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Distribution and Concentration of Canadian Livestock

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Highlights

The total number of livestock farms in Canada has shrunk over time. However, the number of large farms is on the rise. With large farms come large concentrations of animals and manure in some areas.

This study gives a 'snapshot' of where the larger concentrations of livestock and poultry were at the time of the Census of Agriculture in May 1996. Livestock concentrations (or densities) were analysed in terms of the total livestock population, irrespective of the different types of animals raised.

The report shows the following:

- In May 1996, 20% of Canada's livestock was found in areas with high concentrations of livestock (high-density areas).
- Provinces with the most livestock in high-density areas were Quebec, Ontario, Alberta and British Columbia.
- In Quebec, British Columbia and Ontario, over 30% of the livestock in each province was in high-density areas.
- The largest livestock populations found in high-density areas were beef cattle in Alberta, dairy cattle and hogs in Quebec, and dairy cattle in Ontario.
- Livestock concentration is not necessarily linked to large livestock populations. Several high-density areas appeared to be due to a rather limited amount of livestock associated with an even smaller farmland base.

More research, using farm-level data and characteristics, is required to determine which type of farms contributed the most to a greater concentration of livestock in some areas. Further work is required before concluding whether or not the livestock concentration in certain regions has reached limits where it could pose an ecological threat.

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Introduction and background

Although the number of farm holdings in Canada is shrinking, the number of large farms is growing. The decreasing importance of small farms in terms of production and their position in the marketplace is a long-term trend observed in Canada and in most developed countries.¹ Decreasing commodity prices and cost efficiencies achieved through economies of scale and the adoption of new technologies have contributed more than anything else to reshaping and redefining the structure of modern agriculture.

It is not yet clear how the industrialization of agriculture has affected Canada's natural resources such as soil and water. The perception is that smaller family-run farms represent a lesser threat to human health and the environment. However, smaller farms are often operating under tight margins, making the capital investments required for sound environmental and manure management practices difficult. In the livestock² industry, large and intensive operations have become a nuisance for some and a symbol of pride for others. Many people are concerned about the intensification of livestock farms and its possible impacts on the resource base, particularly on water and air quality.³

Large livestock operations produce large amounts of manure that must be carefully stored, moved and incorporated into the soil. Manure is a natural fertilizer whose benefits include adding nutrients and organic matter to the soil and reducing the use of chemical fertilizers. Manure also improves the soil structure, which in return reduces the risk of erosion, run-off and the infiltration of chemicals, organic substances or pathogens into surface and ground water. The agronomic and environmental contributions of manure are well documented.⁴ However, high concentrations of livestock and the large amounts of manure they produce are leading many people to wonder whether we can get 'too much of a good thing' and whether production systems based on large intensive operations are sustainable in the long term. Caldwell (1998) notes that the capacity of the soil, ground water and air in a given area to receive livestock manure is at least partially related to the concentration of livestock in that area.⁵ However, these links have yet to be defined.

Some argue that manure management is a non-issue as long as manure is applied on a large land base and its management is closely monitored. There appears to be a positive correlation between farm size and the ability to adhere to the recommended management practices—perhaps because large operations also have the financial resources required to allow them to stay up to date with more stringent environmental standards and manure management practices. On the other hand, these same larger farms tend to be more intensive and have higher concentrations of livestock than smaller farms.⁶

1. For examples of the increasing importance of large livestock farms worldwide, see Janzen et al. (1999), Glenn (1999), Caldwell (1998) and Fedkiw (1992). As a comparison closer to home, the 1995 Quebec provincial average was 996 pigs per pig farm, compared with 475 in Ontario, 516 in Denmark and 2,352 in North Carolina (MAPAQ 1999).

2. For simplicity, the term 'livestock' is loosely used to include all animal farms, including poultry.

3. For examples, see Toombs (1997, 1998), Fleming et al. (1997), Manitoba Agriculture (2000), Tessier (1998), Mallin (2000), Stone et al. (1998), Nikiforuk (2000) and Mitchell et al. (2000). Analyses of the risk of nitrogen and phosphorus contamination are produced in MacDonald (2000a,b), Bolinder et al. (2000) and Eghball and Gilley (1999).

4. For thorough reviews, see Eghball and Power (1994), Choudhary et al. (1996), Haynes and Naidu (1998) and Van Horn and Hall (1997).

5. Caldwell (1998), p. 104.

6. Schmitt et al. (1996).

The disposal of manure is an issue, given that manure hauling costs increase with distance. In many cases, manure must be transported some distance from the source in order to avoid applying it more heavily than recommended. This can be a real concern in areas where animal populations and densities are high.⁷ Land near livestock operations may receive more manure than the soil and plants can use, while land further away receives none.⁸ Possible accidents or spills associated with large storage, hauling and spreading equipment also may present greater environmental risks. These potential problems could be amplified in areas where farmland adjoining the livestock operations is limited.

Using geographic information systems (GIS) to analyse the concentration of livestock production expressed in generic animal units, this report focusses on the locations of high concentrations of livestock and the types of livestock found in these high-density areas. Most other studies have produced density information for specific types of livestock.⁹ This report provides maps and research that analyse livestock densities in terms of the total livestock population, irrespective of the different types of animals raised.¹⁰ Presenting the density of the total livestock population in a particular area is a good way to evaluate its impact on the environment.

The analysis provides information that will benefit planners, investors, non-governmental organizations, rural communities and governments interested in expanding livestock production in a sustainable and responsible manner.

7. Lauwers et al. (1998).

8. Roka and Hoag (1994).

9. For examples, see Marchand and McEwan (1997), Statistics Canada (1994, 1999a, 2000a,b) and CSALE (1996).

10. For examples, see Bernard (1999), GREPA (2000) and Letson and Gollehon (1998).

Concepts

Animal units

In order to determine livestock density, we used the concept of ‘animal units’ to create equivalence among different types of livestock, regardless of type, age or end use. This concept is often used in regulations, codes of practice and municipal by-laws related to livestock production (see Appendix B).

This concept, originally developed in the United States in the 1960s, is based on the number of animals that would produce the 73 kilograms of nitrogen required to fertilize one acre of corn for one year. The number of animals of a given kind—such as broiler chickens or beef steers—in one animal unit is expressed as a coefficient. One cow, for example, equals approximately one animal unit, while four sows or 125 broiler chickens will be required for one unit. Because of genetic and nutritional improvements to livestock, these coefficients have been recalculated since they were first developed.

Two methods have been used to estimate the amount of nitrogen produced by animals in a 12-month period: the Nitrogen Production Method,¹¹ based on average live animal weights; and the Feed Consumption Method, based on the conversion of feed protein into excreted nitrogen. More recent research has calculated coefficients based on phosphorus excretion.¹² For a number of reasons, coefficients vary across regions, provinces and countries. The coefficients used in Canada were reviewed and have proved to be very similar and consistent. (See Appendix C for the coefficients used in this study.)

Livestock density on farmland area

Livestock density refers to the number of animal units per km² (100 hectares) of farmland. Farmland includes all cropland, summerfallow, and improved and unimproved pasture. Land that was not in agriculture and areas of farms—such as barnyards, laneways, woodlots and marshes¹³—that were not suitable for manure disposal were excluded from the calculation. Appendix D presents a map showing the proportion of farmland to total land.

Livestock density was calculated using the farmland available for spreading manure within a 20-kilometre radius of the centre of each enumeration area, the smallest standard geographic area for which census data are reported.¹⁴ The 20-kilometre radius was selected based on two assumptions: it represented the maximum distance manure could be hauled economically; and no quantity was transported outside this circle. (For more detail, see **Radius** under **GIS methods**.)

To derive the livestock density within each circle, the number of animal units within 20 kilometres of the centre of each enumeration area was calculated and divided by the farmland area. (See **GIS methods** for further details.)

11. For details, see American Society of Agricultural Engineers (1993) and Midwest Plan Service (1985).

12. In some regions, buildup of phosphorus in the soil has become a limiting factor in soil fertilization. See Simard et al. (1995, 1998, 1999), Bolinder et al. (2000) and Eghball et al. (1996). Because less can be applied, manure must be hauled to a greater distance (Fleming et al. 1998).

