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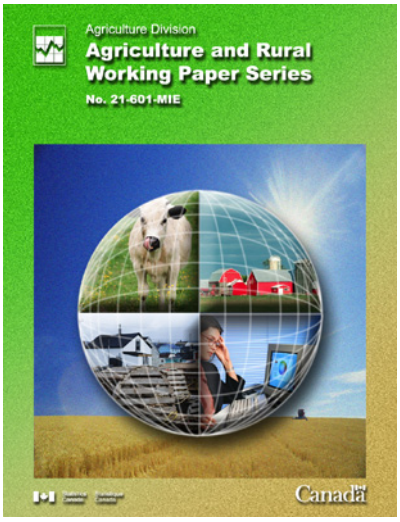
Research Paper

A Geographical Profile of Manure Production in Canada, 2001



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Note of appreciation

Canada owes the success of its statistical system to a long standing partnership between Statistics Canada, the citizens of Canada, its businesses, governments and other institutions. Accurate and timely statistical information could not be produced without their continued cooperation and goodwill.

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Introduction

The objective of this study was to estimate and map livestock manure production by the environmental geography unit known as the Sub-Sub-Drainage Area (SSDA) in 2001 and to calculate the change in manure production over the 1981-2001 period. The total amount of manure produced was estimated for each SSDA along with the production of nitrogen and phosphorus, which are two key elements found in manure.

In this study, the estimates of manure production in each SSDA are normalized by their respective total SSDA land area. This normalization is necessary to allow comparison of manure production totals across drainage areas of different sizes. The resulting estimates provide measurements that are comparable across different regions or over time.

Measuring the balance between the supply and utilization of manure nutrients and assessing the potential environmental impacts of manure are not in scope for this article. Further analysis would be required to link the production of manure with air, water and soil quality because many factors – such as soil type, climate, precipitation, topography, quantity of manure applied onto land and management practices – influence the effect of manure on the environment. Such analysis would also need to account for the contribution of other human activities such as industrial and municipal waste water discharge as well as other farm activities such as the application of chemical fertilizers. Water quality problems result from a number of factors, including the quantity of manure produced.

The geographic observation unit: the sub-sub-drainage area

The geographic unit used to present the data in this report is the sub-sub-drainage area (SSDA). River basins, drainage basins, basins, and watersheds are used synonymously to describe surface drainage catchment areas. The hierarchy of drainage areas includes ocean drainage basins which receive water from major river basins which in turn receive water from sub-drainage areas and sub-sub-drainage areas. There are 978 SSDAs in Canada and, in 2001, livestock farming activities were practiced in fewer than 400 SSDAs. The analysis presented in this report refers to only those SSDA with livestock farming activities.

The use of drainage areas is valuable for analysis since they reflect the fixed physical features of the land rather than changing political or administrative boundaries. The environmental impacts of human activities transcend political and administrative boundaries and an analysis using drainage area framework can be viewed as more relevant from an environmental perspective. For example, manure produced in one part of a basin can impact other areas of the same basin, whether that area is agricultural, urban or has another use. The drainage area framework is particularly important in this research because of the relationship between manure and water quality issues. The precision of the sub-sub-drainage area level also provides valuable localized information.

A previous study[1] estimated manure production in Canada for the 1996 reference year. However, results cannot be readily compared because of differences in methodology and changes to the SSDA framework. Therefore, care should be taken when comparing 1996 numbers from the earlier publication with the 2001 numbers in this study.

Drainage area boundaries for this publication are based on the boundaries defined in the Canadian digital drainage area framework, which is available for free on Natural Resources Canada's Geogratis website (*www.geogratis.cgdi.gc.ca*).

[1] Statistics Canada. 2001. *A Geographical Profile of Manure Production in Canada*, Catalogue no. 16F0025XIB (http://www.statcan.ca:8096/bsolc/english/bsolc?catno=16F0025XIB)

Manure and the environment

Livestock manure contains a variety of elements including nitrogen, phosphorus, potassium and various types of bacteria that can, in certain conditions, impact on the environment. The production of livestock manure has both environmental benefits and drawbacks. Although manure is a valuable fertilizer for crop production, it can also become a source of pollution if not managed properly. Some crops can absorb adequate nutrients from manure and natural sources without additional commercial fertilizers. In addition, incorporating the organic matter from manure into the soil can substantially reduce the risk of soil erosion and enhance the water retention capacity of the soil.

Nitrogen

Nitrogen is found naturally in air, water and soil. It is continually cycled through the environment by a number of processes such as nitrogen fixation, nitrogen assimilation, ammonification, nitrification, and denitrification. As part of this cycle, nitrogen can be chemically transformed into nitrate, nitrite, ammonia or organic components. These various forms of nitrogen have different impacts on the environment and their occurrence in manure is dependent on a variety of conditions including type of manure storage, duration of manure storage and method of land application. The nitrate form of nitrogen is of particular concern for its potential to compromise drinking water that can lead to infantile methaemoglobinaemia (“blue-baby” syndrome). Adults who consume nitrate-contaminated water over an extended period of time could experience compromised kidney or spleen function.

Phosphorus

Along with nitrogen, phosphorus is one of the major nutrients found in manure. However, if manure is applied improperly to agricultural land, some forms of these nutrients can run off into local streams, lakes and other surface water bodies. An overabundance of nutrients can foster excessive plant growth (e.g., algae) in water bodies. When these plants die, their decomposition removes dissolved oxygen from the water, thus making that water uninhabitable for fish and other forms of aquatic life. In terms of reducing or preventing excessive plant growth, controlling the build-up of phosphorus into soil which could eventually run off into water is often considered more effective than controlling nitrogen.

