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Estimation of Water Use in Canadian Agriculture in 2001

2001

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.	not available for any reference period
..	not available for a specific reference period
…	not applicable
0	true zero or a value rounded to zero
0^s	value rounded to 0 (zero) where there is a meaningful distinction between true zero and the value that was rounded
^{p}	preliminary
^{r}	revised
x	suppressed to meet the confidentiality requirements of the *Statistics Act*
A	excellent
B	very good
C	good
D	acceptable
^{E}	use with caution
F	too unreliable to be published

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I. Introduction: Estimation of water use in Canadian agriculture

Water is used for different activities in agricultural production. Water can be used to irrigate crops at specific times in the growing season to supplement water from precipitation or to simply replace it in a closed environment like a greenhouse. Water can be used to spray liquid pesticides and other products applied to protect crops, and to wash spraying equipment. Water can be sprayed on some crops for frost protection. It can also be used for harvesting a crop (e.g. flooding a cranberry field) or for cleaning equipment and facilities, washing produce and on–farm processing (e.g. canning produce). Water is also used in livestock production, e.g. livestock watering, cleaning, and washing and sanitizing equipment such as milk pipelines, parlours, buckets and tanks. In fact, the agricultural sector accounted for 9% of all water used in Canada in 1996, and 74% of this was consumed (Statistics Canada, 2003).

However, provincial agricultural water use estimates vary across Canada. While some estimates are derived from actual metered measurements of water flow, others are derived from surveys, and yet others are simply the result of educated guesses. The fact is that there is no common denominator across the country with regards to agricultural water use estimates. This paper describes the efforts and results of Statistics Canada to produce comparable agricultural water use estimates at the national, provincial and sub-sub-drainage area level for the reference year 2001.

The paper will first describe the methods that were adopted to produce the estimates. This is followed by a presentation of the results, including maps that show the quantity of water used by sub-sub-drainage area. We show how we calculated that Canadian agriculture water use was estimated at 4,786,590 thousand cubic meters (m^3) in 2001.

1 Methodology to produce agricultural water use estimates

In 2003, Statistics Canada estimated agricultural water use for the 1996 reference year (Statistics Canada, 2003). Irrigation water use estimates were developed based on the compilation of administrative data (e.g. irrigation district data), on the application of a model based on soil moisture deficit (where direct measurement did not exist) backed by expert opinions, and on water use coefficients applied to livestock counts.

These approaches were again applied to estimate agricultural water use for the 2001 reference year. However, another model was also developed: The “irrigated crop water allocation model” relates individual crops and their probability of being irrigated. These approaches are explained below.

1.1 Methods to estimate crop water use

Crop water use is estimated using several models and approaches related to irrigation water use and to the category “other crop use”. Crop water use includes water used for the following activities: irrigation; spraying herbicides, insecticides and fungicides; frost protection, sanitation washing, and harvesting; on-farm processing and other miscellaneous uses.

1.1.1 Estimation of irrigation water use

This section presents the methods used to estimate specifically irrigation water use.

Irrigated crop water allocation model

The irrigated crop water allocation model (ICWAM) was developed to address the issue of identifying which crops are effectively irrigated[1]. The model makes use of farm level Census of Agriculture data, i.e. crop area and irrigated area.

In the first step, logistic regression models are used to identify which crops are more likely to be irrigated. Ten models were developed, one for each province. These models reproduce the likelihood of the decision to irrigate crops (dependant variable) based on the presence or absence of various crops (explanatory variables).[2]

The logistic regression model is designed to estimate the parameters of a multiple regression analysis in which the dependent variable is categorical (in this case, the dependant variable takes the value of 1 when a farmer reported irrigated land and 0 otherwise). The model expresses the conditional log odds of reporting irrigated land as a linear function of a set of explanatory variables (in this case, a specific dummy variable for each crop that takes the value of 1 when the crop area was reported and 0 otherwise).

The model is specified as shown below.

$$\log\left(\frac{P_i}{1-P_i}\right) = \alpha + \sum_{k=1}^{K} \beta_k X_{ik} + \varepsilon_i$$

1. The Census of Agriculture asks farmers to report the total irrigated area in the year prior to the Census reference year, but does not ask which crops are irrigated.
2. Other variables, such precipitation, soil moisture deficit, irrigation permits, etc, could have been included in the models, but due to time constraints, the decision has been made to develop a simple model that could be improved upon later.

In this model P_i is the conditional probability that a farm $_i$ uses irrigation ($P(Y_i)=1$) given the explanatory variables in the model; $1-P_i$ is the conditional probability that a farm does not use irrigation; $\left(P_i/1-P_i\right)$ is the odds or the relative probability of falling into one of the two categories of interest; α (the intercept) and β_k (the predicted odds) are the logistic regression parameters to be estimated; X_{ik} is the kth explanatory variable associated with the ith farm in the model; and ε_i is the random error associated with the ith farm. Odds ratios are obtained by exponentiation of the logistic regression parameters. β is estimated by solving the weighted score equations. Variance was estimated via implicit Taylor linearization.

In the second step, specific crop water requirement coefficients[3] were applied to specific crops that were identified in the first step. For example, if the model for Ontario identified that growers reporting apple and peaches had significant greater odds of irrigating these crops, irrigation water was estimated for all farms in Ontario that reported irrigated land and apple or peaches using apple and peaches water requirements. As displayed in Appendix A, there is a lot of variability in the crop water requirement coefficients depending on the province. These coefficients will need to be revised and adjusted to local conditions to improve the quality of irrigation water use estimates. The odds ratios for each crop and province are presented in Appendix B.

The last step was to take into account the level of adoption of different irrigation technology used in each province. Irrigation water use estimates were adjusted according to the efficiency of different irrigation systems, based on the land area irrigated by each system. For example, 39% of irrigated area in Quebec was irrigated using gun systems, which have an average efficiency of 65%[4] (35% of water is lost through evaporation, run-off, etc.). Therefore, 39% of the irrigation water use was divided by 65%.