13. Also excluded were farm buildings, gardens, greenhouses, idle land, tree windbreaks, bogs, sloughs, etc.

14. For details, see Statistics Canada. (1999b), pp. 210–212.

A standard shape, such as the circle around the centre point of each enumeration area, does not appear to distort the results and the visual display of the values as much as the multitude of irregular shapes associated with political, administrative or environmental boundaries do. (Map 1 illustrates how irregular shapes and sizes of the enumeration area could affect the measurement of density.) Moreover, livestock densities may have little to do with predefined administrative boundaries and areas since grazing or manure hauling may cross administrative or watershed boundaries, especially in regions divided into many small administrative areas.

Census geographical component

The census geographical component (CGC) of each farming operation is the geographic area(s) where the operation is located. An enumeration area may contain several CGCs, depending on the number of farming operations reported within it.

Agricultural operations may comprise numerous parcels of land in a number of locations. Farm operators were asked to report on the Census form the location (quarter, section, lot number, township, concession, meridian, parish and county) of all land owned or leased from others, starting with the farm headquarters. However, there was no specific question about the exact location of livestock.

In general, livestock reported by a farm were assumed to be kept near the farm's headquarters. Animal units were assigned to the enumeration area of the headquarters. This allocation was done regardless of the location of land holdings in the farm unit. Exceptionally large operations, with land holdings located in more than one municipality or even province, were divided into parts corresponding to the different enumeration areas they occupied. This way, we were able to assign the livestock a geographical location that more closely reflected reality. However, this adjustment affected less than 0.2% of all the livestock.

Density classes

The continuum of livestock density, which can range from 0 to more than 1,000 animal units per km² of farmland, is classified into 10 categories.¹⁵ In addition to the 0 animal unit per km² category, this research has clustered the other nine categories into three broad classes of livestock density: low (0.1 to 3 animal units per km²); medium (between 3 and 80 animal units per km²); and high (over 80 animal units per km²).

Livestock operations

A livestock operation is a census farm (see definition in Appendix A) that produces at least one of the following products intended for sale: cattle, pigs, sheep, horses, exotic animals, hens, chickens, turkeys, exotic birds, milk or cream, eggs, wool, furs and meat.

15. The values of the 10 density classes can be seen in the legends of the maps in Appendix F. The divisions were made based on statistical distribution. Thresholds for the high-density classes were reported in a number of studies indicating at which level there is potential risk to the environment. See Paquette (1998) and Schreier and Berka (1999).

Methods, coverage and limitations

Conversion to animal units

The animal inventory reported by farmers was converted to a common basis, animal units, by multiplying the inventory for each type and age of livestock by specific coefficients (see Appendix C).

Individual totals were calculated at the enumeration area level for total livestock, cattle (beef and dairy), pigs, poultry and other livestock. Poultry included birds such as broilers, pullets and pullet chicks, laying hens and turkeys. Less common birds (such as geese and ducks) and exotic birds (such as ostriches, game birds and emus) were included in the 'other' category.

On the 1996 Census of Agriculture questionnaire, it was not possible to indicate whether calves, heifers and bulls were beef or dairy. They were allocated as dairy or beef cattle based on historical patterns, farm types, ratios and provincial supply and disposition tables. This breakdown could be useful in future studies, as beef and dairy cattle excrete different amounts of nutrient and pathogens.

In the case of turkeys, inventories were reported together without distinction for age or type of production. Turkey animal unit coefficients were adjusted at the provincial level to compensate for the predominance of one type of bird, such as broilers versus heavy-weight broilers.

GIS methods

Centroids: In order to build a map, data had to be transformed into a layer of geographic points, expressed in terms of longitude and latitude (X, Y) co-ordinates. Since the geographical references collected or assigned to census farms were the addresses of the headquarters, mapping using these co-ordinates would raise the issue of confidentiality. Also, the exact location of the field used for pasture or manure disposal or the barn in which the animals were housed did not necessarily match the location of the headquarters.

To deal with these issues, different farms were aggregated together inside the boundary of a geographical area or unit. A few key variables influenced the decision to select a specific geographical level: if too small, data would need to be suppressed, aggregated to a higher level or merged with close neighbouring units to protect confidentiality; if too large, the map would lose precision. The scale of the maps also influenced this decision.

In this study, the enumeration area was chosen as the indicator of the livestock location mainly because it is the smallest standard geographic area for which census data are reported and it is available for the whole country.

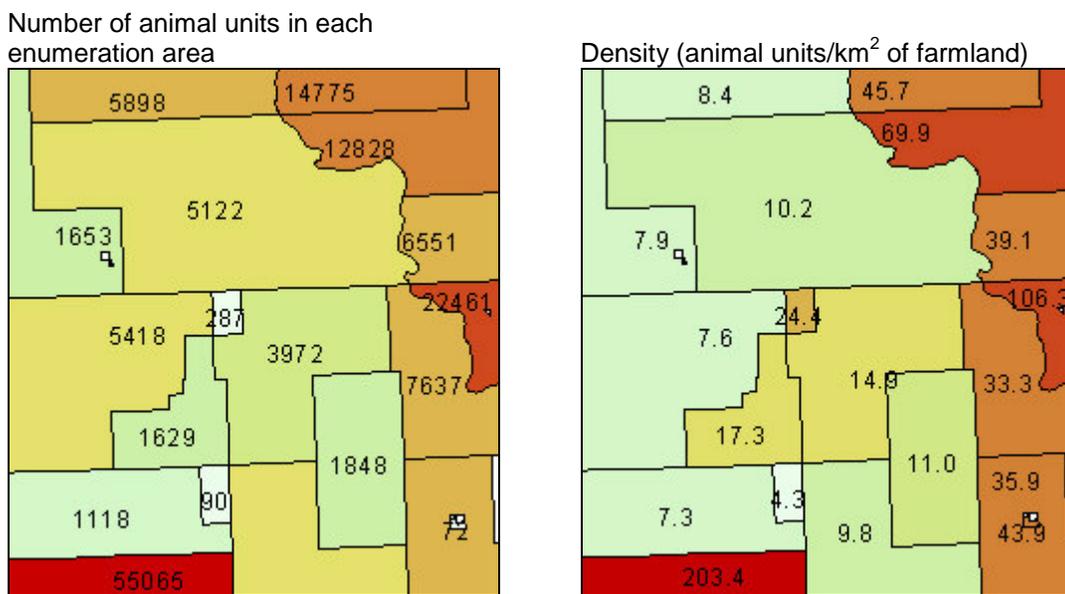
Enumeration area boundary and size are primarily based on human geography and rivers. It represents the geographic area canvassed by one census representative. It can cover as much as 440 dwellings in large urban areas to a minimum of 125 in rural areas. In low population density areas, enumeration areas are likely to cover more land than in highly populated areas.

A conventional way to measure livestock density is to take the sum of all animal units inside a particular enumeration area divided by that enumeration area's farmland area. This approach has several limitations associated with the irregularity of the enumeration area shapes and sizes. Unrepresentative hot spots (high livestock density areas) and cold spots (low livestock density areas) may be induced simply from the substantial differences in the size of individual enumeration areas.

Artificial hot spots could be produced for farm headquarters located directly beside or near a small town (which would delineate a small enumeration area). Conversely, artificial cold spots could be created by the diluting effect on intensive livestock operations of being located in a large enumeration area.

The approach also produces a mosaic display that could be visually very difficult to interpret. As well, the farming activities of the farm headquarters located inside a particular enumeration area are likely to transcend the enumeration area boundaries (Map 1).

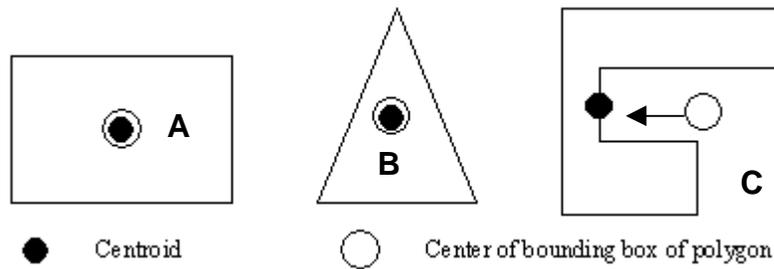
Map 1: Impact of irregular shapes and sizes of enumeration areas on livestock density measurement



Note: Colour changes from light green to dark red as livestock density increases.

