Land Requirements for Livestock Operations in Manitoba

November 2019

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PROVINCIAL AUTHORITY

Manure is a by-product of livestock production and an excellent source of nutrients for plant growth. Most livestock operations recycle the nutrients in their manure as fertilizer for crop production. Manure is typically applied to meet the nitrogen (N) requirements of the crop. This often results in more phosphorus (P) being applied than the crop can remove and a build-up of soil test P. Unfortunately, increasing soil test P can result in increased soluble P being lost to surface water in runoff. In surface water, these nutrients accelerate the growth of unwanted plants and algae.

To be environmentally sustainable over the long-term, livestock operations need access to a sufficient quantity of land for the manure N and P. The optimal time to ensure there is enough land is prior to establishing or expanding a livestock operation. In Manitoba, this is achieved during Provincial Technical Review of livestock operations that are over 300 AU requesting Municipal Conditional Use Approval. Sufficient suitable land to implement an appropriate manure management plan is also required to obtain a permit to construct, modify or expand a manure storage facility or a confined livestock area (300 AU or greater) under the Livestock Manure and Mortalities Management Regulation (M.R. 42/98).

THE MANITOBA LAND CALCULATOR

The Manitoba Land Calculator is a user-friendly tool that estimates the amount of land for the medium to long-term management of manure N and P generated by livestock operations. It is intended for planning purposes. It does not calculate annual land requirements for manure management plans or manure application rates. The latter are established in manure management plans.

Output of the Manitoba Land Calculator

The basic concept behind the Manitoba Land Calculator is simple:

Acres Required	=	**Nutrients Excreted (lb)**	÷	**Nutrients in the Crop (lb/acre)**
A		**B**		**C**

A. Acres Required

Although there are extensive calculations and assumptions within the land calculator, users are only required to enter their livestock inventories, crop yields and respective acreages. From that, the calculator generates 3 acreages based on Government of Manitoba Policy:

1. Acres for Nitrogen (N) – The land required to balance the N in the manure after storage losses with the average N utilized by the crops over the course of a rotation.
2. Acres for Phosphorus (P_2O_5) – For lands in areas of high livestock density, the amount of land required to balance the P in the manure with crop P_2O_5 removal over the course of a rotation. For lands in areas of lower livestock density, the amount of land required to balance the P_2O_5 in the manure with twice crop P_2O_5 removal over the course of a rotation. For operations that have lands inside and outside of Hanover and/or La Broquerie, the acres for phosphorus is based on an average, weighted removal.

3. Phosphorus (P_2O_5) Balance – The land required to balance the P_2O_5 in the manure with crop P_2O_5 removal over the course of a rotation. Phosphorus balance is required for lands located in Hanover and/or La Broquerie

The land requirement is the greater of the acres required for N (1) or the acres required for P_2O_5 (2). Phosphorus balance is provided to give an indication of how much land may be required over the life of the operation to balance P_2O_5 excretion with crop P_2O_5 removal, based on current practices.

P_2O_5 is the nomenclature for P used by the fertilizer industry.
$P_2O_5 = 2.29 \times P$

B. Nutrients Excreted

The nutrients excreted by the livestock are calculated for the livestock inventory entered by the user, as follows:

Nutrients excreted (lb) = Nutrients fed (lb) – Nutrients retained (lb)

The total amount of nutrients fed to the livestock are based on typical Manitoba feeding practices (Appendix A). The nutrients retained by the livestock and livestock products are based on typical Manitoba weight gains and productivities for the various production systems (Appendix A) and literature values for the N and P composition of whole animals, eggs and milk (Appendix B).

All of the P that is excreted is assumed to end up in the manure, whereas the total amount of N excreted is adjusted for gaseous N losses (primarily due to volatilization) during collection, handling and storage (Appendix C). The calculation also assumes that any feed that does not get consumed ends up in the manure.

C. Nutrients in the Crops

The nutrients utilized (for N) and removed (for P) by crops are calculated for the crop rotation specified by the user. International Plant Nutrition Institute (IPNI) nutrient concentrations for Western Canadian crops are used (Appendix D) as well as long-term yield averages for the region that reflect realistic yield averages for the farm. Long-term yield averages are available through the Manitoba Agricultural Services Corporation (MASC) website.