One serious limitation with the ICWAM model approach (as with any coefficient-based water requirement approach) is that the crop water coefficients reflect average environmental conditions. They are not adjusted to take into account regional environmental conditions (distribution of the precipitation and moisture deficit over growing seasons, temperature, soil type, wind speed, evaporation, ground coverage, etc.), or economic and regulatory conditions (water licences, conservation measures, expected economic returns, and fuel to run irrigation systems, etc.). Furthermore, the adoption of different irrigation systems is likely to change over time and within a province. Using average percentages for the adoption of irrigation systems may bias the geographical distribution of irrigation water use within a province. Nevertheless, the application of the model to the province where irrigation water is measured (Alberta) has demonstrated the usefulness and precision of the model.

Soil moisture deficit (SMD)

The soil moisture deficit (SMD) represents the amount of water that is needed to restore the soil moisture to the level necessary to grow a crop. This number is calculated by subtracting the effective precipitation (the portion of precipitation that actually reaches the surface) from potential evapotranspiration (the estimated amount of water that evaporates and transpires from the soil and plants). As evapotranspiration is continually drawing from soil moisture until the soil has dried up, irrigation is applied to replenish the soil moisture content when precipitation doesn't suffice. Thus, the SMD can be used to estimate irrigation since irrigation is only applied when necessary. Volume of irrigation water was calculated using this approach by multiplying the area irrigated (from the 2001 Census of Agriculture) by the depth of the soil moisture deficit.

3. Coefficients used were mainly from Ivey (1998) but also from various sources. Ivey's coefficients are the most comprehensive sources of coefficients at this point of time. There were substituted by other coefficients based on their availability.
4. The average efficiency used for the different irrigation systems was 65% for gun, 75% for sprinkler, 90% for drip, 50% for flood and 90% for the other systems.

Moisture deficit (depth, in meters) = $\dfrac{\textit{Volume of water (cubic meters)}}{\textit{Land area irrigated (square meters)}}$

A limitation with this method is that it is based on the assumption that all crop growers will apply irrigation only when necessary while it is known that other factors may influence their decision. These factors include expected economic return, the immediate availability of irrigation equipment and water to irrigate. Furthermore, SMD overestimates irrigation water use as potential evapotranspiration calculations are normally greater than actual crop use. Potential evapotranspiration is usually estimated for a reference crop like a grass plot. Adjustments should be made to take account that the irrigated crops usually have lower water requirements than the reference crop, that they are usually shorter season crops, and that they use non-consumptive (yet beneficial) irrigation water applications.

Model for British Columbia

This method was developed to produce an irrigation water use estimate that takes advantage of readily available spatial data for British Columbia. The Geographical Information System for Irrigation Water Use (GISIWU) is executed in a few steps. First, SMD values were retrieved through the “farmwest.com” website for the 38 meteorological stations reporting data throughout the May 1st – September 30th growing season of 2001. These values were entered as point data into a GIS coverage, and Thiessen Polygons were built to extrapolate SMD values across the province. To account for the inefficiency of irrigation methods, provincial irrigation regions (a total of eight for the province) were digitised and the efficiency coefficient for each region was entered as a polygon attribute[5]. Census irrigated areas were available at the Enumeration Area[6] (EA) level, so this polygon coverage was overlayed with the moisture deficit Thiessen polygons and the regional irrigation efficiency polygons. The resulting attribute table was then exported for further analysis.

Any EA which fell into more than one polygon in either of the overlayed coverages would have produced multiple records in the table. To overcome this situation, irrigated area in an EA was divided evenly between the records for that EA. For example, if an EA overlapped with four different SMD /efficiency polygons, then the reported irrigated area for this EA was divided evenly by four and assigned to each different SMD /efficiency polygon. This irrigated area (square meters) was then multiplied by the SMD (meters) and the efficiency (dimensionless) values from the overlayed polygons to derive the volume of water used for irrigation (cubic meters).

Average efficiency values for the eight regions ranged from 50% to 69%. Actual efficiencies of systems in the various regions ranged from 10% for contour ditch–wild flooding techniques to 92% for trickle–drip systems.

One limitation with GISIWU estimates is the assumption made that there was no change in the distribution of irrigation systems between 1995 and 2001.

1.1.2 Methods to estimate other water uses in crop production

Water in crop production is used for many other activities such as spraying liquid pesticides, washing spraying equipment, irrigating crops produced in greenhouses, protecting crops from frost, harvesting crops, cleaning equipment and facilities, washing and on–farm processing of produce. It is difficult to measure water used for each activity. Even if water use was metered, it would be quite difficult to differentiate the amount that was used for sanitation purposes versus the amount used for spraying. The amount of water used for these activities was based on a set of coefficients, presented in Appendix C. Since the amount of water used for these activities is not as important as the amount used for irrigating crops, the use of these coefficients is judged sufficient for this study.

5. Region boundaries and efficiency coefficients were retrieved from an unpublished paper from the government of British Columbia.
6. An enumeration area is the smallest standard geographic area for which Census data are collected. Canada’s entire surface area is divided into enumeration areas.

Water use for spraying pesticides

The amount of water used to spray pesticides (i.e. herbicides, insecticides and fungicides) was estimated with coefficients that were applied to each crop if a farmer reported chemical expenses. This was estimated for all crop growers, regardless of whether they had reported irrigating their crops or not. Spraying water use coefficients are presented in Appendix C. The precision of these estimates could potentially be improved using pesticide suppliers' sales data of more commonly used products and recommended rate of application. However, this was beyond the scope of this study.