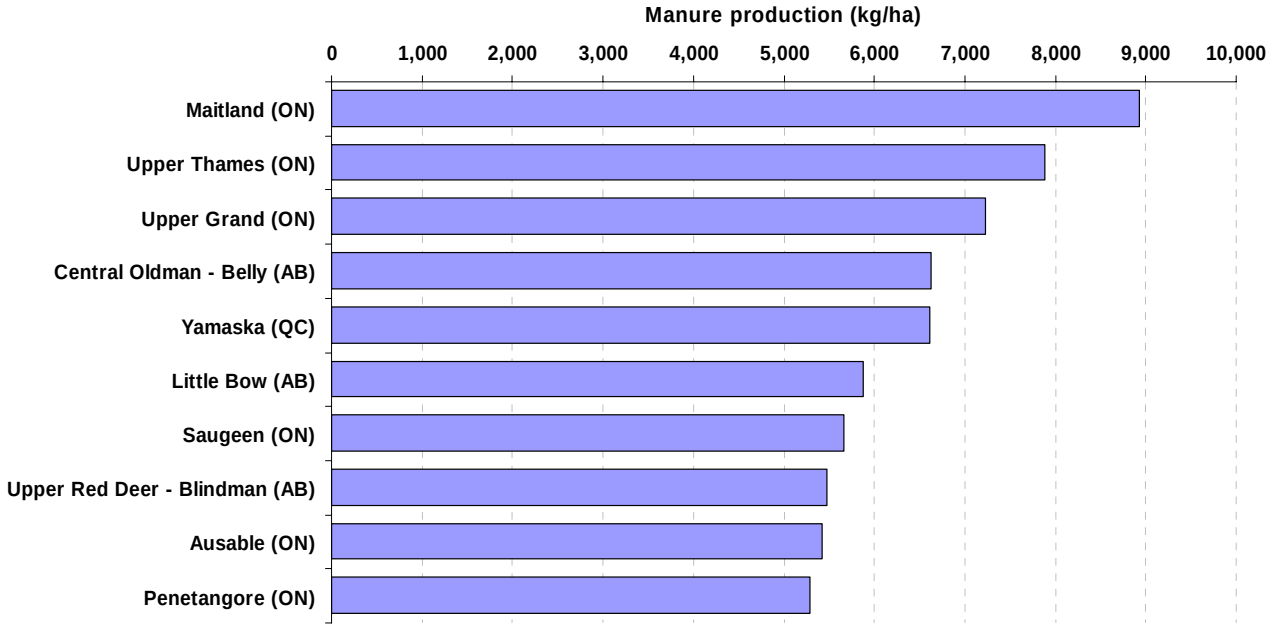
Livestock manure production

In 2001, Canadian livestock produced an estimated 177.5 million tonnes of manure. Cattle accounted for 86.2% of total livestock manure production, of which 36.3% was produced by beef cows, 13.5% by milk cows, 12.6% by calves, 12.5% by heifers, 9.2% by steers and 2.2% by bulls. Hogs produced 8.3% of livestock manure while poultry produced 2.7%, followed by horses (2.2%), and sheep and goats (0.6%).

The average production of manure per SSDA was calculated at 890 kilograms per hectare (kg/ha). However, the median was much lower at 570 kg/ha, meaning that half of the SSDAs had production of less than 570 kg/ha. Although results ranged from 0 kg/ha to 8,927 kg/ha, the bulk of manure production was concentrated in a few SSDAs. For example, the ten SSDAs with the largest manure production, when combined, accounted for 15.1% of total manure production. Manure production was 4,000 kg/ha or over (i.e., the highest production category) in 17 SSDAs (Maps 1a and 1b). These 17 SSDAs accounted for 21.6% of total manure production.

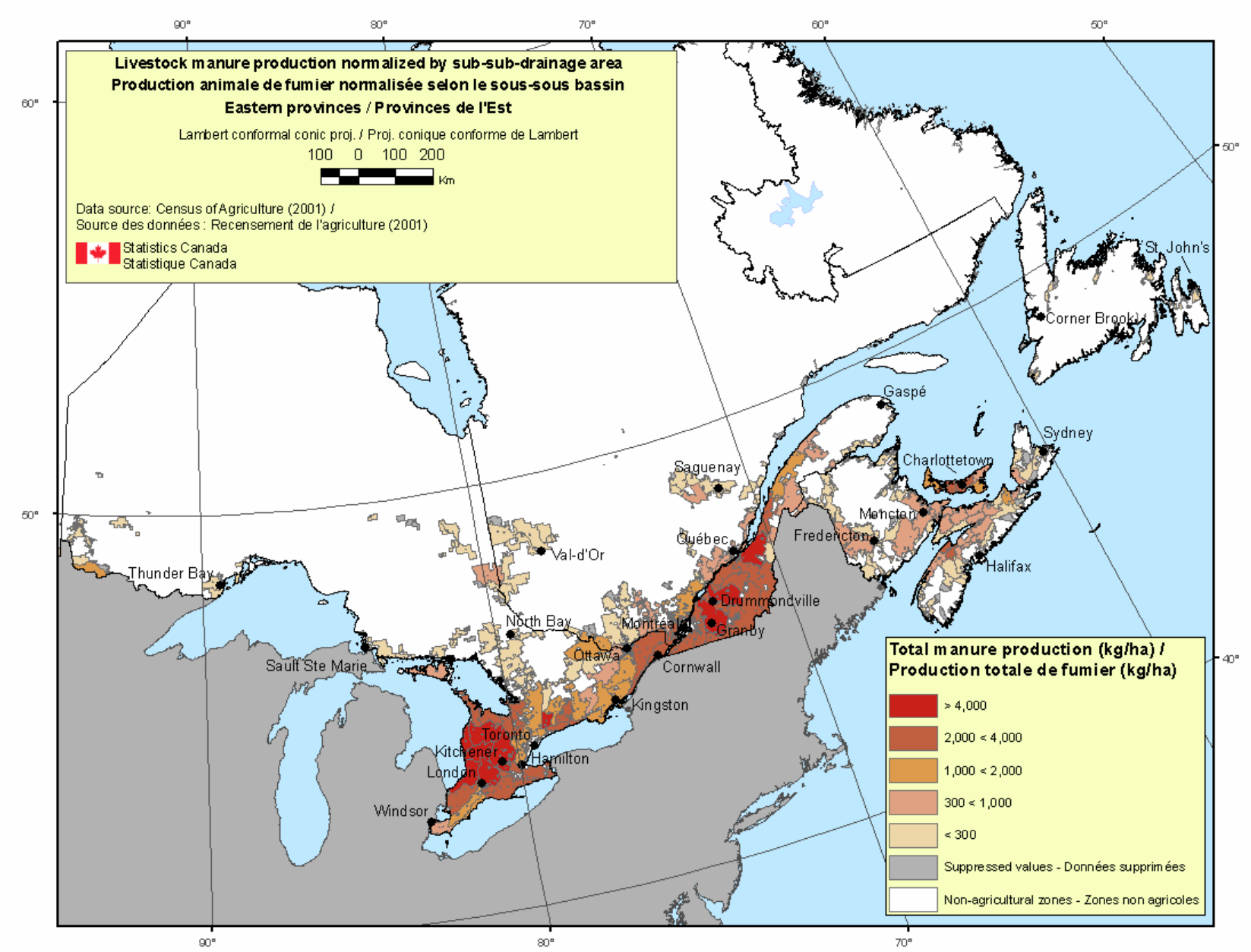
The livestock in Ontario's Maitland SSDA produced the most manure per hectare, with 8,927 kg/ha (Figure 1). The Upper Thames SSDA, also in Ontario, was the second highest producing SSDA with 7,885 kg/ha, about 10% less than the Maitland SSDA. Not only was Ontario home to the three largest manure-producing SSDAs in 2001 (Appendix B), it also had more SSDAs with significant production of manure than any other province. Of the ten SSDAs with the highest production of manure, six were located in southwestern Ontario.