Source: Statistics Canada, derived from the 1996 Census of Agriculture.

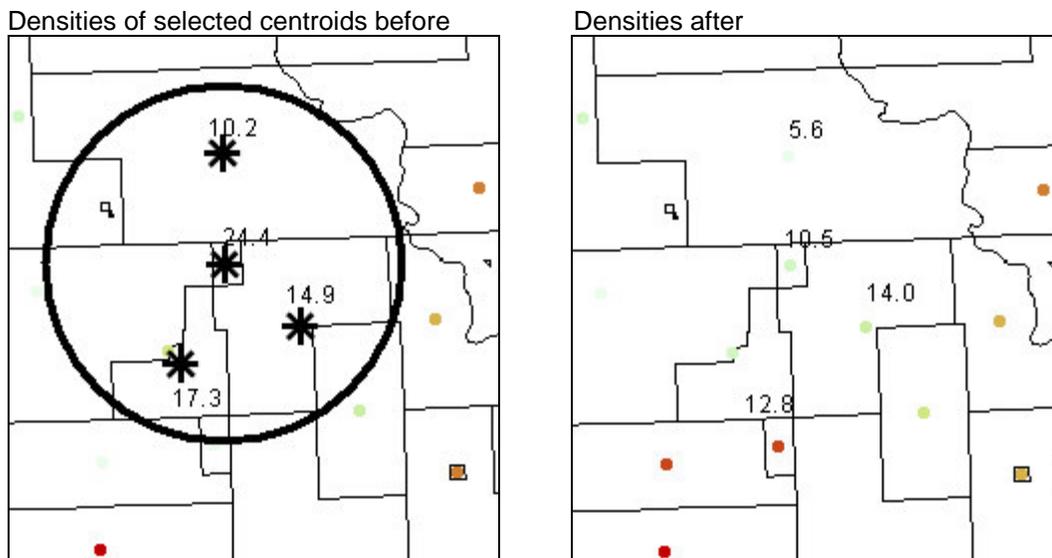
The first step to reduce this effect was to determine the centroid (centre) of each enumeration area. The centroid is always located inside the polygon and is usually the centre point of a polygon's bounding box (see examples A and B). However, for irregular shapes where the point falls outside the polygon, it is moved in the shortest horizontal direction required to put it inside the polygon (example C).



Radius: Dealing with the smallest geographical level available also raised the issue of confidentiality. The solution to this issue, and to the issue related to irregular shapes and sizes, was to impose a standard geometric shape—a circle with a 20-kilometre radius—around each centroid. The assumption was that the loss in precision resulting from this normalization would be offset by the removal of artificial hot spots or cold spots. Also, since there were more data points inside a circle with a 20-kilometre radius than inside an individual enumeration area, fewer data would need to be suppressed to protect their confidentiality.

The density within each circle was then calculated by dividing the total number of animal units for all centroids falling within the circle by the farmland area within the circle (1,257 km² for the whole circle multiplied by the percentage of farmland within it). The calculation was then repeated for each centroid. Instead of calculating a density value for the enumeration area itself, this approach raised a weighted average for all centroids that fell inside the same 20-kilometre circle (Map 2 and Appendix E).

Map 2: Impact of selecting centroids inside a standard circle on livestock density measurement



Note: Densities are in animal units/km² of farmland.
Source: Statistics Canada, derived from the 1996 Census of Agriculture.

A 20-kilometre radius was selected because a number of studies suggested that 20 kilometres was the farthest that manure could be economically hauled. Farm operators had little incentive to haul manure beyond the point where transportation was economically viable.¹⁶ However, there is no simple method to calculate the break-even point for transporting manure. It is uneconomical to haul some types of manure even 4 kilometres. “The two most important factors that determine the net benefit of manure to farming are the distance the manure has to be hauled and the nutrient content of the manure.”¹⁷ Returns to the livestock operation, input costs such as fuel and fertilizer, crop requirements, landscape, soil composition and the nutrient content of the manure all influence the maximum distance manure is transported. Farmers, like other business owners, generally want to maximize profits and consequently try to minimize their manure handling and transportation costs. The distances that they are prepared to transport manure may, therefore, not always conform to manure management recommendations.

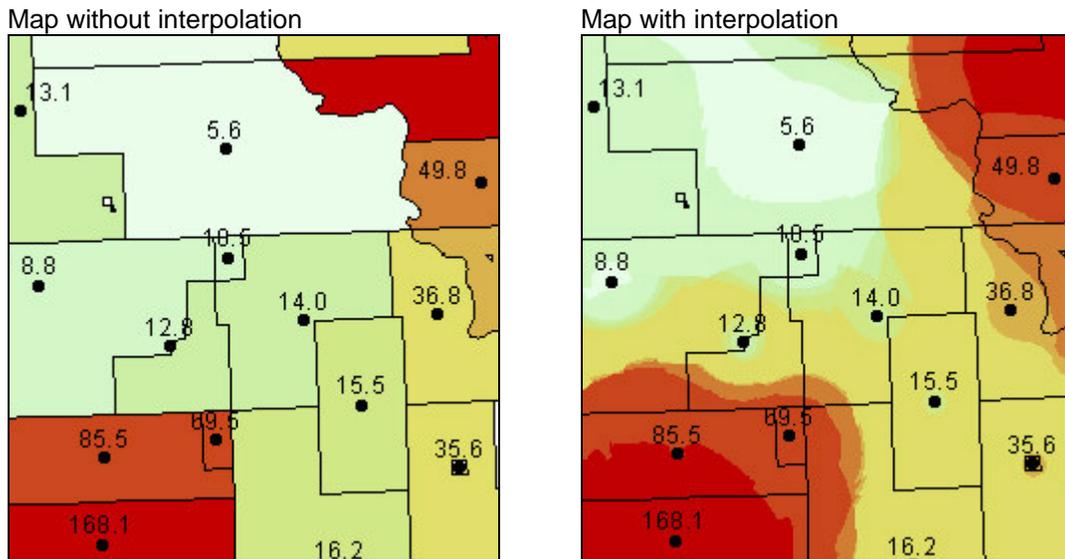
Interpolation: The interpolation technique¹⁸ allows the creation of a continuous map with a set of geographic references (enumeration area centroids). With this technique, new density boundaries appear between centroids as the relative densities influence each other. A very dense enumeration area impacts less dense neighbouring enumeration areas; this effect decreases with distance (Map 3).

16. Much of the research cited in the literature refers to work done by Freeze and Sommerfeld (1985) and Roka and Hoag (1994, 1996). In theory, the break-even point and the transportation distance can be higher, but they may change based on the nutrient and moisture content of the manure. Composted manure can be transported greater distances but not much farm manure is composted (Janzen 1999). Transport distances can also be greater if there is a regional structure such as the Manure Management Organization in Quebec to export manure from surplus regions. He and Shi (1998) estimated the maximum distance to be 4 kilometres with their manure transport model for Michigan.

17. Fleming et al. (1998).

18. Using the inverse distance weighted (IDW) technique (one of several types of interpolation), the value or colour of each of the pixels in an image (i.e. the points that compose the image) is influenced by each of its surrounding points—an influence that decreases with distance. A fixed radius of 20 kilometres and an exponent of 2 were used to limit the influence of surrounding points on the value given to an analysed pixel. For example, a point A located at mid-distance between a point B and pixel C had four times more weight ($[1/(1/2)^2]=4$) on the final value of pixel C than the point B did. For details, see ArcView (1996).

Map 3: Impact of the interpolation technique on livestock density display for irregular areas



Note: Colour changes from light green to dark red as livestock density increases.
Source: Statistics Canada, derived from the 1996 Census of Agriculture.

As the livestock population is not evenly distributed across Canada, a major advantage of the chosen interpolation technique was to assign a value of zero where there was no animal reported inside a 20-kilometre circle. In other words, white spots in the maps mean ‘no animals within a 20-kilometre radius of the centroid’—not a lack of data.

Data sources and coverage

This research uses a data set of Canadian census farms reporting livestock on the 1996 Census of Agriculture. Farm operators were asked to report inventories of all livestock, including cattle, pigs, poultry, horses, sheep and lambs, and more exotic animals such as emus, ostriches, elk, deer, bison and wild boars.