Other water use in field crop farming

Other water use in crop farming includes water used for washing spraying equipment, frost protection, sanitation washing, harvesting/transport, on-farm processing and other miscellaneous uses. Other crop water use coefficients were applied to specific crops for all crop growers, regardless of whether they had reported irrigating their crops or not. For washing spraying equipment, coefficients were only used for farmers reporting chemical expenses. Other crop water use coefficients are presented in Appendix C.

Greenhouse water use

Area of greenhouse operations collected from the 2001 Census of Agriculture were used with greenhouse water use coefficients (Appendix C). The Census collects data on the area of greenhouse space used in the production of greenhouse vegetables, flowers, and other products (such as cuttings and seedlings).

On one side, greenhouse irrigation coefficients are based on the depth of water (m/m^2/year) applied and the average number of applications required per year for watering. On the other side, greenhouse equipment washing coefficients and for pesticides spraying are based on the volume applied and the number of applications required per year (L/m^2/year). They were available for both potted and (other) flowers, a few varieties of vegetables, and other greenhouse products. The average of the coefficients for the different vegetable varieties was calculated and used for the greenhouse vegetable area. Data regarding the area required to grow potted vs. non-potted flowers is unavailable, so the total greenhouse area used for flowers was divided in half and the potted and non-potted flower coefficients were applied to equal areas. The other products category was not considered further.

1.2 Methods to estimate water use in livestock and poultry production

Like water use for crop production, it is quite a complex task to try to measure the actual amount of water that is used for livestock production. Even if the amounts were closely monitored with a water meter, it would be difficult to determine the share related to specific livestock production activities among all other farming activities accomplished on a farm. Therefore, it is necessary to estimate the amount of water used for livestock production based on animals' biological water requirements and the frequencies and amount required for some other activities.

For this study, livestock water use was estimated through the application of different water use coefficients to the inventories of each type of livestock in the 2001 Census of Agriculture. Several sources were used to compare the selected coefficients (see Appendix D).

There are several limitations to this approach. For example, Canadian farmers reported livestock inventories at a specific Census time (May 15 in 2001 for the 2001 Census of Agriculture) on their Census form. Livestock and poultry inventories at one point in time do not represent the number of animals on farms during the whole year. Depending on the species and growth stage, inventories are likely to change over the year. The assumption was taken for this analysis that in the absence of better information or an appropriate method to distribute the inventories within a year, the Census inventories represent the average size of the total livestock inventories for the whole year.

Another limitation is that no adjustments were made to livestock water use coefficients to account for differences in various climatic conditions, watering and washing equipment use across regions and/or over time. The assumptions were made that the watering coefficients represent average climatic conditions and that all farms are using watering or cleaning devices with similar efficiencies.

Coefficients could be rendered more scientific if adjusted to reflect climatic variations throughout the year. Livestock water intake, for example, may increase by as much as 30% during very hot months. However, knowing more about the distribution of animals confined in barns with climate controlled environments, and animals raised for most of the year outdoors, would improve the estimates.

The type of equipment used may also influence water use. Efficiency of watering devices and spillage, especially in swine operations, may vary significantly depending of the type of equipment used. Different methods for cleaning barns may also alter water use. The farrowing component of swine farms would be adjusted if different methods of cleaning were considered. Some farms may use straw for litter and remove it when the sows wean, instead of cleaning using water from a pressure washer. Little information exists on the adoption of different types of equipment used across Canada, making it difficult to introduce additional precision in a statistically reliable matter.

Genetic changes to animals may also change water use coefficients over time. For example, the size of dairy herds has been decreasing but milk production has continued to climb. Declines in the dairy cattle population may not affect water consumption at uniform rate, given that water intake increases when dairy cattle produce more milk.

1.2.1 Drinking water in livestock and poultry operations

The water use estimate for livestock watering was calculated by multiplying livestock counts from the 2001 Census of Agriculture by livestock water use coefficients (Appendix D). In some cases, provincial coefficients existed but their values were fairly consistent with other sources so no provincial differentiations were made.

1.2.2 Cleaning water in hog farrowing operations

In addition to pig watering, water use coefficients were used to measure amount of water lost by spillage and used for cleaning in farrowing operations. A significant proportion of drinking water is lost to spillage (sometimes as much as 50%). A spillage coefficient of 0.2 L per animal per day was applied to the number of pigs weighting less than 20 kg. A spillage coefficient of 3.5 L per animal per day was multiplied to the pig inventories in the other weight categories.

Water is also used to clean out the farrowing facilities after the sows farrow their litters. Based on feedback from pig specialists, farrowing water usage on a per sow basis is set to:

Water per farrow operation per sow = 500 L;   Farrowing = 2.2 times per year

Water used in farrowing operations (L per year) = 500 L x 2.2 x sow inventories

1.2.3 Cleaning water in poultry broiler operations

In poultry broiler operations, barn cleaning and washing takes place after each shipment of birds for slaughtering. The amount of water used to clean poultry barns (1.5 gallons / square foot) was obtained from the records of a water service company. The minimum square footage per bird was obtained from Agriculture and Agri-Food Canada and the water use per square foot was applied to the entire broiler inventories, as measured in the Census of Agriculture.

1.34 square feet (sq.f.) per bird

Water use per square foot of space = 0.2271 L

Frequency = 5.5 times per year (shipments of birds same size as inventories profiled on Census day)

Water used in broiler operations (L per year) = 1.34 sq. f. x 0.2271 L x 5.5 x broiler inventories

1.2.4 Cleaning water in dairy cattle operations

The cleaning of dairy equipment requires water, with the specific amount depending on the type of milking system the dairy farm uses. There are three main types of milking systems: pipeline, parlour and bucket.