Figure 1: Ten sub-sub-drainage areas with the highest manure production, 2001

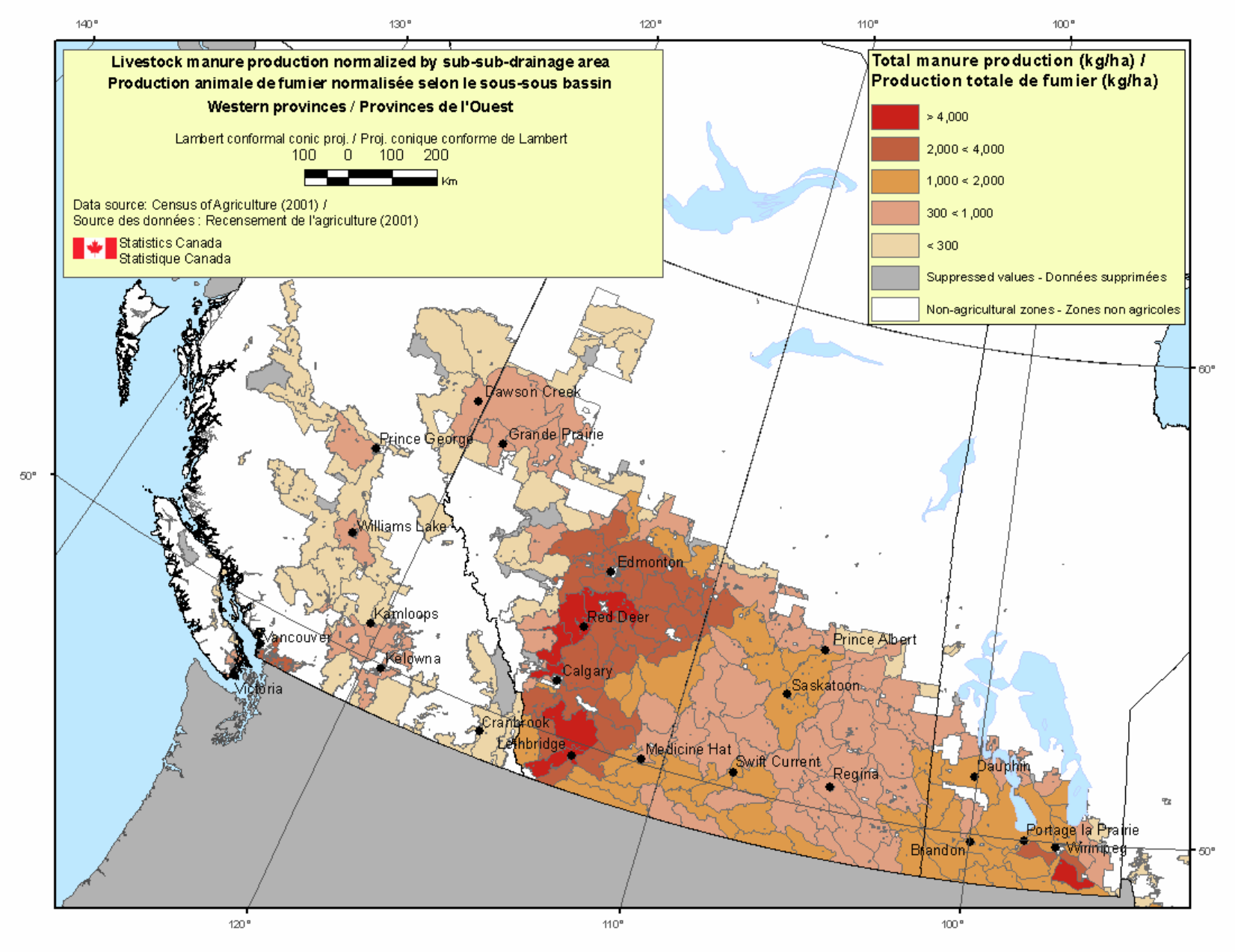


Sources: Statistics Canada, derived from the 2001 Census of Agriculture.

Map 1a: Livestock manure production by sub-sub-drainage area, Eastern Canada, 2001



Map 1b: Livestock manure production by sub-sub-drainage area, Western Canada, 2001



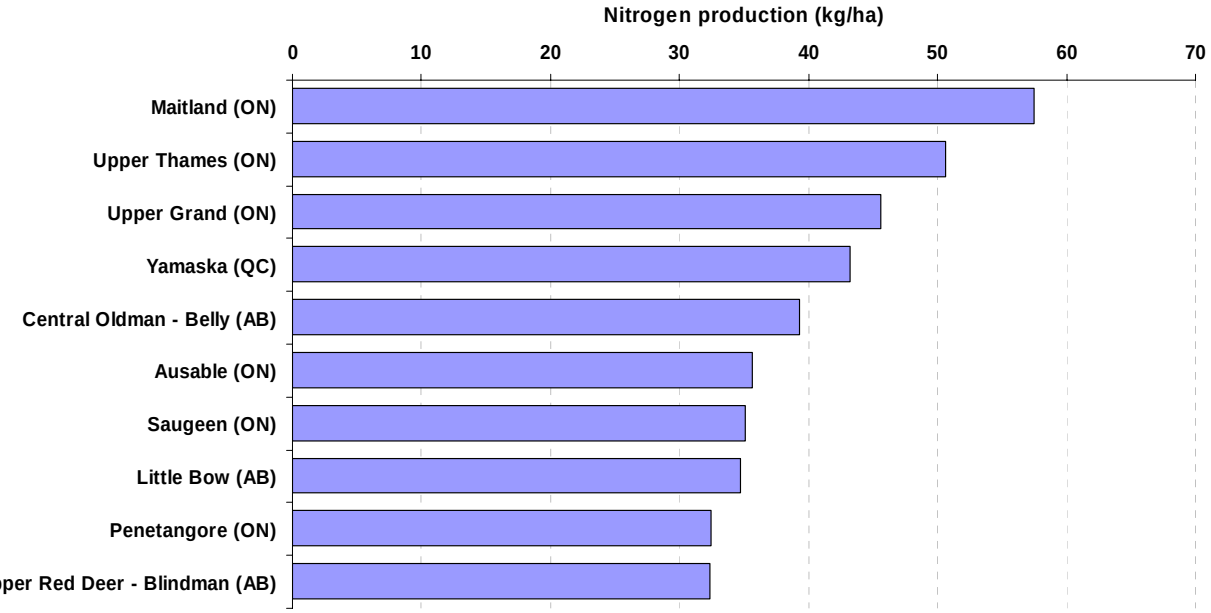
Maps 1a and 1b display the distribution of livestock manure production normalized by SSDA in 2001. Manure production was higher than 2,000 kg/ha (i.e., the top two production categories that were defined using natural breaks) in five regional clusters. These clusters were located in central and southern Alberta, southern Manitoba, southern Ontario, southeastern Quebec and Prince Edward Island. Beyond these clusters, there were two other individual SSDAs producing more than 2,000 kg/ha, one located in the lower Fraser River area in southern British Columbia and one in the Annapolis area of Nova Scotia.

Nitrogen production in livestock manure

In 2001, Canadian livestock produced over one million tonnes of nitrogen in manure. Cattle manure contained 82.2% of total nitrogen production, of which 35.0% was produced by beef cows, 11.9% by milk cows, 12.2% by calves, 12.0% by heifers, 8.8% by steers and 2.2% by bulls. Nitrogen production by other livestock was 9.8% by poultry, 8.9% by hogs, 2.1% by horses and 1% by goats and sheep.