Initially, 184,000 farms were identified. Some records that could not be linked to any areas classified as agricultural (see the ‘headquarters rule’) were excluded, as were records on farms that did not report significant numbers of livestock and other records where confidentiality might be compromised if the data were included. Overall, however, less than 1% of all animal units were excluded from the study. The data set used for analysis represented 175,000 farms.

Limitations

Inventory versus flow: Livestock inventories in mid-May, as reported by farmers on the Census of Agriculture, do not represent the number of animals that were on the farm during the whole year. The capacity of the barns, pens or pastures in mid-May is unknown since this information was not elicited on the 1996 Census of Agriculture questionnaire. No adjustment was made to estimate the average size of the herd, the total livestock production during the year or the number of livestock in confinement (in pens, for example) for the whole year or part of the year. The calculated livestock densities refer specifically to the situation on May 14, 1996.

Headquarters rule: Although the Census of Agriculture data were used at the CGC level, the barns and livestock may not be as accurately located as they would have been had geographic co-ordinates been reported on the census questionnaire.

Census errors: Data originating from a project as large and complex as the Census of Agriculture are subject to error despite extensive efforts deployed at census time to correct detected undercoverage, misreporting and data capture errors. The most common types of errors were related to coverage, missing responses, response errors, and processing errors that were not identified by subsequent checks. However, the Census of Agriculture had a high response rate and the data were of very good quality.

Terrain analysis: With limited resources available, it was almost impossible to validate the results of national-level census coverage with field observations. However, to make sure the results were displayed within a reasonable level of accuracy at the selected scale level, a few maps were validated at the provincial level with the assistance and local knowledge of provincial agricultural statisticians.

No attempts were made to make adjustment to the spatial distribution of livestock based on physical geology, geomorphology, hydrology, meteorology, or human settlement patterns and transportation and communication networks.

Findings

Locations of high concentrations of livestock

The livestock inventories reported in the 1996 Census of Agriculture were converted into a common measure, animal units, and mapped to display the spatial distribution and concentration of Canadian livestock production.

In May 1996, there were 13.4 million animal units in Canada. Alberta had the greatest share of the national livestock population (34.1%), followed by Ontario (18.7%), Saskatchewan (15.2%), Quebec (13.8%) and Manitoba (9.5%). The size and location of the cattle industry largely determined these distributions.

Eight out of 10 farm animals—10.9 million animal units held on 147,000 livestock operations—were located in medium-density areas, where the concentration of livestock was between 3 and 80 animal units per km² of farmland. Two-thirds of this livestock was located in the three Prairie provinces.

Less than one-fifth of all livestock was located in high-density areas, where there was a concentration of more than 80 animal units per km² of farmland. Most of the livestock located in high-density areas was in Quebec, followed by Ontario, Alberta and British Columbia. (Table 1).

Table 1: Distribution of livestock, by province and density, May 1996

Livestock density	B.C.		Alberta		Saskatchewan		Manitoba		Ontario		Quebec		Atlantic prov.		Canada	
	'000AU	%(1)	'000AU	%(1)	'000AU	%(1)	'000AU	%(1)	'000AU	%(1)	'000AU	%(1)	'000AU	%(1)	'000AU	%(2)
Low _less 3 AU/km²	5.4	6.1	15.8	17.7	60.9	68.4	3.8	4.3	--	--	--	--	1.7	1.9	89.1	0.7
Medium _3-80 AU/km²	496.7	4.6	4,043.5	37.2	1,977.2	18.2	1,248.9	11.5	1,748.7	16.1	1,005.9	9.3	340.3	3.1	10,861.0	81.1
High _over 80 AU/km²	275.2	11.4	499.3	20.7	--	--	20.1	0.8	747.4	30.9	846.9	35.0	27.6	1.1	2,416.7	18.1
Exclusion (3)	8.4	46.7	4.2	23.3	1.1	6.1	1.5	8.3	1.1	6.1	--	--	1.4	7.8	18.0	--
All densities	785.6	5.9	4,562.7	34.1	2,039.5	15.2	1,274.2	9.5	2,498.0	18.7	1,853.7	13.8	371.1	2.8	13,384.8	100

Notes:

-- too small to be expressed

1. Provincial share of each density class.

2. National share of each density class.

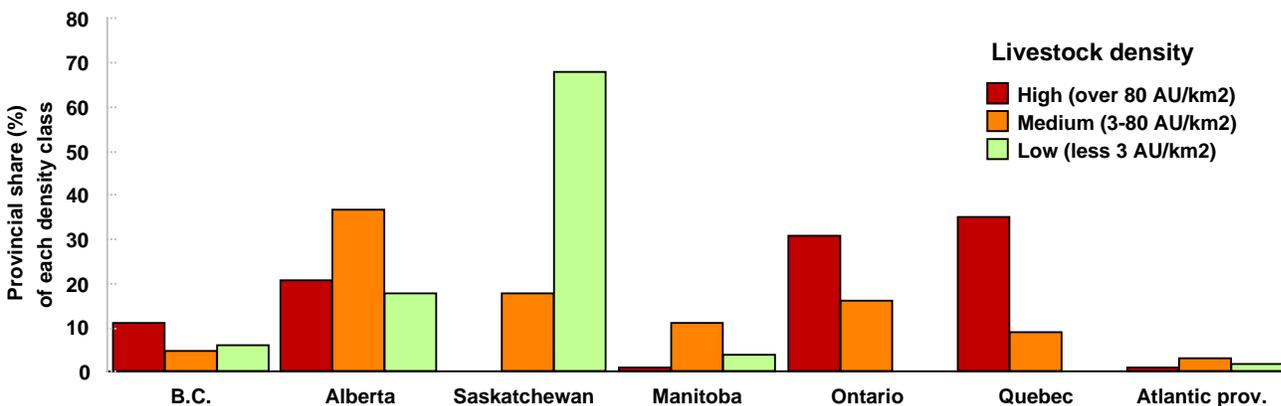
3. No density recorded. Excluded from the map to hide data that could be confidential.

Due to rounding, figures may not add up to totals.

Source: Statistics Canada, derived from the 1996 Census of Agriculture.

Quebec (35.0%) and Ontario (30.9%) together held two-thirds of the livestock in high-density areas. Alberta (20.7%) had the third largest share (Figure 1).

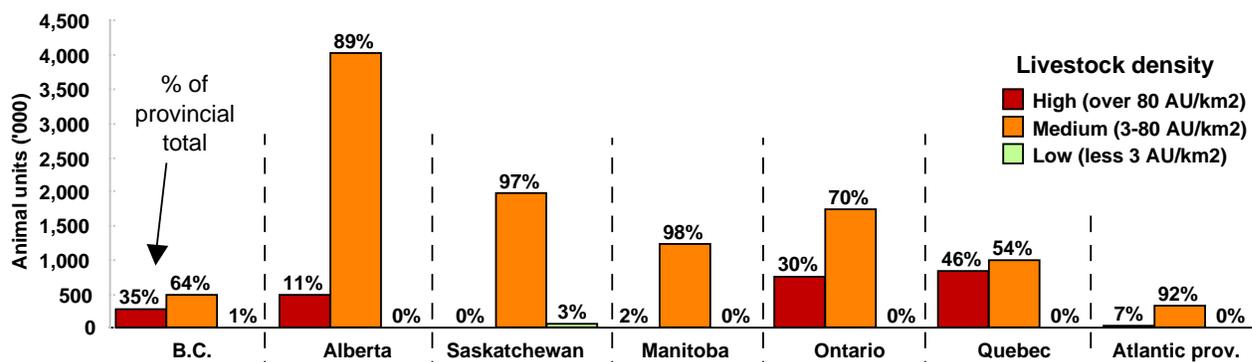
Figure 1: Distribution of livestock within each density class, by province, May 1996



Source: Statistics Canada, derived from the 1996 Census of Agriculture.

Within each province, over 50% of all the livestock was located in medium-density areas. However, nearly half the livestock in Quebec and around one-third of the livestock in British Columbia and Ontario was in high-density areas. These areas were predominant where there was a high population of livestock and/or a relatively low proportion of farmland to total land. (Figure 2).