A coefficient was provided by the Ontario Ministry of Agriculture, Food and Rural Affairs representing the average water use regardless of the type of milking system. It was decided to use this proxy given the inherent difficulty of assessing the distribution of these different systems, and also given the fact that more specific coefficients for milking system sanitation and washing were not sufficiently precise to improve the analysis. The coefficient represents average water used per cow in milking operations. Using this coefficient enables all dairy use to be captured by applying it to the milk cow inventories, as estimated on Census day. Dairy farm water use is 18 L of water per cow per day. This includes equipment washing and sanitizing, floor spraying and udder rinsing.

2 Agricultural water use estimates

This section presents the estimates for total agricultural water use following the estimates for the various categories described above.

2.1 Total irrigation water use

In 2001, 4,424,600 thousand cubic meters (m^3) were used to irrigate crops (Table 1). Alberta had the greatest share of irrigation water use with 2,900,000 thousand m^3. British Columbia and Saskatchewan were in second and third position with 845,000 and 500,000 thousand m^3 respectively. The three westernmost provinces constituted 95.9% of total water used for irrigation (Table 1).

Table 1
Total irrigation water use, Canada and provinces, 2001

	Irrigation estimation models			Final irrigation water use estimates	
	ICWAM[1]	GISIWU[2]	Others[5]	Total	
	thousand m^3				percent
Canada	**4,370,750**			**4,424,600**	**100.0**
Newfoundland and Labrador	189	2,042[3]	..	200	0.0
Prince Edward Island	1,664	1,368[3]	7,207[6]	1,400	0.0
Nova Scotia	5,379	8,184[3]	..	5,400	0.1
New Brunswick	1,602	1,790[3]	1,661[7]	1,600	0.0
Quebec	49,599	..	32,994[8]	49,000	1.1
Ontario	91,526	182,076[3]	109,614[9]	92,000	2.1
Manitoba	32,490	..	28,970[10]	30,000	0.7
Saskatchewan	431,292	542,131[3]	278,275[11]	500,000	11.3
Alberta	3,017,486	2,959,830[3]	2,705,551[12]	2 900,000	65.5
British Columbia	739,524	844,900[4]	..	845,000	19.1

Notes:
Due to rounding, figures may not add up to totals.
1. Irrigated Crop Water Allocation Model.
2. Geographical Information System for Irrigation Water Use.
3. Adjusted using an average irrigation system efficiency of 72%.
4. Adjusted using average irrigation system efficiency estimates for eight regions in British Columbia.
5. Other irrigation estimation models and data are described in section 1.1.1 of this text.
6. Based on average deficit of 127 mm and average irrigated area of 75 ha per farm; estimates provided by provincial specialists.
7. Based on average deficit of 130 mm; estimate provided by a provincial specialist.
8. BPR Groupe-conseil (2003), excludes nursery and sod operations.
9. de Loë (2005), also includes water used in pesticide applications and greenhouse operations.
10. 2001 Manitoba Irrigation Survey (2002): Survey of farmers with more than 50 acres of irrigated land (Gaia Consulting, 2002).
11. Based on soil moisture deficit estimate provided by a provincial specialist.
12. Measured discharge at provincial irrigation infrastructure. This estimate accounts for about 95% of water used for irrigation. Return flow of water that was diverted but not consumed is not included.

Final irrigation water use estimates were agreed upon after close review of all available information. The reliability and accuracy of the different estimates were considered for each province with respect to the methodology behind each approach, and the province's unique growing conditions. The final provincial irrigation water use estimate therefore is not, in most cases, the output from any one of the approaches, but a composite value that the authors believe reconcile the shortcomings of the various approaches.

2.1.1 Mapping total irrigation water use

Different combinations of ecological and agronomic conditions (such as soil type, crop grown, climatic conditions, moisture deficit, water use regulation, etc.) can affect the use of irrigation from region to region. Maps 1 and 2 show in which sub-sub-drainage areas (SSDA) irrigation water use was concentrated in 2001, based on the results of the ICWAM.

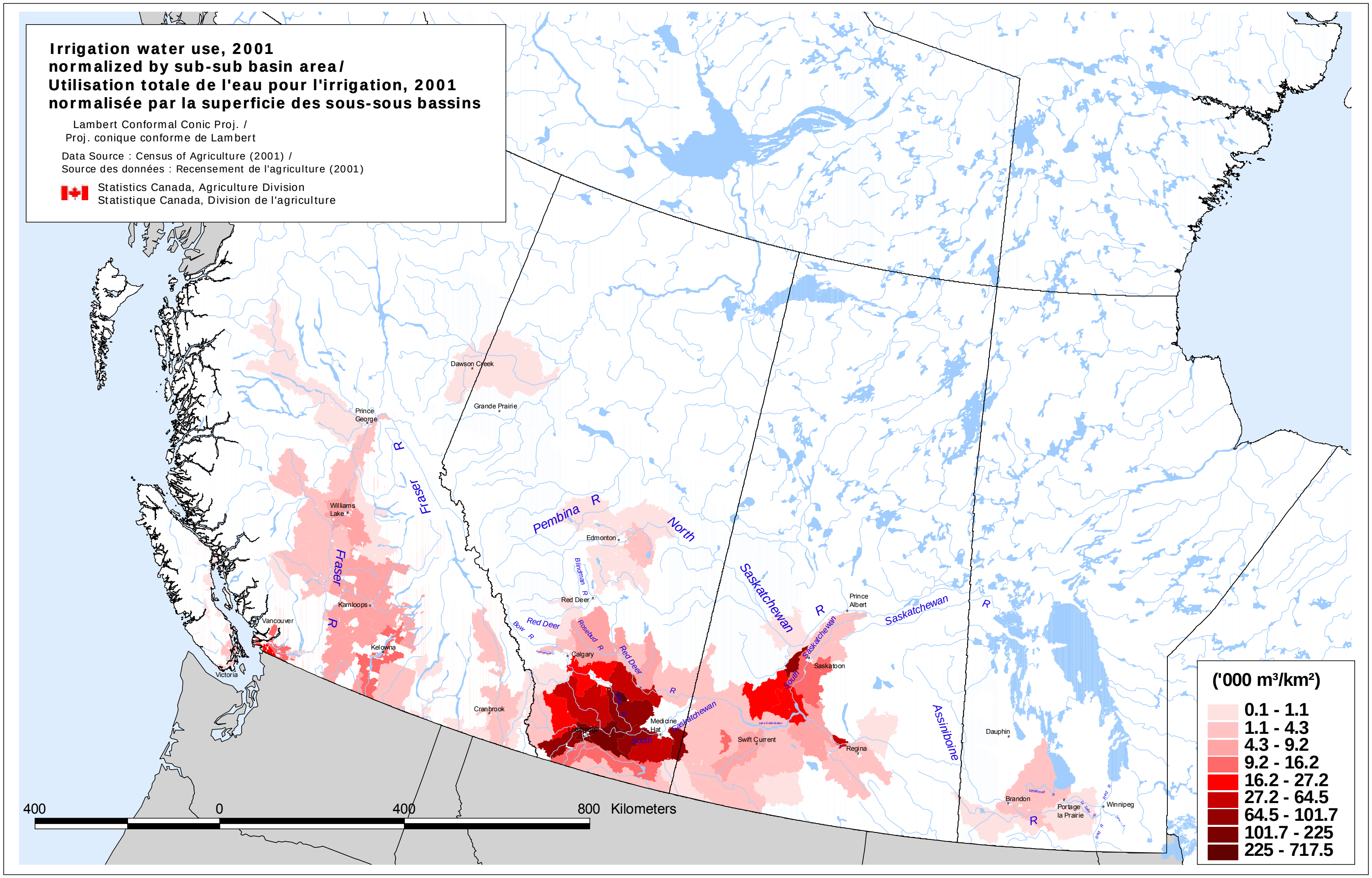
There was relatively more irrigation water use in the Lower Fraser Coast and the Okanagan SSDAs than in other areas of British Columbia (Map 1).