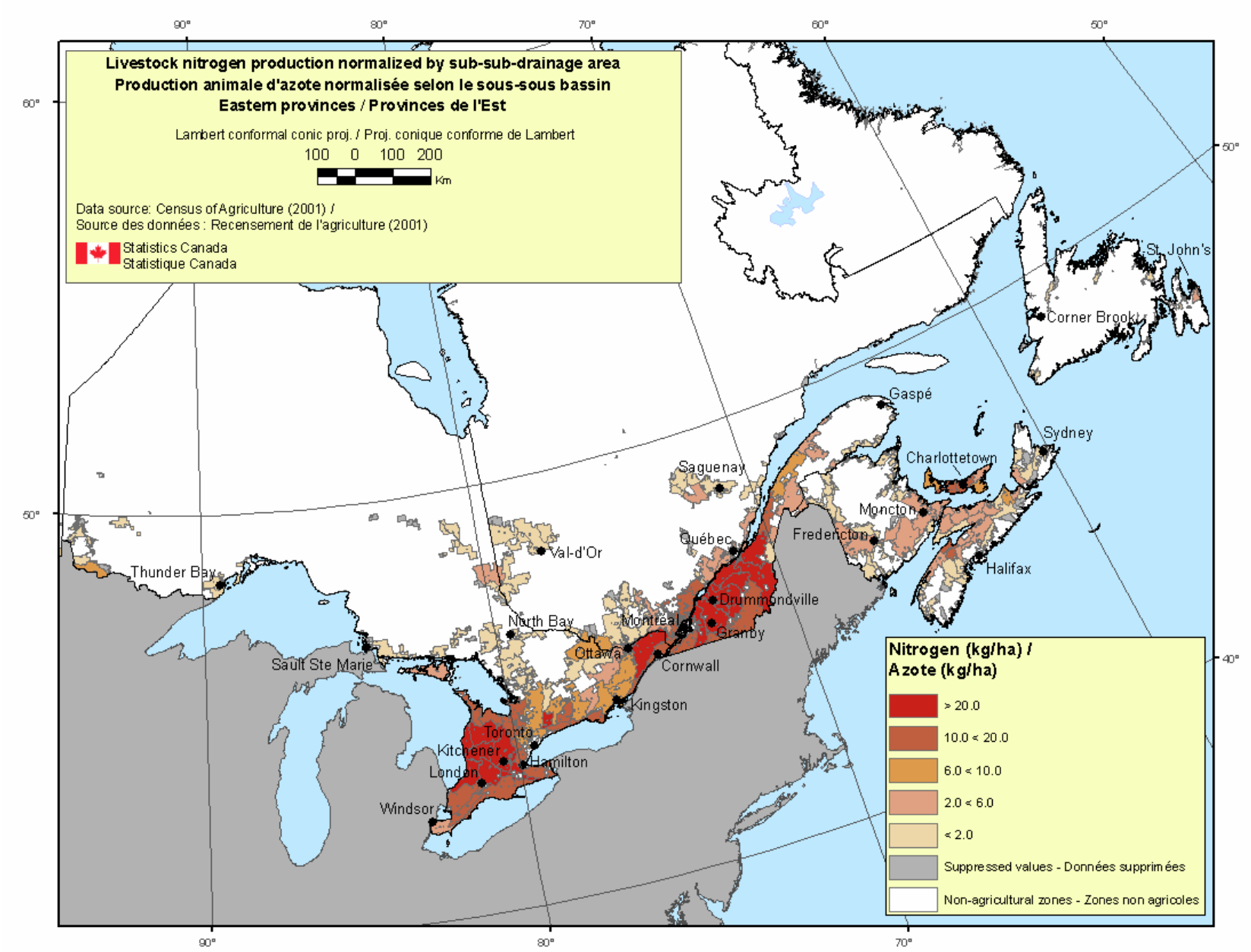
The average amount of nitrogen in manure produced by SSDA was 5.4 kg/ha. The median was 3.5 kg/ha. Results ranged from 0 to 57.5 kg/ha. Similar to the pattern already established in manure estimates, the bulk of nitrogen production is concentrated in a few SSDAs. The ten SSDAs with the highest nitrogen production, when combined, accounted for 15.4% of total nitrogen production. Nitrogen production was 20 kg/ha or over (i.e., the highest production category) in 34 SSDAs (Maps 2a and 2b). These 34 SSDAs accounted for 36.5% of total nitrogen production.

Figure 2: Ten sub-sub-drainage areas with the highest nitrogen production, 2001

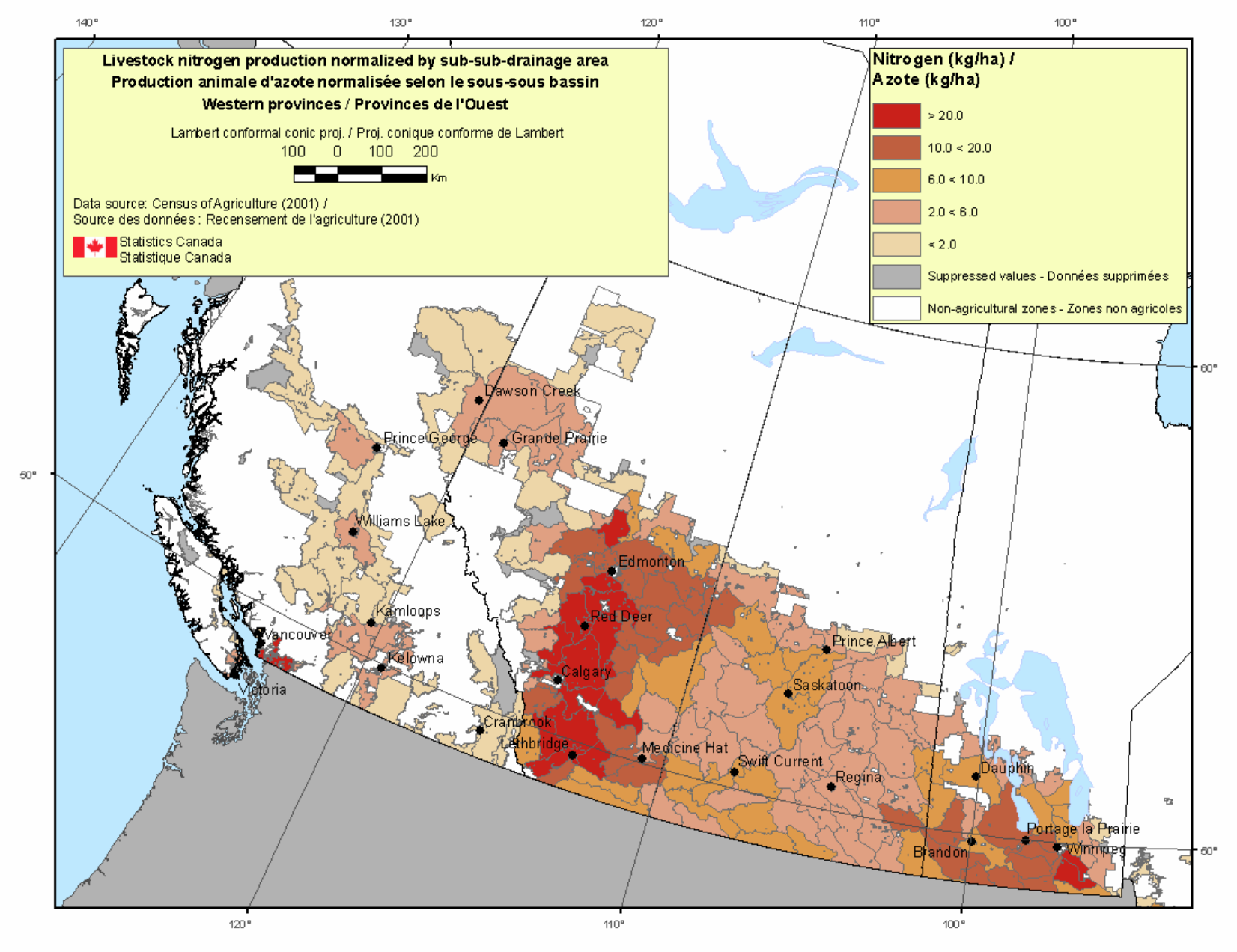


Sources: Statistics Canada, derived from the 2001 Census of Agriculture.