Nutrients in the crop (lb/acre) = Nutrient concentration x Yield

DAIRY EXAMPLE – 300 Mature Cows (600 Animal Units) with liquid manure stored in a steel tank, located in the RM of Grey

Data Entry

For this example, the user must enter the total number of mature cows (300 lactating and dry) in the Dairy tab of the land calculator and indicate via a drop down menu the type of manure storage.

In the Crop Rotation tab, the user must also enter long-term MASC yields and their respective acreages for each of the crops in a typical rotation. MASC yields can be obtained on the Manitoba Agricultural Services Corporation website.

Internal Assumptions and Calculations

Livestock Inventory

For a typical dairy operation in Manitoba, for every 100 mature cows there are approximately 56 lactating mature cows, 24 lactating first cow heifers, 20 dry, 35 replacements greater than 13 months of age, 20 replacements between 4 and 13 months and 8 calves between 0 and 3 months.

For an operation with 300 mature cows, the land calculator assumes 168 mature lactating cows, 72 lactating first calf heifers, 60 dry cows and 189 replacement calves and heifers. Typical weights have been determined for each of these categories in order to get a reasonable estimate of weight gain or loss and nutrient retention on the farm.

Category	Livestock Inventory Places	Weight in kg	Weight out kg	Ave Weight kg	Gain kg
	a	*b*	*c*	*d*	*e*
Lactating Mature Cows	168	669	653	661	-16
Lactating First Calf Heifer	72	590	669	629	40
Dry Cows	60	653	710	682	57
Calves, 0-3 months	24	41	125	83	84
Calves, 4-13 months	60	125	367	246	243
Replacements, >13 months	105	367	590	479	222

$e = (c-b)$

Nutrients Fed

The total nutrients fed to the cows is based on the total dry matter weight of the feed provided to the cows and average dry matter protein and P levels in the feed.

Category	Days on Feed per Cycle	DM Feeding Rate % BW/day	Feed Protein % DM	N Fed kg	Feed P % DM	P Fed kg
	f	g	h	i	j	k
Lactating Mature Cows	348	3.7	18.3	245.9	0.48	40.3
Lactating First Calf Heifer	348	3.6	18.3	230.9	0.48	37.8
Dry Cows	86	2.2	11.5	23.7	0.22	2.8
Calves, 0-3 months	90	2.0	22.5	5.4	0.66	1.0
Calves, 4-13 months	270	2.0	12.6	26.8	0.33	4.4
Replacements, >13 months	330	2.2	10.7	59.5	0.24	8.3

i = (d x g/100 x h/100 x f)/6.25
k = d x g/100 x j/100 x f

Nutrients Retained

The nutrients retained by the animals in weight gain are calculated by multiplying weight gain of the animals by the whole body N and P composition of the animals. The N and P compositions of the cows are based on literature values from studies where the entire animal was analyzed.

Category	Weight Gain kg	Body N g/kg	Body P g/kg	N retained per animal kg	P retained per animal kg
	e	l	m	n	o
Lactating Mature Cows	-16	27	8.3	-0.429	-0.132
Lactating First Calf Heifer	40	27	8.3	1.072	0.329
Dry Cows	57	27	8.3	1.531	0.471
Calves, 0-3 months	84	27	8.3	2.266	0.696
Calves, 4-13 months	243	27	8.3	6.552	2.014
Replacements,>13 mo	222	27	8.3	6.001	1.845

n = (e x l)/1000
o = (e x m)/1000

The nutrients exported in the milk are estimated using average daily milk production rates for Manitoba dairy farms and the nutrient composition of whole cow's milk.

Category	Ave Milk Production kg/day	Protein Content % DM	P Content %	N retained in milk kg	P retained in milk kg
	p	q	r	s	t
Lactating Mature Cows	31	3.3%	0.09	56.961	9.709
Lactating First Calf Heifer	28	3.3%	0.09	51.448	8.770

s = (p x f x q/100)/6.25
t = p x f x r/100

Nutrients Excreted

The nutrients excreted per animal can be calculated by subtracting the nutrients retained in the cows and exported in the milk from the total nutrients fed. This can then be scaled up for the year and summed up for the entire herd.