In Alberta, irrigation water use was clustered among a few SSDAs: the Central Oldman (Belly and Willow), Upper South Saskatchewan, Little Bow, St. Mary, Lower Oldman, Lower Bow (Crowfoot and Mouth), Lower Red Deer – Matzhiwin and the Seven Persons.

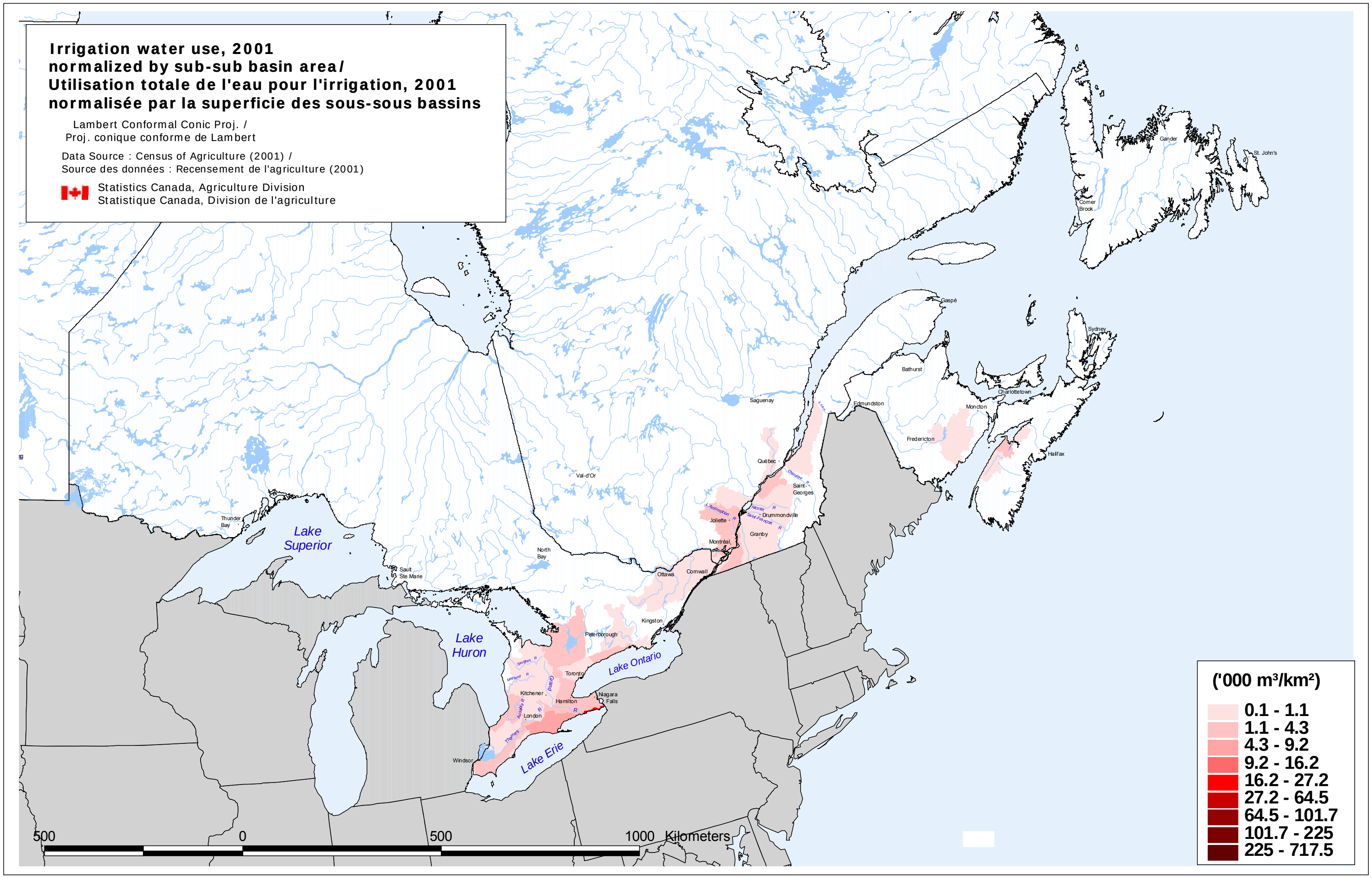
In Saskatchewan, irrigation water was concentrated in the Lower South Saskatchewan (Diefenbaker and Brightwater), Miry-Antelope and the Upper-Qu'Appelle Thunder SSDAs. The Central Assiniboine-Cypress and the Southwestern Lake Manitoba–Whitemud SSDAs had relatively more irrigation water use than other parts of Manitoba.