Map 2a: Nitrogen manure production by sub-sub-drainage area, Eastern Canada, 2001



Map 2b: Nitrogen manure production by sub-sub-drainage area, Western Canada, 2001



Ontario's Maitland SSDA had the highest manure nitrogen production at an estimated 57.5 kg/ha. The Upper Thames SSDA, also in Ontario, ranked second with estimated nitrogen production of 50.7 kg/ha. Among the ten SSDAs with the highest nitrogen manure production estimates, six were found in Ontario (Figure 2 and Appendix B).

The distribution of nitrogen production per hectare in 2001 is shown on Maps 2a and 2b. SSDAs with a production of over 20 kg/ha (i.e. the top category that was established using natural breaks) were principally found in five regions: southeastern Quebec, southwestern Ontario, southern Manitoba, southern central Alberta and southwestern British Columbia.

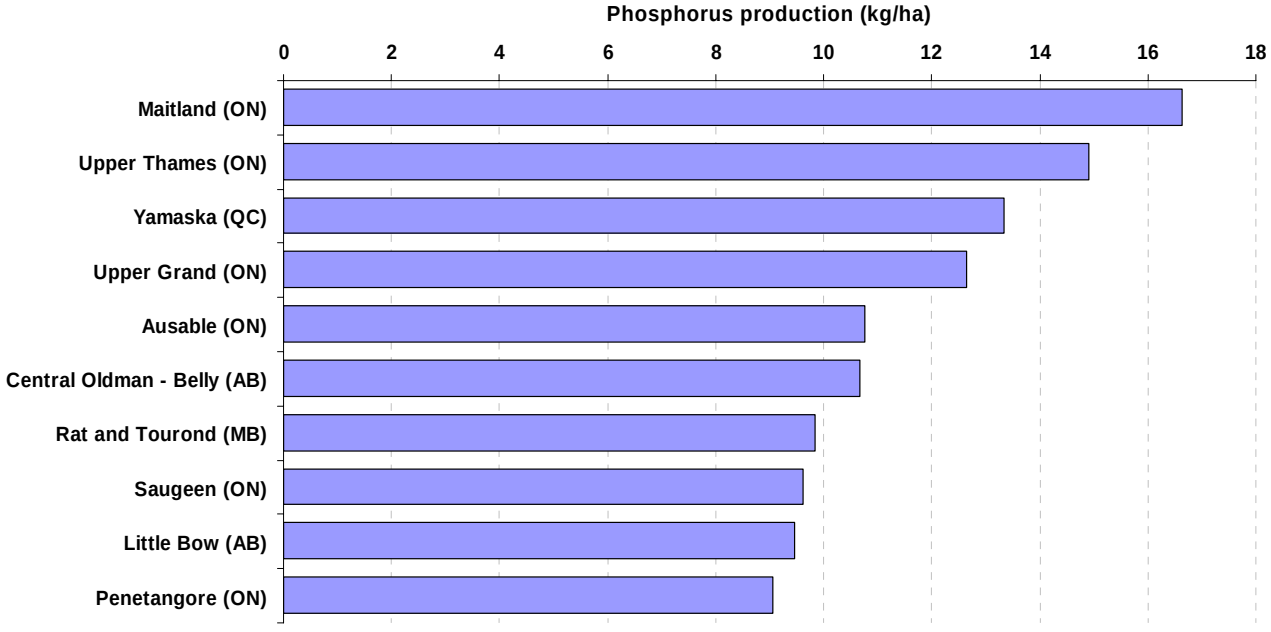
Phosphorus production in livestock manure

In 2001, Canadian livestock produced an estimated 296.6 thousand tonnes of phosphorus in manure. Cattle were responsible for 78.6% of total phosphorus production, of which 34.4% was produced by beef cows, 12.0% by calves, 11.8% by heifers, 9.5% by milk cows, 8.7% by steers and 2.1% by bulls. The contribution of other livestock to phosphorus production was 12.3% for hogs, 3.1% for poultry, 1.8% for horses and 0.8% for goats and sheep.

Average phosphorus production by SSDA in 2001 was 1.5 kg/ha. Half of the SSDAs with livestock had production of 1.0 kg/ha or less. Phosphorus production was 9 kg/ha or over (i.e., the highest production category) in ten SSDAs (Maps 3a and 3b). These ten SSDAs accounted for 15.1% of total phosphorus production.

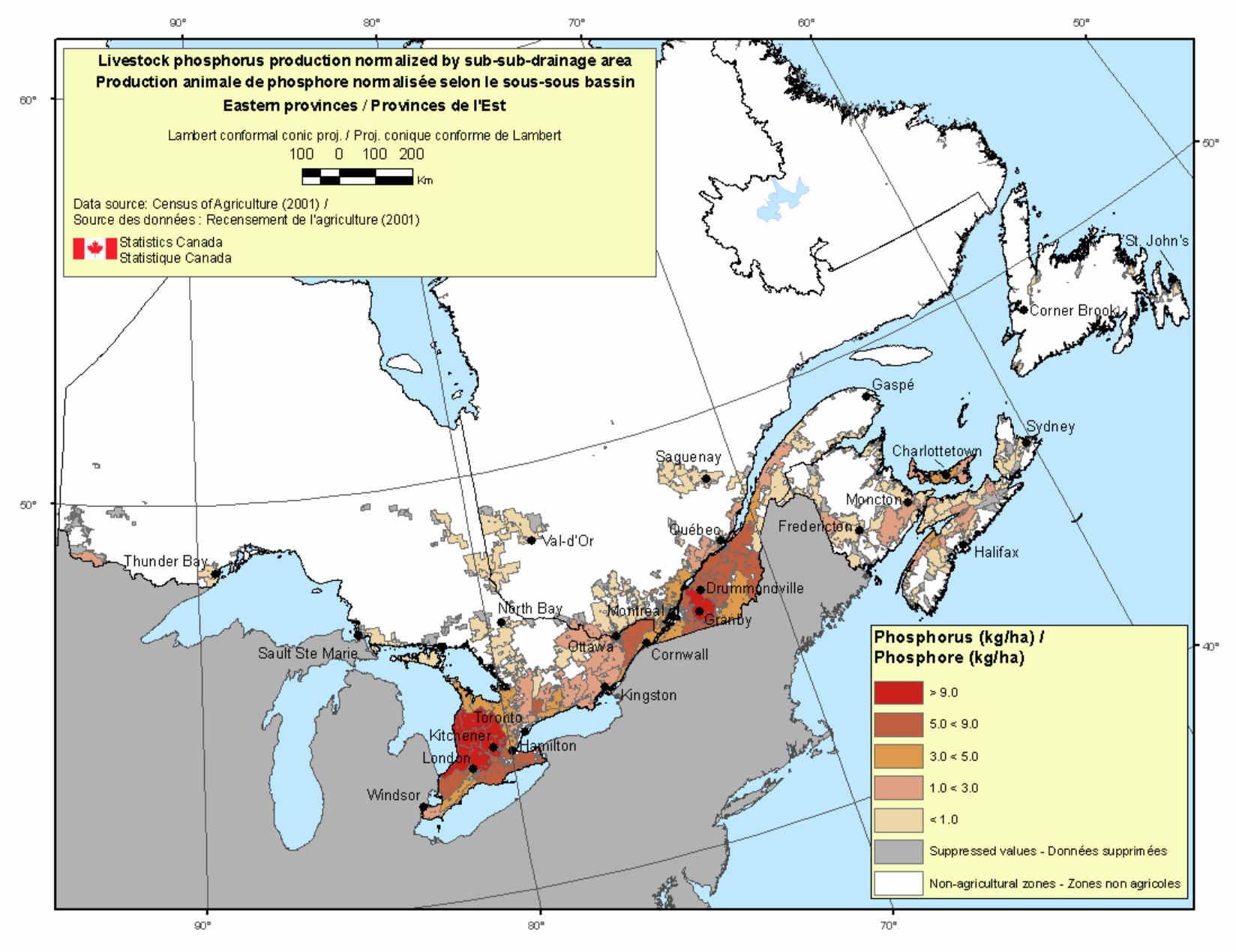
The livestock in the Maitland SSDA produced the highest amount of phosphorus per hectare at 16.6 kg/ha. Six of the ten highest SSDAs for phosphorus production were found in Ontario (Figure 3 and Appendix B).