Nitrogen Excretion

Nitrogen						
Category	Livestock Inventory Places	Cycles per Year	N Fed kg/cycle	N Retained kg/cycle	N Excreted	
					Per Animal kg/cycle	By the Herd kg/year
	a	u	i	w	y	z
Lactating Mature Cows	168	1.049	245.9	56.53	189.3	33364
Lactating First Calf Heifer	72	1.049	230.9	52.52	178.3	13468
Dry Cows	60	4.244	23.7	1.53	22.2	5652
Calves, 0-3 months	24	4.056	5.4	2.27	3.1	302
Calves, 4-13 months	60	1.352	26.8	6.55	20.2	1641
Replacements,>13 mo	105	1.106	59.5	6.00	53.5	6211
Total N Excreted by the Herd (kg N /year)						60638
Total N Excreted by the Herd (lb N /year)						133683

u = cycles per year. Assumes that all livestock places are full 365 days per year for a dairy operation.

w = n + s

y = i – w

z = a x u x y

kg x 2.205 = lb

Accounting for Nitrogen Losses

The total amount of N excreted by the livestock should be adjusted for N volatilization losses in the barn and storage. (Appendix C).

Storage Type	Volatilization loss	Total N Excreted (lb)	N in the Manure (lb)
Liquid Uncovered Steel/Concrete	20%	133683	106946

Phosphorus Excretion

Phosphorus						
Category	Livestock Inventory Places	Cycles per Year	P Fed kg/cycle	P Retained kg/cycle	P Excreted	
					Per Animal kg/cycle	By the Herd kg/year
	a	u	k	ww	yy	zz
Lactating Mature Cows	168	1.049	40.3	9.58	30.73	5415
Lactating First Calf Heifer	72	1.049	37.8	9.10	28.75	2171
Dry Cows	60	4.244	2.8	0.47	2.37	603
Calves, 0-3 months	24	4.056	1.0	0.70	0.29	28
Calves, 4-13 months	60	1.352	4.4	2.01	2.37	192
Replacements,>13 mo	105	1.106	8.3	1.85	6.49	754
Total P Excreted by the Herd (kg P /year)						9163
Total P_2O_5 Excreted by the Herd (kg P_2O_5 /year)						20983
Total P_2O_5 Excreted by the Herd (lb P_2O_5 /year)						46259

ww = o + t

yy = k – ww

z = a x u x yy
P x 2.29 = P_2O_5
kg x 2.205 = lb

Crop Nutrient Utilization and Removal

Crop Nitrogen Utilization

Assuming a total land base of 1200 acres with a crop rotation of alfalfa, silage corn, oats and soybeans with the following acres, yields and N concentrations, the average N uptake per acre is:

Crop	N Content	Yield	Acres	Uptake lb N
	a	b	c	d
Alfalfa	58 lb N/ton	3 tons/acre	480	83,520
Corn Silage	31.2 lb N/ton	4 dry tons/acre	480	59,904
Oats	1.07 lb/bu	110 bu/acre	160	18,832
Soybeans	5.2 lb/bu	34 bu/acre	80	14,144
		Total	1200	176,400
Average N Uptake per Acre				
147 lb N/acre				

d = a x b x c
Average N Uptake per Acre = 176,400 lb N ÷ 1200 acres = 147 lb N/acre

Corn silage yields must be converted to dry weights in the land calculator. An 11.5 ton/acre corn silage yield at 65% moisture is equivalent to 4.0 dry ton/acre, as follows:
11.5 ton/acre x (1 - 0.65) = 4.0 ton/acre

Crop Phosphorus Removal

Using the same acreage, rotation and yields, the average crop P_2O_5 removal per acre is:

Crop	P Content	Yield	Acres	Removal lb P_2O_5
	e	b	c	f
Alfalfa	13.8 P_2O_5/ton	3 tons/acre	480	19,872
Corn Silage	12.7 P_2O_5/ton	4 dry tons/acre	480	24,384
Oats	0.26 P_2O_5/bu	110 bu/acre	160	4,576
Soybeans	0.84 P_2O_5/bu	34 bu/acre	80	2,285
		Total	1200	51,117
Average P_2O_5 Removal per Acre				
42.6 lb P_2O_5 /acre				

f = e x b x c
Average P_2O_5 removal per acre = 51,117 lb P_2O_5 ÷ 1200 acres = 42.6 lb P_2O_5 /acre

Acres Required

Nitrogen Land Requirement

If the total N excretion after volatilization losses is 106,946 lb N and the N removal is 147 lb/acre, then the N land requirement is:

106,946 lb N ÷ 147 lb/acre = 728 acres.