The Big, the Lower Grand and the Niagara SSDAs had more irrigation water use than any other area in Ontario. In Quebec, most irrigation water was used in the Montreal Island SSDA. In Atlantic Canada, the Gaspereau SSDA in Nova Scotia used relatively more irrigation water than any other SSDA in that region (Map 2).

Map 1
Irrigation water use, Western Canada, 2001



Map 2
Irrigation water use, Eastern Canada, 2001



2.2 Total crop water use

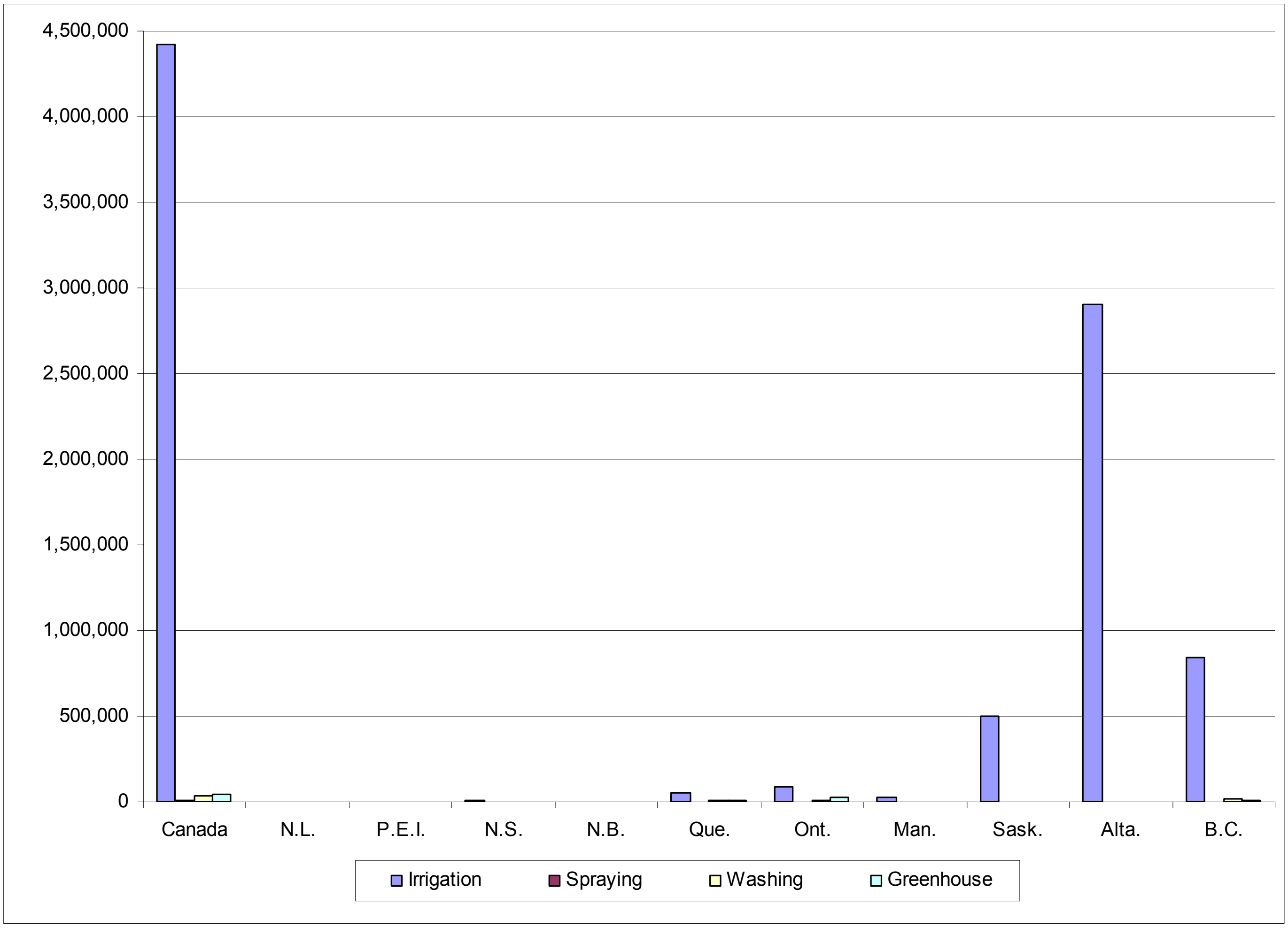
The provincial distribution of total crop water use by various detailed uses is similar to the distribution observed for water used for irrigation - an outcome that is expected given that irrigation accounts for most of the water used in crop farming (Table 2 and Figure 1).