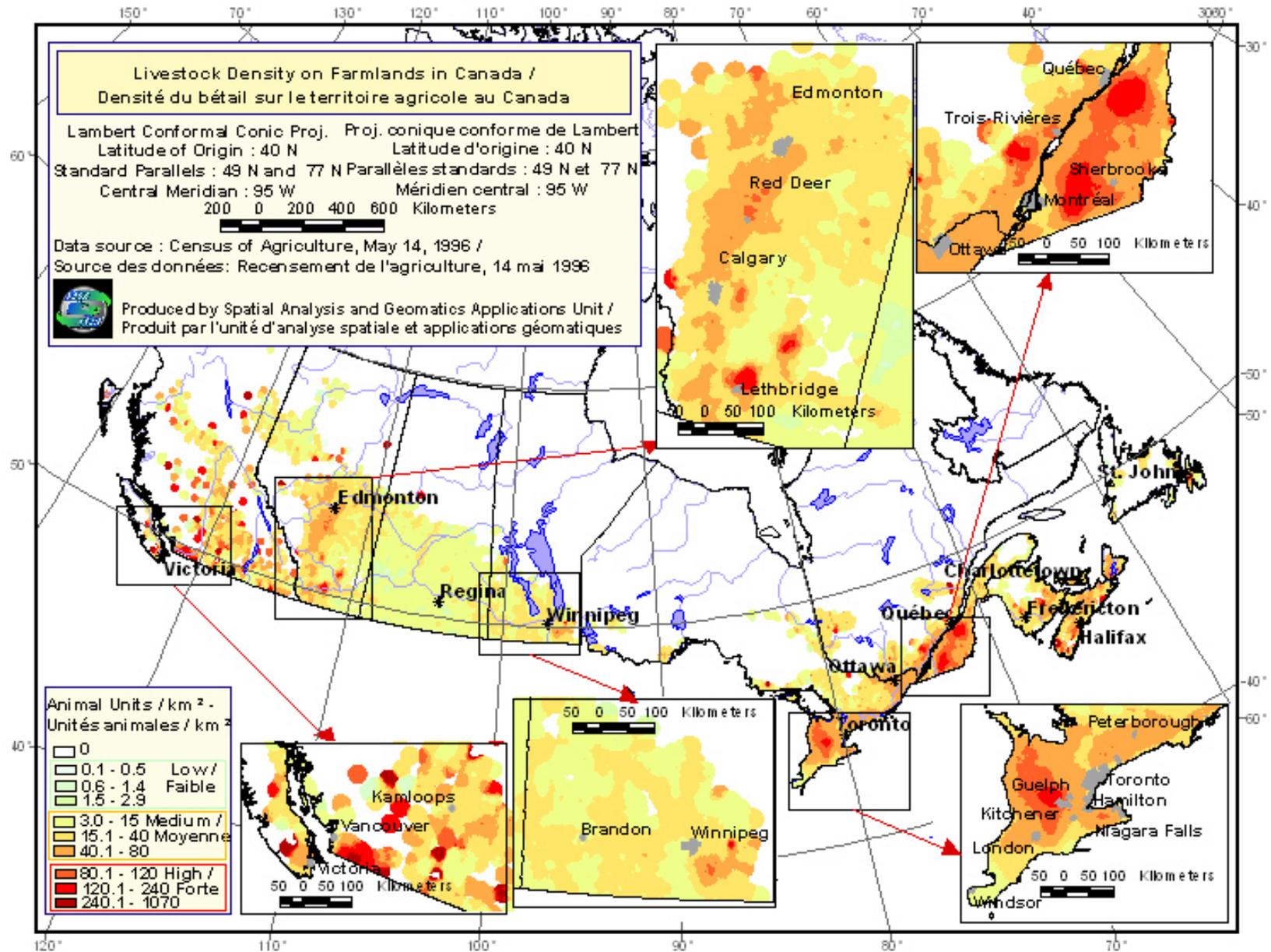
Figure 2: Distribution of livestock, by province and density, May 1996



Source: Statistics Canada, derived from the 1996 Census of Agriculture.

From west to east on Map 4, pockets of higher concentration of livestock can be seen in the following regions: south of the Fraser River in British Columbia; Lethbridge and Newell counties in Alberta; near Winnipeg in Manitoba; the area north of Waterloo Regional Municipality and parts of Perth, Wellington, Bruce and Grey counties in southwestern Ontario; and Chutes-de-la-Chaudière, Nouvelle-Beauce, Acton and Haute-Yamaska in Quebec. (See Appendix F for detailed regional maps.)

Map 4: Livestock density, Canada, May 1996



Within each province, some clusters or groups of enumeration areas had high densities of livestock. Sub-provincial livestock concentration was analysed using sub-drainage basin boundaries.¹⁹ Table 2 summarizes the data at the sub-basin level for enumeration areas with a high concentration of livestock. The sub-basins were sorted by decreasing number of total livestock in high-density areas. For example, the Central St. Lawrence sub-basin contained 5,510 farms, 419 enumeration areas,²⁰ 535,592 animal units, 270,347 animal units of cattle, 170,570 animal units of pigs and 78,463 animal units of poultry, all located in areas of high livestock density. The highest count in a single enumeration area was 14,700 animal units. The highest number of livestock in a 20-kilometre radius circle around the centroid of one enumeration area was 115,738 animal units. And the circle with the highest density in this particular sub-basin had 212.6 animal units per km².

This table reveals that some hot spots were not necessarily the result of a large number of livestock. In some areas, a small number of farms with limited livestock may also have high livestock density in situations where there is a limited amount of farmland available.

Table 2: High livestock density areas, by sub-basin, May 1996

Province	Sub-basin	In high livestock density areas						Within an enumeration area (EA)		Within a 20-kilometre radius		Density (AU/km ²)	
		Total	Cattle	Pigs	Poultry	Farms	EAs	Livestock animal units (AU)		Density (AU/km ²)			
		animal units (AU)						number	Max.	Min.	Max.	Min.	Max.
Quebec	Central St. Lawrence	535,592	270,347	170,570	78,463	5,510	419	14,700	1	115,738	3,309	213	80.2
Ontario	North Lake Erie	382,090	237,669	89,400	37,793	4,734	143	10,490	15	166,733	40,679	177	80.6
Ontario	East Lake Huron	313,913	231,890	40,952	28,527	4,278	118	9,522	5	136,139	31,815	147	80.3
Quebec	Lower St. Lawrence	309,111	183,828	98,346	21,428	3,564	191	16,771	1	131,804	3,194	250	80.4
Alberta	Upper South Saskatchewan	271,048	253,058	10,347	3,592	620	16	55,065	10	245,133	89,182	238	85.5
B.C.	Fraser	227,309	126,393	13,407	66,555	3,902	171	8,605	3	127,544	61	890	82.0
Alberta	Red Deer	117,147	102,567	8,454	2,748	634	15	34,529	155	75,448	53,076	167	80.2
Alberta	Battle	86,632	76,759	6,723	229	512	10	25,585	5	99,110	62,486	117	80.3
Ontario	Lake Ontario	35,099	13,808	2,150	17,407	522	19	5,186	94	56,891	26,354	101	80.1
B.C.	Thompson	30,480	28,050	2	11	91	10	24,496	74	25,047	296	2,543	81.9
Alberta	Bow	19,106	18,131	378	37	112	9	12,828	5	71,906	1,310	154	87.1
Manitoba	Red	18,779	9,105	5,355	3,756	194	7	4,041	645	87,164	47,127	119	83.1
Atlantic	Bay of Fundy	11,873	4,890	1,883	626	154	21	2,618	1	9,322	1,301	1,167	82.4
Ontario	East Georgian Bay	10,469	8,352	354	800	224	10	3,085	17	49,118	35,087	88	80.6
Atlantic	Saint John	7,463	811	560	6,086	37	7	5,177	29	10,357	2,625	551	94.8
B.C.	Upper Peace	6,044	5,270	4	8	38	2	4,841	1,203	4,841	1,203	251	163.1
Ontario	Rideau and Lower Ottawa	5,747	4,786	548	190	69	4	3,252	216	47,620	42,470	86	80.1
Alberta	Pembina and Central Athabasca	5,062	4,441	88	3	84	4	3,427	95	13,882	1,351	201	91.6
B.C.	Upper Fraser	3,447	2,974	37	3	62	3	2,089	659	2,089	659	124	100.3
Atlantic	Southeast Atlantic Ocean	3,362	1,143	7	1,722	77	21	1,206	1	5,168	46	569	88.7
B.C.	Columbia	3,157	2,393	6	7	93	14	860	4	2,243	71	1,251	87.4
Atlantic	Saint John & S.Bay Fundy	1,829	1,309	138	288	47	9	439	41	7,663	374	165	80.6
B.C.	Skeena	1,798	1,593	3	3	36	3	1,566	24	1,647	24	147	86.8
Atlantic	Gulf St. Lawrence & N.Bay Fundy	1,794	1,385	2	360	33	4	697	86	3,932	1,969	120	81.2
B.C.	Knight Inlet & S.Pacific Ocean	1,502	1,363	0	0	17	1	1,502	1,502	1,502	1,502	173	172.5

Note: Includes only enumeration areas with livestock density greater than 80 animal units/km².