Phosphorus Land Requirements

In this example, all of the lands are located in the RM of Grey. Therefore, if the total P_2O_5 excreted is 46,362 lb P_2O_5 and the P land requirement is based on twice crop P_2O_5 removal over the course of a rotation, the P land requirement is:

46,259 lbs P_2O_5 excreted ÷ (2 x 42.6 lb P_2O_5 removed by the crops) = 543 acres.

Phosphorus Balance

Based on current practices, the number of acres required to balance all of the manure P_2O_5 with crop P_2O_5 removal over the life of the operation is:

46,259 lbs P_2O_5 excreted ÷ 42.6 lb P_2O_5 removed by the crops = 1086 acres

Land Requirement Summary

Since the N land requirement exceeds the P land requirement in this example, this operation would be required to demonstrate access to 728 acres of suitable land to satisfy Provincial Technical review or when seeking a permit to construct a manure storage facility. The actual acreage needed in any given year would be established in the manure management plan. Over the long-term, the operation may require additional acres to balance phosphorus excretion by the livestock with crop phosphorus removal.

Appendix A – Default Livestock Production Values in the Manitoba Land Calculator

Default Production Values for Pigs

	Livestock Inventory for a 100 sow herd	Weight In (kg)	Weight Out (kg)	Feed consumed (kg/day)	Days on Feed per cycle	Cycles per year	Protein (%, as fed)	P (%, as fed)
Gestating Sow	84	203	286	2.3	121	3	14	0.53
Nursing Sow	16	244	244	6.5	21	15.2	20	0.63
Nursing Litter	16	1.4	6.2	0	21	15.2	n/a	n/a
Live Cull Sow	2	286	286	2.3	14	26.1	14	0.46
Bred Gilt	16	154	203	2.3	121	3	14	0.53
Gilts (purchased)	4	127	154	3.2	28	13	16	0.46
Boars (purchased)	4	122	299	2.5	365	1	14	0.46
Weanlings	402	6.2	28	0.7	52	6.9	20	0.64
Grower/Finisher	861	28	127	2.8	112	3	16	0.46

Default Production Values for Beef

	Livestock Inventory for a 100 cow herd	Weight In (kg)	Weight Out (kg)	Feed consumed per animal per day (% bw)	Days on Feed per cycle	Number of cycles per year	Protein (%, as fed)	P (%, as fed)
Mature Cows > 2 years old	85	624	624	2.5	365	1	10	0.19
Bred Heifer 14 mo – 2 yr	15	420	561	2.5	280	1	10	0.19
Replacement Heifer 1 mo – 14 mo	15	264	420	2.5	225	1	11	0.22
Unweaned Calf 0 – 7 mo	90	39	264	2.5	210	1	11	0.22
Bulls	4	953	998	2.5	365	1	10	0.19
Feedlot cattle – long keep	n/a	264	590	2.1	240	1	12	0.33
Feedlot cattle – short keep	n/a	442	590	2.1	116	1	12	0.33
Backgrounders – pasture	n/a	360	442	2.3	105	1	10	0.19
Backgrounders - confined	n/a	227	360	2.7	180	1	11	0.25

Default Production Values for Dairy

	Livestock Inventory for a 100 cow herd	Weight In (kg)	Weight Out (kg)	Feed consumed per animal per day (% bw)	Days on feed per cycle	Number of cycles per year[1]	Protein (%, as fed)	P (%, as fed)
Lactating Mature Cows	56	669	653	3.7	348	1.049	18.3	0.48
Lactating First Calf Heifers	24	590	669	3.6	348	1.049	18.3	0.48
Dry Cows	20	653	710	2.2	86	4.244	11.5	0.22
Calves 0-3 months	8	41	125	2.0	90	4.056	22.5	0.66
Calves 4-13 months	20	125	367	2.0	270	1.352	12.6	0.33
Replacements >13 months	35	367	590	2.2	330	1.106	10.7	0.24

[1] The number of cycles per year has been set to keep the barn at capacity for the year.