Figure 3: Ten sub-sub-drainage areas with the highest phosphorus production, 2001

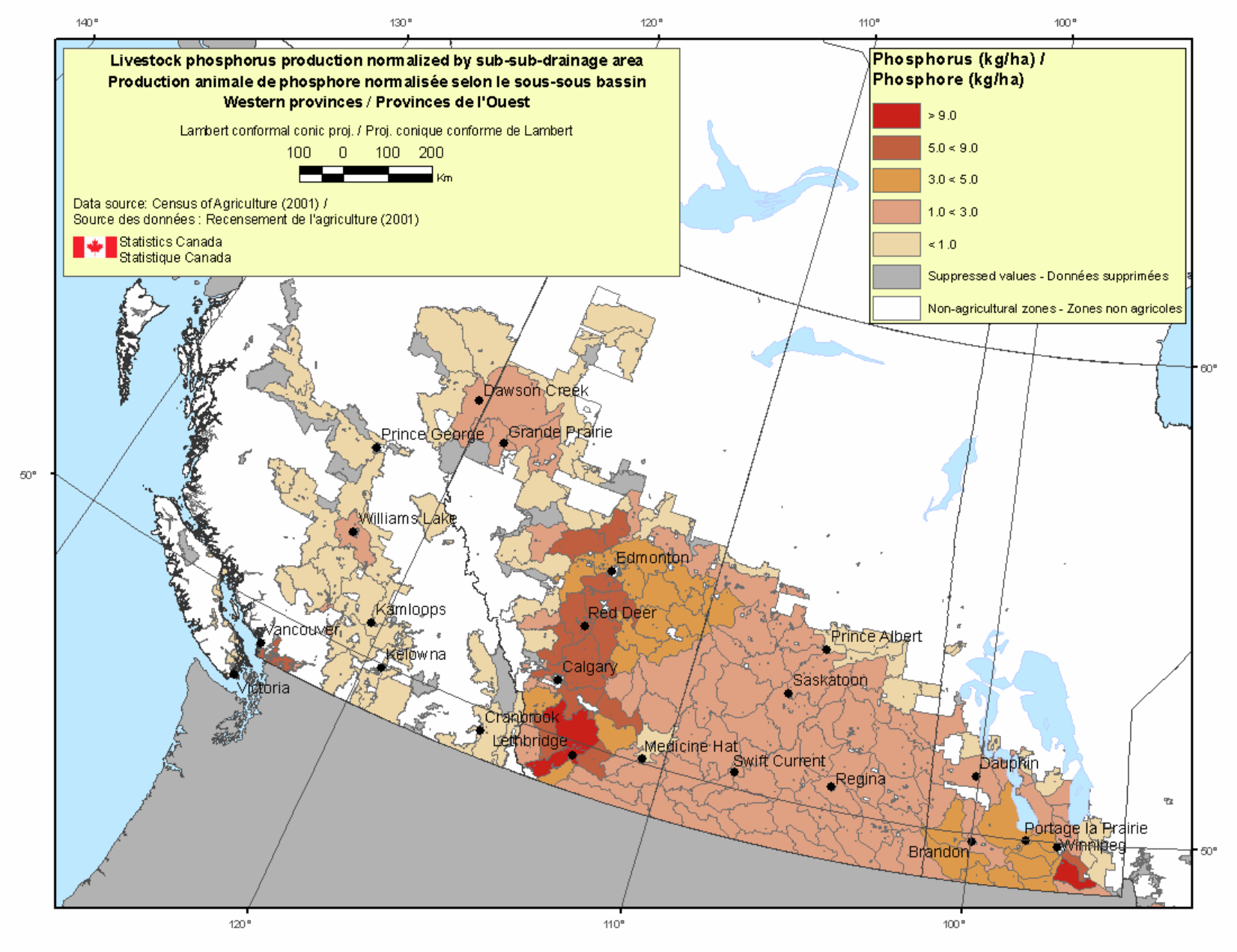


Sources: Statistics Canada, derived from the 2001 Census of Agriculture.

Map 3a: Phosphorus manure production by sub-sub-drainage area, Eastern Canada, 2001



Map 3b: Phosphorus manure production by sub-sub-drainage area, Western Canada, 2001



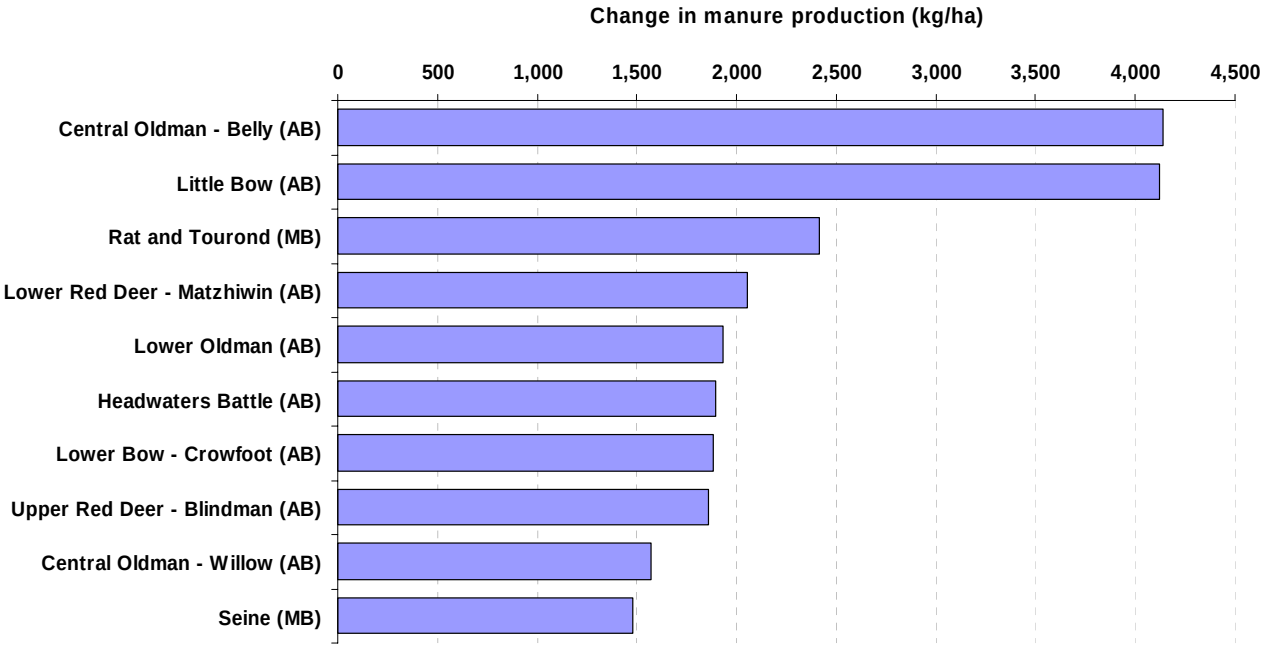
The amount of phosphorus in Canadian livestock manure by SSDA in 2001 is shown on Maps 3a and 3b. There were 39 SSDAs with production of phosphorus over 5 kg/ha (i.e., the top two categories that were established using natural breaks). Of the 39 SSDAs in these two categories, 20 were located in Ontario and Quebec.