Source: Statistics Canada, derived from the 1996 Census of Agriculture.

The measurements of livestock densities reported here are understated because the method used makes the assumption that all farmland could be used to spread the manure. In practice, not all farmland can be fertilized with manure. As well, a farm operator may decide to spread manure on only a portion of the

19. Sub-basins are subsets within river basins or watersheds. Their boundaries follow heights of land and delineate water surface drainage areas. These physical boundaries, which transcend administrative, political and other types of boundaries, are more relevant for assessing the potential environmental impact of livestock concentration.

20. A high number of enumeration areas can be expected in highly populated areas.

farmland, depending on the cropping system, the hauling distance and the minimum distance from neighbours or bodies of water. Consequently, the livestock densities reported here might very well be higher, but it was not possible in this study to identify the area and location of farmland actually used for manure spreading. Nevertheless, the maps and tables in this report that show animal densities on farmland are still unique because they provide a good image of the spatial concentration of all farm animals, regardless of their types.

Types of livestock found in high-density areas

At the national level, in May 1996, almost two-thirds of all livestock was beef cattle (62.6%), followed by dairy cattle (17.8%), hogs (8.5%), other livestock (6.2%) and poultry (4.9%). Livestock and poultry are expressed in animal units.

Beef cattle were predominant in Alberta, Saskatchewan and Ontario. As expected, dairy cattle were predominant in Quebec and Ontario. Hog inventories were largest in Quebec, followed by Ontario, Manitoba and Alberta. Most poultry stocks were in Ontario and Quebec. Production of 'other livestock and poultry,' including sheep, horses and exotic animals, was predominant in the Prairie provinces (Table 3).

Table 3: Livestock in high-density areas, by livestock type and province, May 1996

Livestock type	B.C.		Alberta		Saskatchewan		Manitoba		Ontario		Quebec		Atlantic prov.		Canada	
	'000AU	%(1)	'000AU	%(1)	'000AU	%(1)	'000AU	%(1)	'000AU	%(1)	'000AU	%(1)	'000AU	%(1)	'000AU	%(2)
Beef cattle	438.8	5.2	3,851.2	45.9	1,754.7	20.9	824.7	9.8	982.4	11.7	395.3	4.7	135.4	1.6	8,382.4	62.6
Dairy cattle	154.2	6.5	204.4	8.6	71.3	3.0	114.1	4.8	823.9	34.7	876.9	36.9	132.0	5.6	2,376.7	17.8
Hog	17.3	1.5	179.0	15.8	77.4	6.8	179.6	15.9	290.3	25.6	356.3	31.5	33.0	2.9	1,132.9	8.5
Poultry	84.5	12.8	62.7	9.5	23.1	3.5	47.7	7.2	238.1	36.1	154.7	23.5	47.9	7.3	658.8	4.9
Other	90.8	10.9	265.5	31.8	113.1	13.6	108.2	13.0	163.5	19.6	70.6	8.5	22.7	2.7	834.5	6.2
All types	785.6	5.9	4,562.7	34.1	2,039.5	15.2	1,274.2	9.5	2,498.0	18.7	1,853.7	13.8	371.1	2.8	13,384.8	100

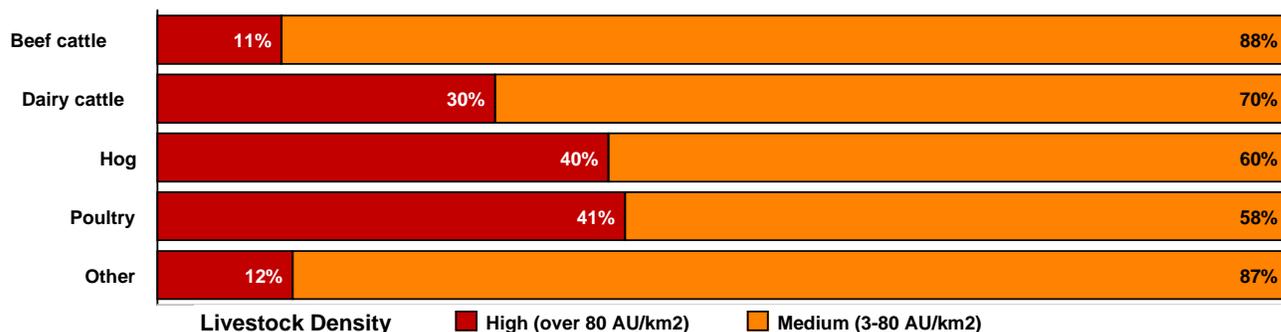
Notes:

1. Provincial share of each livestock type.
 2. National share of each livestock type.
- Due to rounding, figures may not add up to totals.

Source: Statistics Canada, derived from the 1996 Census of Agriculture.

Figure 3 shows, for each livestock type, that a larger share of poultry, hog and dairy animals was found in high-density areas than in medium-density areas. Hog and poultry production and, to a lesser extent, dairy production have been associated with enterprises that purchased their feed grains, thus requiring a relatively small amount of land to operate. Such operations predominate in Central Canada where proportionately less farmland is available.

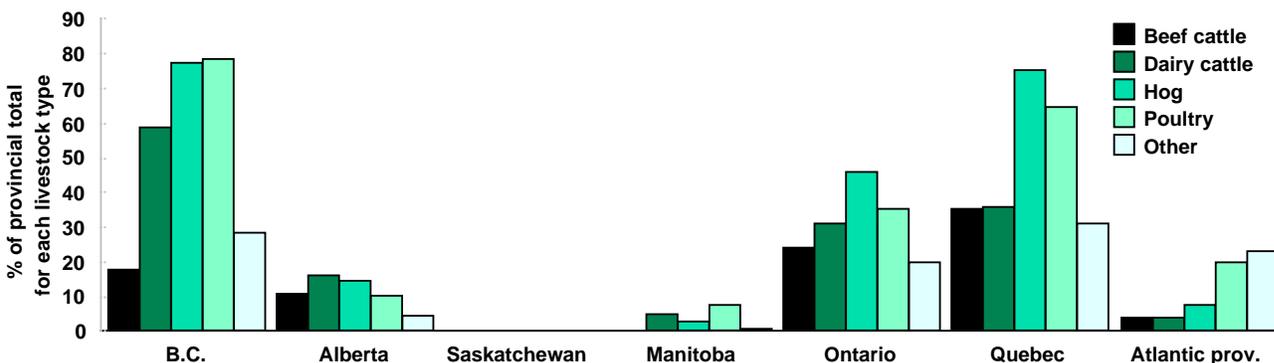
Figure 3: National distribution of livestock, by livestock type and density, May 1996



Source: Statistics Canada, derived from the 1996 Census of Agriculture.

Figure 4 shows the intensity of hog, poultry and dairy production in British Columbia, Quebec and Ontario, compared with the Prairie provinces and the Atlantic provinces. In British Columbia, more than three-quarters of the provincial hog and poultry inventories and well over half of all dairy cattle were concentrated in high-density areas. Quebec and Ontario also had significant proportions of their hog, poultry and dairy stocks in high-density areas.