Table 2
Total crop water use, Canada and provinces, 2001

	Irrigation	Spraying	Washing	Greenhouse[1]	Total	
	thousand cubic meters					percent
Canada	**4,424,600**	**6,540**	**31,370**	**44,920**	**4,507,430**	**100.0**
Newfoundland and Labrador	200	0	110	200	510	0.0
Prince Edward Island	1,400	160	230	110	1,900	0.0
Nova Scotia	5,400	70	410	800	6,680	0.1
New Brunswick	1,600	100	1,190	570	3,460	0.1
Quebec	49,000	530	9,380	6,700	65,610	1.5
Ontario	92,000	1,220	4,780	22,310	120,310	2.7
Manitoba	30,000	770	110	780	31,660	0.7
Saskatchewan	500,000	2,230	110	660	503,000	11.2
Alberta	2,900,000	1,210	230	2,420	2,903,860	64.4
British Columbia	845,000	240	14,820	10,360	870,420	19.3
	percent					
Canada	**98.2**	**0.1**	**0.7**	**1.0**	**100**	
Newfoundland and Labrador	39.2	0.0	21.6	39.2	100	
Prince Edward Island	73.7	8.4	12.1	5.8	100	
Nova Scotia	80.8	1.0	6.1	12.0	100	
New Brunswick	46.2	2.9	34.4	16.5	100	
Quebec	74.7	0.8	14.3	10.2	100	
Ontario	76.5	1.0	4.0	18.5	100	
Manitoba	94.8	2.4	0.3	2.5	100	
Saskatchewan	99.4	0.4	0.0	0.1	100	
Alberta	99.9	0.0	0.0	0.1	100	
British Columbia	97.1	0.0	1.7	1.2	100	

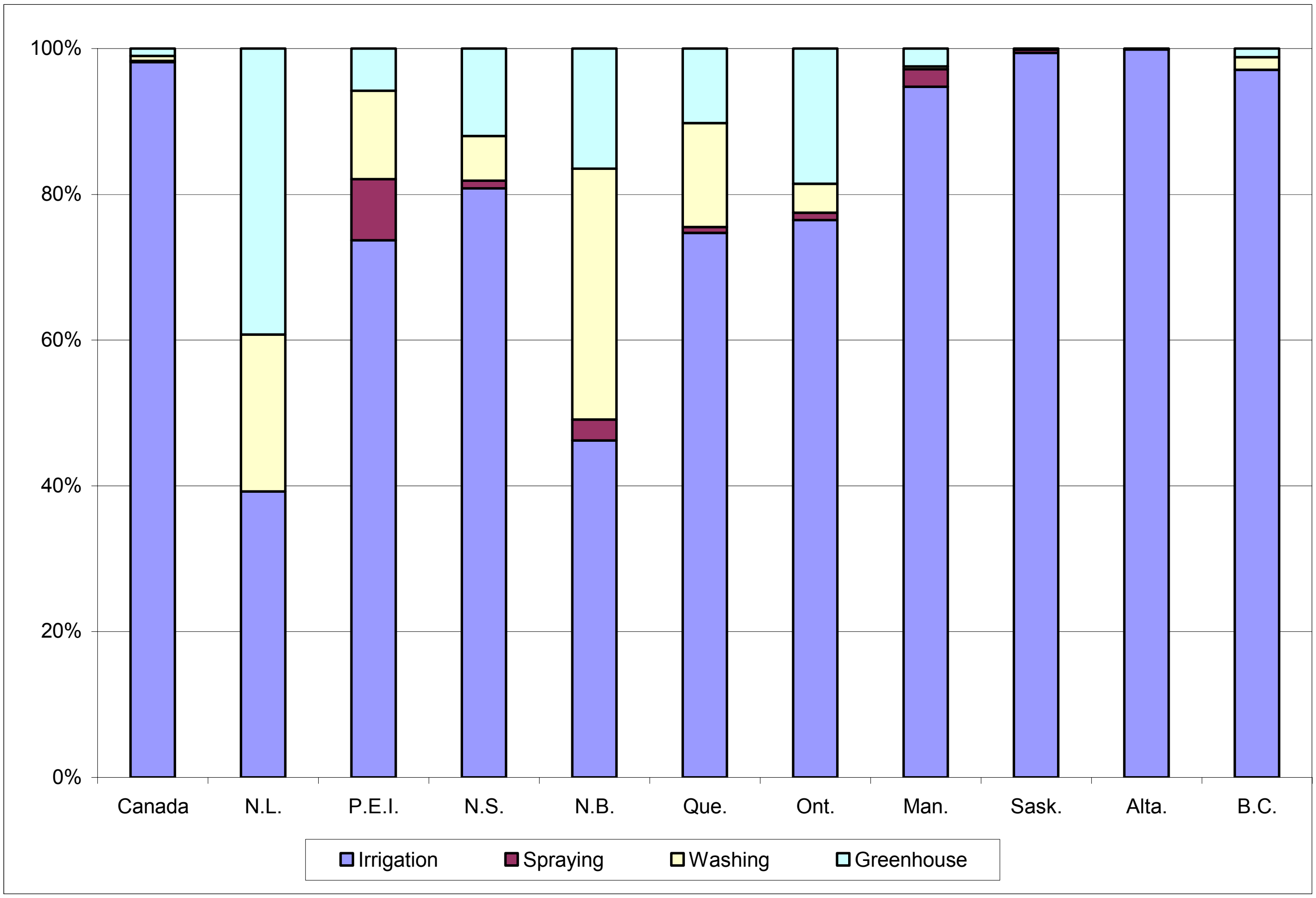
Notes:
Due to rounding, figures may not add up to totals.
1. Includes water used for greenhouse irrigation, spraying pesticides and washing equipment.

Figure 1
Total crop water use, Canada and provinces, 2001



In 2001, irrigation accounted for 98.2% (4,424,600 thousand m^3) of the 4 507 430 thousand m^3 of water used in crop farming in Canada (Table 2). In provinces where irrigation is not as intensively practiced as the three westernmost provinces, non-irrigation water use can account for a higher share of total crop water use. Such is the case in the province of Newfoundland and Labrador and New Brunswick where respectively 60.8% and 53.8% of total crop water use is for non-irrigation activities - mainly used by greenhouses and washing of produce (Table 2 and Figure 2).