Change in manure production: 1981-2001

In Canada, total livestock manure production increased by 13.9% in the 1981-2001 period, or an additional estimated 21.7 million tonnes of manure. Nationally, 15.3 million tonnes or 70.8% of the total increase was a result of increases in the number of cattle. Manure produced by hogs rose by 40.1% or 4.2 million tonnes over the same period. During the same period, manure produced by poultry increased 22.4% or 879 thousand tonnes.

Figure 4 shows the ten SSDAs with the largest changes in manure production over the 1981-2001 period. The Central Oldman - Belly SSDA had the largest growth, at about 4,140 kg/ha, followed closely by the Little Bow SSDA. The growth in manure production in these two SSDAs was greater than all other SSDAs, and over 1.7 times greater than the third largest growth recorded in the SSDA of Rat and Tourond. Overall, eight SSDAs in Alberta were among the ten SSDAs that recorded largest increases in manure production. These increases, for the most part, were attributed to the expansion of various types of cattle.

Figure 4: Sub-sub-drainage areas with largest change in manure production, 1981-2001



Sources: Statistics Canada, derived from the 1981 and 2001 Censuses of Agriculture.

Conclusion

Manure production in Canada is concentrated in five major geographic clusters. These clusters were located in central and southern Alberta, southern Manitoba, southern Ontario, southeastern Quebec and Prince Edward Island. In addition to these clusters, two other significant areas were located in the lower Fraser River area in southern British Columbia and the Annapolis area of Nova Scotia. Nitrogen and phosphorus production were geographically concentrated similar to manure.

In 2001, Ontario was home to the three highest producing manure SSDAs. Livestock in Ontario's Maitland SSDA produced the most manure per hectare. The Maitland SSDA had not only the highest manure production but also the highest nitrogen and phosphorus production. Sub-sub-drainage areas in Ontario also dominated the list of SSDAs with the largest production of these two elements found in manure.

The Central Oldman – Belly SSDA in Alberta accounted for the largest increase in manure production between 1981 and 2001. Overall, Alberta had a high number of SSDAs that recorded high manure production increases over this twenty-year period. These increases, for the most part, were attributed to the expansion of various types of cattle.

In 2001, cattle produced the bulk of Canada's livestock manure. Beef cows, specifically, were responsible for more than a third of the total manure produced. Due to the rapid growth in the number of cattle, beef cows also experienced the largest increase in manure production between 1981 and 2001.

This analysis does not include the impact of events such as the United States border closure on the number of various types of livestock. The impact of such events on the amount and the location of manure production will be examined when the 2006 Census of Agriculture data are available.

Appendix A: Methodology and data sources

The main objective of this study was to estimate 2001 livestock manure production normalized by sub-sub-drainage area. A secondary objective was to calculate changes in manure production between 1981-2001. The 1981 and 2001 livestock numbers from Statistics Canada's Census of Agriculture database were used to estimate manure production re-allocated by sub-sub-drainage areas. These livestock numbers by sub-sub-drainage area were multiplied by relevant coefficients found in Table A1.

To calculate normalized manure production, the total amount of manure, nitrogen or phosphorus produced in a SSDA were divided by the total land area of that SSDA. SSDA data are based on the Canadian digital drainage area framework, which is available for free on Natural Resources Canada's Geogratis website (*www.geogratis.cgdi.gc.ca*).

Table A1: Livestock manure coefficients

Variable	Average animal weight (kg)	Manure (kg/year)	Nitrogen (kg/year)	Phosphorus (kg/year)
Beef cows	635	13,444	78.8	21.3
Horses and ponies	450	8,377	49.3	11.7
Sheep and lambs	45	662	7.0	1.4
Goats	64	958	10.5	2.6
Bulls	726	15,364	90.1	24.4
Calves	204	4,321	25.3	6.9
Heifers	421	8,904	52.2	14.1
Dairy cows	612	22,706	122.0	26.8
Boars	159	1,358	9.9	3.3
Grower and finishing pigs	61	1,287	8.5	3.2
Nursing and weaner pigs	11	613	3.5	1.4
Sows and gifts	125	1,358	9.6	3.1
Steers	454	9,603	56.3	15.2
Broilers, roasters and Cornish hens	0.9	28	0.36	0.09
Laying hens	1.8	42	0.55	0.19
Pullets	0.9	28	0.36	0.090
Turkeys	6.8	117	1.54	0.57

Sources: American Society of Agriculture Engineers, ASAE D384.1 FEB03.
Midwest Plan Service publication, no. MWPS-18 "Manure Characteristics," 2000 as quoted on the Michigan State University Extension website.
Oklahoma State University, "Production and Characteristics of Swine Manure," F-1735.
Agriculture Canada and Agri-Food Canada. Discussions among experts.

For the purposes of this research, total manure production consists of feces and urine. Bedding and other types of material such as feathers, unused feed, etc. are not included in these calculations.