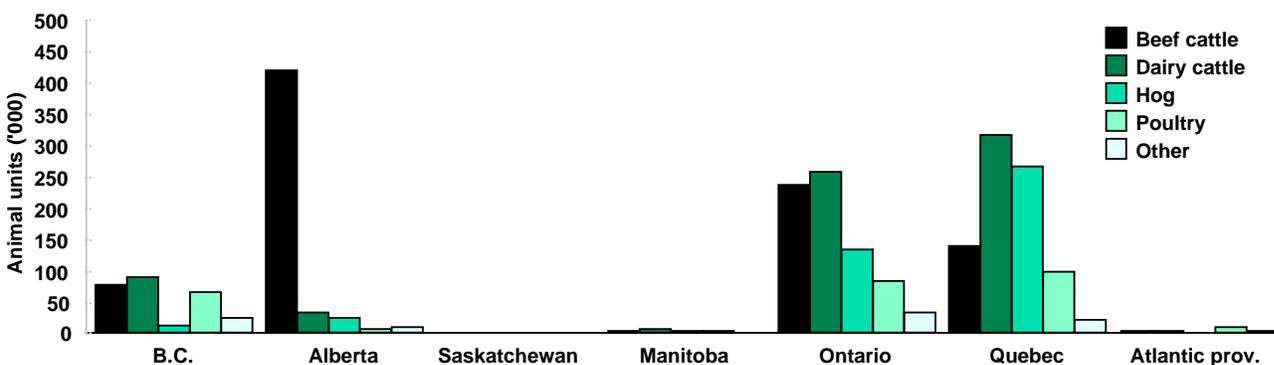
Figure 4: Proportion of livestock in high-density areas, by livestock type and province, May 1996



Source: Statistics Canada, derived from the 1996 Census of Agriculture.

Figure 5 presents the inventories (in animal units) of different types of livestock located in high-density areas and their distribution within each province. The largest livestock populations found in high-density areas were beef cattle in Alberta, dairy cattle and hogs in Quebec, and beef and dairy cattle in Ontario.

Figure 5: Numbers of livestock in high-density areas, by livestock type and province, May 1996



Source: Statistics Canada, derived from the 1996 Census of Agriculture.

Conclusion

The number of livestock farms in Canada is shrinking. However, farming operations are getting larger and more intensive. With large farms come large concentrations of animals and manure. A first reaction would be to think that environmental regulations and codes of practices should focus their attention on large livestock operations.

In order to better understand where the larger concentrations of all livestock and poultry were, inventories reported in the 1996 Census of Agriculture were converted into a common measure, animal units, and mapped to display generically the distribution and concentration of Canadian livestock. Presenting the density of the total livestock and poultry population in a particular area is a good start to evaluate its impact on the environment. It is the cumulative effect of all types of livestock production that may affect the environment.

Findings indicate that livestock concentration is not necessarily linked to large livestock populations. Some high-density areas appeared to be due to a rather limited amount of livestock associated with an even smaller farmland base. Certainly this situation is a factor limiting production expansion. Analysing concentrations of all livestock present on all farms, regardless of the size of the farm and the type of animals, is the best way to get the whole picture.

This study cannot conclude whether or not large livestock farms contributed the most to a greater concentration of livestock in some areas. Exploring this would require further work to link livestock densities with farm level data and characteristics—such as type of farm, operating arrangements and farm size.

Additional research would be required before concluding whether or not the livestock concentration in certain regions had reached limits where it could pose an ecological threat. It would require establishing local or regional nutrient budgets based on amount of manure produced, farmland available for manure disposal, soil characteristics, crop requirements, and use of chemical fertilizer and municipal sewage sludge. This could help identify areas where the environment might be at risk from a lack of sufficient land to recycle animal waste.

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Appendix A Definitions

Census consolidated subdivision (CCS)

A census consolidated subdivision is a grouping of census subdivisions (see below). Generally the smaller, more urban census subdivisions, such as towns and villages, are combined with the surrounding larger, more rural census subdivision, in order to create a geographic level between the census subdivision and the census division.²¹

Census division (CD)

Census division is the general term applied to intermediate geographic areas established by provincial law between the municipality (census subdivision) and the provincial levels. Census divisions represent counties, regional districts, regional municipalities and other types of provincially legislated areas.²²

Census farm

A census farm is an agricultural operation that produces at least one of the following products intended for sale: crops (field crops, tree fruits or nuts, berries or grapes, vegetables, seed); livestock (cattle, pigs, sheep, horses, exotic animals, etc.); poultry (hens, chickens, turkeys, exotic birds, etc.); animal products (milk or cream, eggs, wool, furs, meat); or other agricultural products (greenhouse or nursery products, Christmas trees, mushrooms, sod, honey, maple syrup products).

The definition of a census farm was expanded in 1996 to include commercial poultry hatcheries and operations that produce only Christmas trees.²³

Census of Agriculture

The Census of Agriculture, conducted every five years, produces a snapshot of Canadian agriculture by providing statistics at national, provincial and sub-provincial levels on crop areas, number of livestock, number and value of farm machines, farm operating expenses and receipts, purchase of capital assets, weeks of paid labour, and land management practices.²⁴ The 1996 Census of Agriculture was conducted on May 14, 1996.

Census subdivision (CSD)

Census subdivision is the general term applied to municipalities (as determined by provincial legislation) or their equivalent (for example, Indian reserves, Indian settlements and unorganized territories).²⁵

21. For details, see Statistics Canada (1999b), pp. 178–180.

22. For details, see Statistics Canada (1999b), pp. 180–182.

23. For details, see Statistics Canada (1997), p. xxxi.

24. For details, see Statistics Canada (1999b), pp. 178–180.

25. For details, see Statistics Canada (1999b), pp. 195–197.

Confidentiality

The Statistics Act requires that all census information be kept confidential. No person or institution outside Statistics Canada (including other government departments and agencies, the courts and the RCMP) can access census information provided by individual respondents. For this study, all tabulated data and maps were subject to confidentiality restrictions. A series of computerized checks was performed to suppress data that could result in the disclosure of information concerning a particular agricultural operation or individual. Any area with a 20-kilometre radius that contained very few farms was not displayed separately, but was simply suppressed from the maps.

Enumeration area

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.²⁶

26. For details, see Statistics Canada (1999b), pp. 210-212.

Appendix B

Regulations, codes of practice and municipal by-laws related to livestock manure management²⁷

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Ontario, examples of nutrient management by-laws:

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- County of Brant. <<http://www.county.brant.on.ca/bylaws/bl00-121.htm>>. (Accessed March 2001)

27. This is not a complete list.
Catalogue no. 21-601-MIE01047

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Appendix C—Animal unit coefficients

	1	2	3	4	5	6	7	8
Selected coefficients	N.S.	N.B.	Qc.	On.	Mb.	Sk.	Ab.	B.C.
Poultry								
Broilers/roasters	200	1000 b	240	250	200	170	200	200
Pullets	300	300 b	505	250	500	300		300
Laying hens	120	125	144	125	125	100	100	120
Turkeys	71	100-300b	61-159	55-100	50-100	70-120	50	30-100
Duck				250	100		50	50
Geese	50						50	50
Other	50			100		130		50
Cattle								
Dairy cow s	0.75	1 a	0.8	1	1 a	0.5 b		0.75
Dairy heifers	1			2	2			1
Dairy calves	3.3	40 b		5	3-6			3.3
Dairy bulls	0.75			1				0.75
Beef cow s	1	1 a	1.1	1	1	0.83	1	1
Beef heifers	1.4	2 b	1.7	2	2	1.25-2.2	2	1.3-1.6
Beef Bulls	1	1		1			1	1
Beef steers	1.3	2 b	1.7	2	2		1.5	1.3
Beef calves	4.4			5			4	4.4
Pigs								
Boars	5			3	5	5.5	3	5
Sow s	5	4 a	5.1	4	5	3-4	3	5
Other over 45 lbs.	8	15 b	6.5	5	4	7	4-6	5-11
Other under 45 lbs.	30		23	25	20	50	20	30
Sheep & lambs								
Rams	7					5	7	7
Ew es & w ethers	5	4 a	4.6 a	4	4 a	5 b	7	7
Lambs	16			12-25	10	10	14	16
Other								
Horses	0.75	1		1	1 a	0.75	1	0.75 a
Goats	7		4.6	6	4-10		7	7
Rabbits	40	40 a	40	40	40 a			
Mink	80	100 a	80	100	80 a			
Foxes	40		40	40	40 a			
Bisons	1			1			1	1
Deers	8						8	8
Llamas								
Ostriches	7				3			7
Emus	16			10	5			16
Wild boars	4			5				4
Elks	5						5	1.9