Default Production Values for Poultry

		Weight In (kg)	Weight Out (kg)	Feed consumed per bird per cycle (kg)	Days on feed per cycle	Number of cycles per year	Protein (%, as fed)	P (%, as fed)
Meat Chickens	Light Broilers	0.043	1.8	2.61	30	7	21.1	0.54
	Broilers	0.043	2.275	3.48	35	7	20.6	0.54
	Broiler Breeder Pullets	0.04	2.975	11.60	168	2	15.22	0.55
	Broiler Breeder Hens	2.975	3.85	38.7	245	1	14.03	0.51
Eggs White	White Layer Pullets	0.04	1.355	5.65	130	2	16.0	0.57
	White Layer Hens	1.355	1.875	39.39	357	1	15.0	0.52
	White Breeder Pullets	0.04	1.240	5.65	130	2	16.0	0.57
	White Breeder Hens	1.240	1.670	37.10	351	1	18.25	0.63
Eggs Brown	Brown Layer Pullets	0.04	1.630	5.65	130	2	16.0	0.57
	Brown Layer Hens	1.630	2.025	41.77	357	1	15.0	0.52
	Brown Breeder Pullets	0.04	1.407	5.65	130	2	16.0	0.57
	Brown Breeder Hens	1.407	1.950	37.10	351	1	18.25	0.63
Meat Turkeys	Broiler Turkeys	0.07	4.95	9.40	63	5	23.0	0.75
	Hen Turkeys (0-11 wk)	0.07	6.65	13.43	77	4	23.0	0.78
	Heavy Hens (0-11 wk)	0.07	9.75	22.30	98	3	21.0	0.70
	Toms (0-14 wk)	0.07	13.00	28.05	98	3	21.0	0.73

Turkey Breeders	Hen Growers (0-30 wk)	0.07	12.90	61.85	210	1	12.0	0.73
	Hens (31-end of lay)	12.90	12.40	61.62	252	1	18.0	0.70
	Tom Growers (0-17 wk)	0.07	15.77	35.60	119	1	18.0	0.73
	Tom Growers (17-30 wk)	15.77	25.00	56.88	91	1	11.0	0.73
	Toms (31-end of lay)	25.00	28.18	157.50	252	1	14.0	0.76

Appendix B – Nitrogen and Phosphorus Composition of Livestock and Livestock Products

		Nitrogen (g/kg)		Phosphorus (g/kg)
Sows		26		5.4
Fetuses		26		6.0
Litters		26		5.7
Weanlings Gilts, Grower/Finishers, Boars		26		5.3
Beef cows		26		7.1
Dairy Cows		27		8.3
Broilers		26		4.0
Layer Pullets		35		5.6
Layer Hens		30		5.6
Turkeys		30		6.6
Milk		Production (kg/day) [17]		
Lactating Mature Cows		31		
Lactating First Calf Heifers		28		
		Protein (%)		P (%)
		3.3		0.09
Eggs		Eggs per bird per cycle	N (%)	P (%)
Meat Chickens		153	1.16	0.11
Layers	White Hens	330	1.19	0.09
	Brown Hens	320		
	Breeders	270		
Turkeys		118	1.7	0.21

Appendix C – Total N Adjustments for Various Storage Types and Management Practices

Storage	Total N Decrease (%)
In-Barn Losses Only	10
Liquid Covered	10
Liquid Uncovered Steel/Concrete	20
Solid Manure Shed	20
Manure Pack (No Field Storage)	20
Mole Hill	30
Liquid Uncovered Earthen	30
Field Storage	40
Compost	40
Mechanically Dried	40
Deposited on Pasture	40

Appendix D – Nitrogen and Phosphorus Concentrations in Western Canadian Crops

	Removal		Uptake	Units
	P_2O_5	N	N	
Alfalfa	13.8	58	58	lb/ton
Barley Grain	0.42	0.97	1.39	lb/bu
Barley Silage	11.8	34.4	34.4	lb/ton
Corn Grain	0.44	0.97	1.53	lb/bu
Corn Silage	12.7	31.2	31.2	lb/ton
Dry Edible Beans	1.39	4.17		lb/cwt
Fababeans	1.79	5.02	8.4	lb/cwt
Flax	0.65	2.13	2.88	lb/bu
Grass Hay	10	34.2	34.2	lb/ton
Lentils	1.03	3.39	5.08	lb/cwt
Oats	0.26	0.62	1.07	lb/bu
Pasture (grazed)	10	34.2	34.2	lb/ton
Peas	0.69	2.34	3.06	lb/bu
Potatoes	0.09	0.32	0.57	lb/cwt
Rye	0.45	1.06	1.67	lb/bu
Soybeans	0.84	3.87	5.2	lb/bu
Sunflower	1.1	2.8		lb/bu
Wheat - Spring	0.59	1.5	2.11	lb/bu
Wheat - Winter	0.51	1.04	1.35	lb/bu