Appendix B: Detailed data

Table B1: Sub-sub-drainage areas with more than 2,000 kg/ha of manure, 2001

		Production (kg/ha)		
SSDA	Name	Manure	Nitrogen	Phosphorus
02FE	Maitland	8,926.7	57.5	16.6
02GD	Upper Thames	7,884.4	50.7	14.9
02GA	Upper Grand	7,230.5	45.6	12.7
05AD	Central Oldman - Belly	6,627.8	39.3	10.7
02OG	Yamaska	6,617.0	43.2	13.3
05AC	Little Bow	5,875.7	34.7	9.5
02FC	Saugeen	5,666.4	35.1	9.6
05CC	Upper Red Deer - Blindman	5,468.8	32.4	8.9
02FF	Ausable	5,418.7	35.6	10.8
02FD	Penetangore	5,284.4	32.4	9.0
02OD	Nicolet	5,015.1	29.8	7.9
05FA	Headwaters Battle	5,008.4	29.8	8.1
05CB	Upper Red Deer - Little Red Deer	4,684.8	27.6	7.4
05OE	Rat and Tourond	4,587.3	30.4	9.8
05BH	Central Bow - Jumpingpond	4,174.9	24.7	6.7
02PH	Etchemin	4,027.1	24.8	7.2
02HG	Scugog	4,005.2	24.7	6.5
05AG	Lower Oldman	3,864.2	23.4	6.5
05CD	Central Red Deer - Tail	3,803.7	22.5	6.2
02LB	Lower Ottawa - South Nation	3,759.8	21.7	5.3
05CE	Central Red Deer - Rosebud	3,699.5	22.3	6.2
05CJ	Lower Red Deer - Matzhiwin	3,693.7	21.8	6.0
05DF	Upper North Saskatchewan - Strawberry	3,671.6	21.8	5.8
02OJ	Richelieu	3,639.0	23.6	6.6
02OF	Lower Saint-François	3,571.2	22.2	6.2
05OH	Seine	3,531.7	23.3	7.1
02PK	Lower St. Lawrence - Chêne	3,506.7	20.6	5.6
07BC	Lower Pembina (Alta.)	3,489.1	20.9	5.8
02PL	Bécancour	3,483.0	21.0	5.8
05AB	Central Oldman - Willow	3,423.7	20.3	5.5
05BM	Lower Bow - Crowfoot	3,362.0	20.0	5.6
02GB	Lower Grand	3,233.5	21.7	5.9
07BB	Central Pembina (Alta.)	3,228.9	19.0	5.1
02PJ	Chaudière	3,167.6	20.1	5.9
08MH	Lower Fraser - Coast	3,164.1	24.6	6.8
05FD	Ribstone	3,067.6	18.0	4.9
02GC	Big (Ont.)	2,978.4	19.8	5.6
02OH	Lake Champlain	2,945.5	18.1	5.1
02MC	Upper St. Lawrence - Raisin	2,864.0	17.0	4.3
05AE	St. Mary	2,839.3	17.0	4.7
01CC	Central Prince Edward Island - Hillsborough	2,771.6	16.4	4.5
02FB	Southwest Georgian Bay	2,761.4	16.4	4.4
02FA	Bruce Peninsula	2,754.3	16.2	4.3
05EA	Sturgeon (Alta.)	2,725.5	16.7	4.6
05FC	Central Battle - Meeting	2,713.3	16.3	4.5
01CB	Central Prince Edward Island - Wilmot	2,666.9	15.6	4.1

Table B1: Sub-sub-drainage areas with more than 2,000 kg/ha of manure, 2001 (end)

SSDA	Name	Production (kg/ha)		
		Manure	Nitrogen	Phosphorus
02HJ	Otonabee	2,642.0	16.2	4.2
05BN	Lower Bow - Mouth	2,590.7	15.3	4.2
05EE	Vermilion (Alta.)	2,471.0	14.7	4.0
02HA	Niagara	2,455.8	19.8	5.7
02MB	Upper St. Lawrence - Thousand Islands	2,442.3	17.4	4.8
02GG	Sydenham	2,400.4	16.6	5.2
05FE	Central Battle - Blackfoot	2,334.4	13.8	3.8
05EB	Central North Saskatchewan - Beaverhill	2,274.6	13.9	3.8
02HD	Ganaraska	2,273.6	14.4	3.9
05EF	Central North Saskatchewan - Big Gully	2,270.3	13.4	3.6
05DE	Upper North Saskatchewan - Wabamun	2,250.0	13.2	3.6
02OA	Montreal Island	2,233.2	13.0	3.3
05FB	Upper Battle - Iron	2,177.7	12.9	3.5
02ED	Nottawasaga	2,177.3	13.2	3.6
05EC	Central North Saskatchewan - Redwater	2,173.5	13.1	3.6
05CF	Dowling Lake - Non-contributing	2,147.7	12.7	3.5
05ED	Central North Saskatchewan - Frog Lake	2,070.8	12.2	3.3
02PG	Lower St. Lawrence - Loup	2,043.9	12.0	3.1
05BL	Highwood	2,041.9	12.1	3.3
01DD	Gaspereau	2,029.3	16.5	4.9
05OG	La Salle	2,014.5	12.7	3.8
02OE	Upper Saint-François	2,004.5	11.7	3.1

Appendix C: Limitations

Several assumptions have been made to derive manure production estimates.

First, it is assumed that Canadian livestock of similar types produce similar amounts of manure and have similar characteristics (e.g., production of nitrogen and phosphorous). It is also assumed that feeding practices are the same from one region to another.

Data used for this research were based on the number of livestock on May 15, 2001, the reference date of the 2001 Census of Agriculture. To provide estimates for the entire year, census livestock inventories were used to calculate manure production for the entire calendar year. Some livestock can fluctuate significantly over the course of the year.

Total livestock inventories used in this study comprised beef cows, horses and ponies, sheep and lambs, goats, bulls, calves, heifers, dairy cows, boars, grower and finishing pigs, nursing and weaner pigs, sows and gilts, steers, broilers/roasters and Cornish hens, laying hens, pullets and turkeys. Other livestock in Canada, such as buffalo, deer, and rabbits, were not included into this analysis because their overall contribution to total manure produced was assumed to be marginal.

One limiting assumption is that the amount of farm land used for manure disposal varied by SSDA, meaning that the intensity of this farming activity could be understated in SSDAs containing small amounts of farm land. However, not all manure may be applied in the SSDA where it is produced. Some manure could be exported to neighbouring SSDAs where more land, or land deemed more suitable, is available to receive manure.

Precise geographic co-ordinates (longitude and latitude) are not reported to the Census of Agriculture. The geographical references collected or assigned to Census farms are therefore addresses of the farms' headquarters. The exact location of crop fields, pasture fields or barns in which the animals were housed do not necessarily match the location of the headquarters. Precise geographic information is not therefore available, meaning that the allocation of farm activity according to headquarters could be a source of geospatial misrepresentation.

Since the 1996 Census, follow-up calls and validation efforts are made to re-allocate exceptionally large operations (i.e., farms that hold land located in more than one municipality, enumeration area or province) into geospatial areas corresponding to the different Enumeration Areas[2] where Census respondents reported land. These adjustments are made to only a small fraction (less than 1%) of Census farms, but these reallocated data are regarded as possessing geographical information that more closely approximates where livestock and therefore manure are located.

The geospatial re-allocation of Census farm data by drainage framework may be affected by the same limitations as large farm re-allocation described above. The re-allocation or re-assignment of the whole data (or a fraction) of a farm operation from the headquarter location to a specific Census Enumeration Area, or to one or more sub-sub-drainage area results in information on "pseudo farms". The exact location of land and livestock is still unknown. "Ground truthing" investigation and use of satellite information could help to refine this information.

Data originating from a project as large and as complex as the Census of Agriculture are subject to error despite extensive efforts deployed at census time to correct errors detected from undercoverage, misreporting and data capture errors. Census of Agriculture quality and coverage studies report that errors relate most often to coverage, missing responses, response errors, and processing errors that were not identified by subsequent checks. However, the Census of Agriculture has a high response rate (estimated at over 96%) and the data are deemed to be generally of very good quality.

[2] An enumeration area is the geographic area canvassed by one census representative. It is the smallest standard geographic area for which census data are reported. Canada's entire surface area is divided into enumeration areas.

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