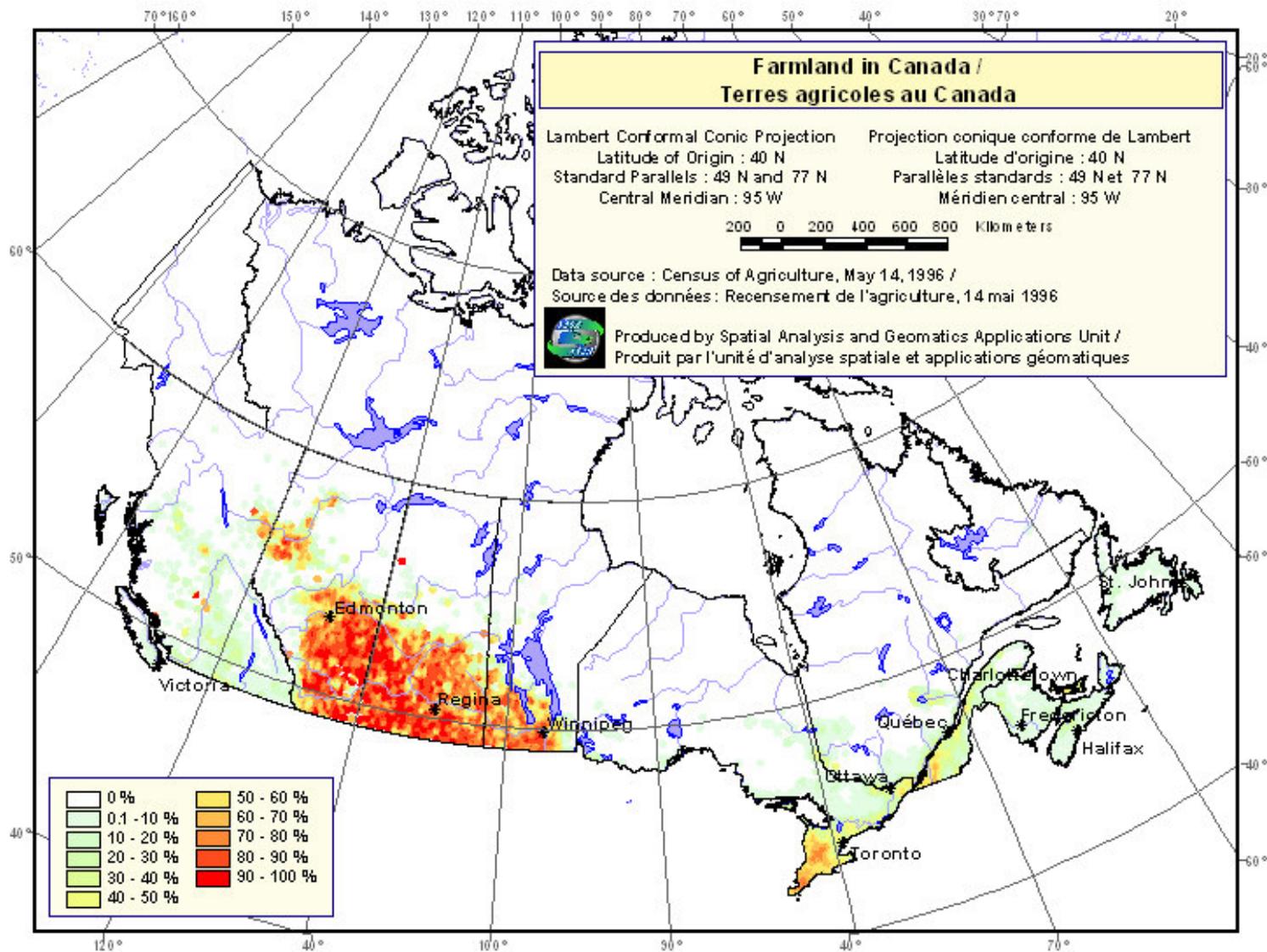
Notes:

- Includes offspring, calf, litter, kits or associated males.
- Marketed during a year.

Sources:

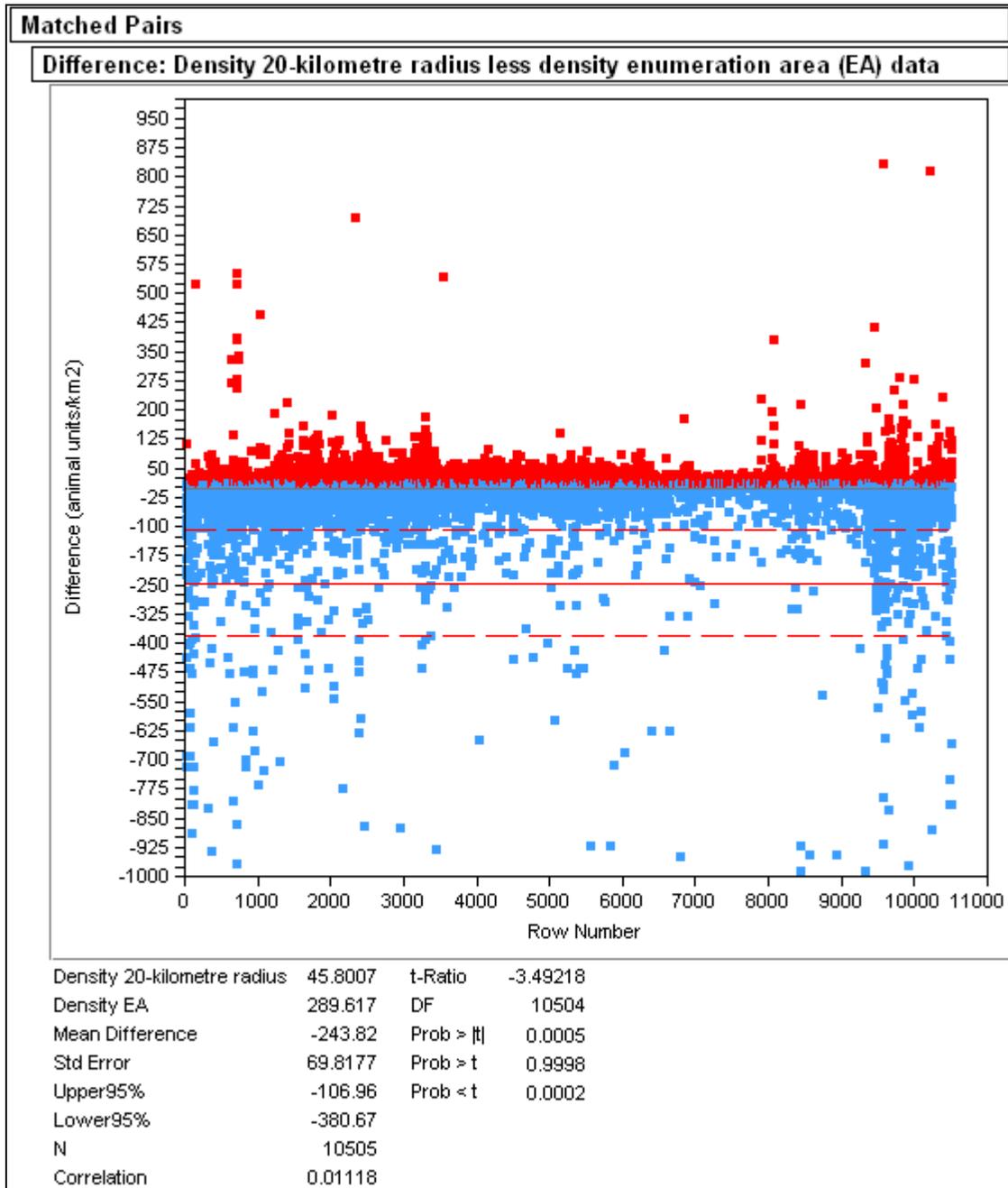
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- Combination of livestock equivalent to 455 kg. B.C. Agricultural Waste Control Regulation Waste Management Act.

Appendix D Map D1: Proportion of farmland over total land



Appendix E

Figure E1: Difference between livestock densities based on 20-kilometre radius method and densities based on enumeration area data



Notes:

Excludes extreme values (differences above 1000 or less than -1000 animal units/km²).

Overall, the 20 kilometre-radius method lowered density values (lower mean compared with mean value of densities calculated with enumeration area data).