manure, respectively. Swine manure has an economic hauling distance from 0 to 13.6 km at the Dixon site and 0 to 6.3 km at the Burr site. The low economic hauling distances at the Burr site are due to the lower observed crop response to applied nutrients as a result of the droughtier soil conditions.

Table 10: Economic Hauling Distance of Hog Manure (km)

	Treatment[1]	MR 1997[2]	Distance[3]	MR 1998[2]	Distance[3]
Site	**1997**	**$/ha**	**km**	**$/ha**	**km**
Dixon	**1xI-0xI**	187.70	12.2	23.21	13.6
	1xI-1xI	157.72	10.3	-39.76	
	2xI-0xI	286.33	9.3	28.33	10.2
	2xI-0xI	280.25	9.1	28.93	10.0
	2xI-2xI	224.45	7.3	19.44	.91
	4xI-0xI	119.39	2.1	137.73	4.2
	4xI-4xI	129.17	2.2	-53.76	
	1xS-1xS	55.21	3.85	1.67	.48
	1xN-1xN	195.12	12.6	-10.00	
	1xBI-1xBI	115.38	13.25	-51.18	
Burr	**1xI-0xI**	98.38	3.6	25.72	4.6
	1xI-1xI	172.89	6.3	-22.73	
	2xI-0xI	30.63	.2	70.00	2.0

1. Treatments (RxA) by year are the rate x type of application where rate = 0 - no manure, 1 - low rate, 2 - medium rate and 4 - High rate. Application = I - injection @ 30 cm spacing, S -sweep @60 cm spacing, N - spike @60 cm spacing, BI -broadcast and incorporated, U - urea.
2. MR is the revenue for each treatment less the revenue of the check.
3. Distance is calculated by dividing marginal revenue by the cost of hauling. The hauling distance for 1998 when no manure is applied is calculated as the distance for 1997 plus the distance for 1998.

Cattle manure has an economic hauling distance from 0 to 7.9 km at the Dixon site and 0 to 4.7 km at the Burr site. Generally, the positive economic return where no manure was applied in 1998 increased the economic hauling distance of the initial application for all sites.

Table 11: Economic Hauling Distance of Cattle Manure (km)

		MR 1997[2]	Distance[3]	MR 1998[2]	Distance[3]
Site	**Treatment[1]**	**$/ha**	**km**	**$/ha**	**km**
Dixon	**2xBI-0xBI**	46.33	4.8	30.12	7.9
	2xBI-0xBI	25.83	2.7	29.52	5.7
	4xBI-0xBI	52.23	2.7	60.12	5.8
	4xBI-4xBI	54.37	2.9	60.63	4.1
Burr	**1xBI-0xBI**	5.92	.72	22.86	3.3
	2xBI-0xBI	43.12	2.4	40.12	4.7
	2xBI-0xBI	-2.45		19.88	1.0
	2xBI-2xBI	19.10	1.1	51.16	7.0
	4xBI-0xBI	80.79	2.2	58.81	3.9
	4xBI-4xBI	44.33	1.3	67.17	4.6
	1xBD-1xBD	75.51	8.35	-7.06	

1. Treatments (RxA) by year are the rate x type of application where rate = 0 - no manure, 1 - low rate, 2 - medium rate and 4 - High rate. Application = I - injection, S -sweep, N - spike, BI -broadcast and incorporated, U - urea.
2. MR is the revenue for each treatment less the revenue of the check.
3. Distance is calculated by dividing marginal revenue by the cost of hauling. The hauling distance for 1998 when no manure is applied is calculated as the distance for 1997 plus the distance for 1998.

Summary and Conclusions

Optimal rates of application of manure, given the observed yield response in the field trials near Humboldt would maximize the profit where the livestock and grain operation act in collaboration. When the two enterprises are viewed separately the livestock operator will want to ensure rapid and timely removal of the manure using the highest rates to reduce the costs while the grain producer will want to maximize the expected profit. If the grain producer paid for the cost of hog manure application, then only the low to medium rates (40,000 to 80,000 l/ha) would be profitable with no manure application in the second year. Hog manure supplied at no cost to the grain producer maximized profits at 2xI (~76,000 l/ha) and at the 4xI (~152,000 l/ha) for the Dixon site for 1997 and 1998, respectively. At the Burr site the grain farmer would maximize profits at 1xI (~70,000 l/ha) in 1997 and 2xI (~74,000 l/ha) in 1998 if the manure was applied at no cost. Application of cattle manure at the Dixon site was profitable at the 2xBI (~20 tonnes/ha) rate for 1997 and at the 4xBI (~40 tonnes/ha) rate for 1998 if the farmer paid the application costs. Profit would be maximized with the 2xBI-0xBI treatment over the two years. If the manure was supplied at no cost then the 2xBI or 4xBI would be selected in 1997 and the 4xBI in 1998. Over the two years the 4xBI-4xBI would be the optimum if the manure was applied at no cost to the grain producer. A grain producer at the Burr cattle site would choose the 1xBD (~18 tonnes/ha) treatment for 1997 and the 2xBI (~36 tonnes/ha) treatment when paying the cost of application. Over the two years the 1xBD-1xBD would be the optimal strategy. The 4xBI would maximize profits in 1997 and 1998 if the manure was applied at no cost.

The positive marginal return of some of the treatments indicates that grain producers would be willing to pay to have manure hauled to gain the benefits.

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