Figure 2
Distribution of total crop water use, Canada and provinces, 2001



2.3 Total livestock water use

Overall, the total amount of water used by the livestock operations is relatively small compared to the amount of water used to irrigate crops. For example, total livestock water use for example represents less than 6% of the total water use in agriculture. However, livestock water use can be important in regions where livestock farming is more concentrated (Alberta).

In 2001, 279,160 thousand m^3 of water was used on Canadian livestock and poultry farms (Table 3 and Figure 3). Alberta used the most water for livestock farming: about 30.7% (85.8 million m^3) of total water used for livestock farming was used in this province.

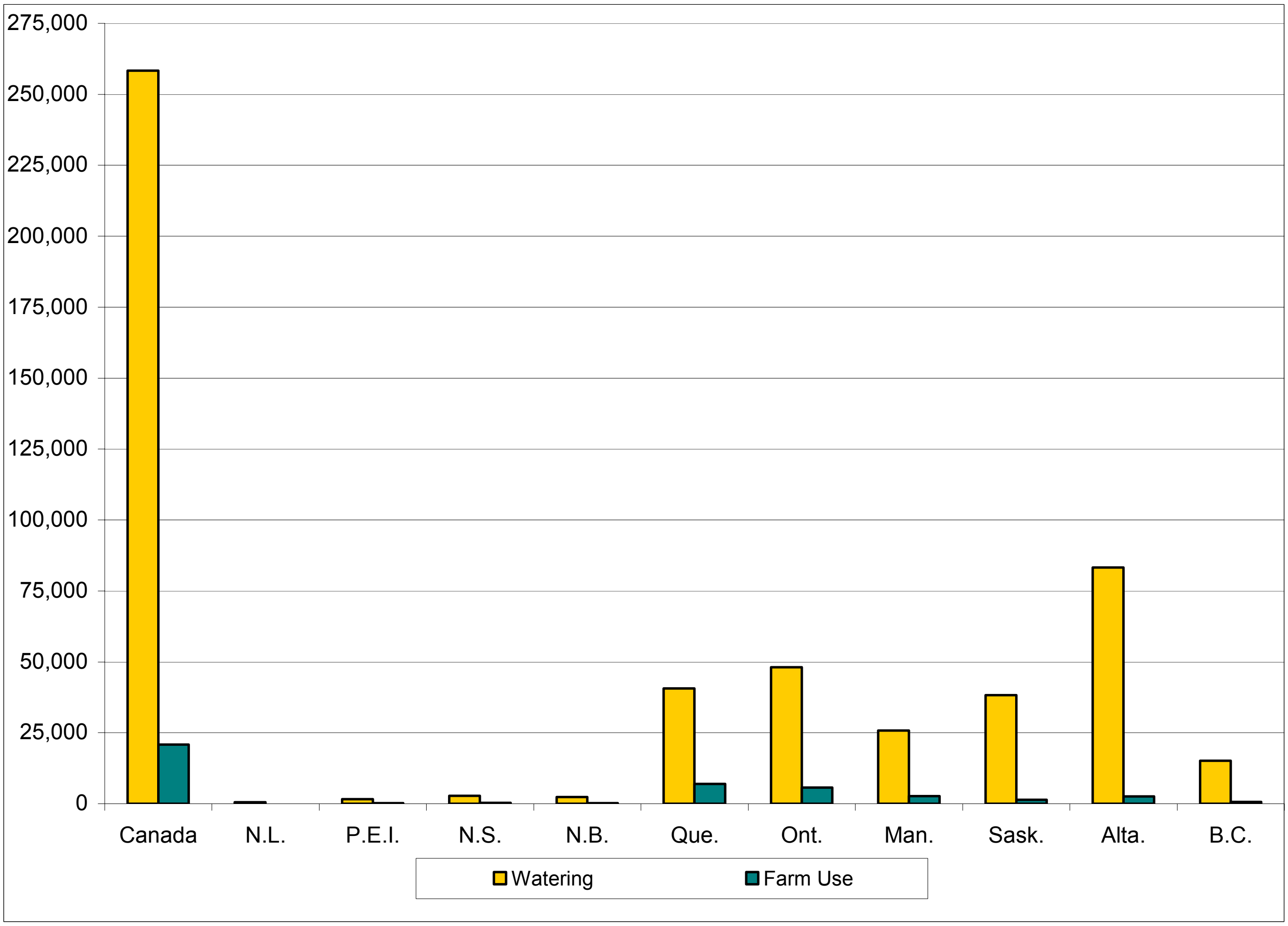
Table 3
Total livestock water use, Canada and provinces, 2001

	Watering	Farm use	Total	
	thousand cubic meters			percent
Canada	**258,360**	**20,800**	**279,160**	**100.0**
Newfoundland and Labrador	510	40	550	0.2
Prince Edward Island	1,620	220	1,840	0.7
Nova Scotia	2,800	290	3,090	1.1
New Brunswick	2,350	260	2,610	0.9
Quebec	40,630	7,000	47,630	17.1
Ontario	48,120	5,700	53,820	19.3
Manitoba	25,730	2,690	28,420	10.2
Saskatchewan	38,230	1,400	39,630	14.2
Alberta	83,260	2,550	85,810	30.7
British Columbia	15,120	650	15,770	5.6
	percent			
Canada	**92.5**	**7.5**	**100.0**	
Newfoundland and Labrador	92.7	7.3	100.0	
Prince Edward Island	88.0	12.0	100.0	
Nova Scotia	90.6	9.4	100.0	
New Brunswick	90.0	10.0	100.0	
Quebec	85.3	14.7	100.0	
Ontario	89.4	10.6	100.0	
Manitoba	90.5	9.5	100.0	
Saskatchewan	96.5	3.5	100.0	
Alberta	97.0	3.0	100.0	
British Columbia	95.9	4.1	100.0	

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

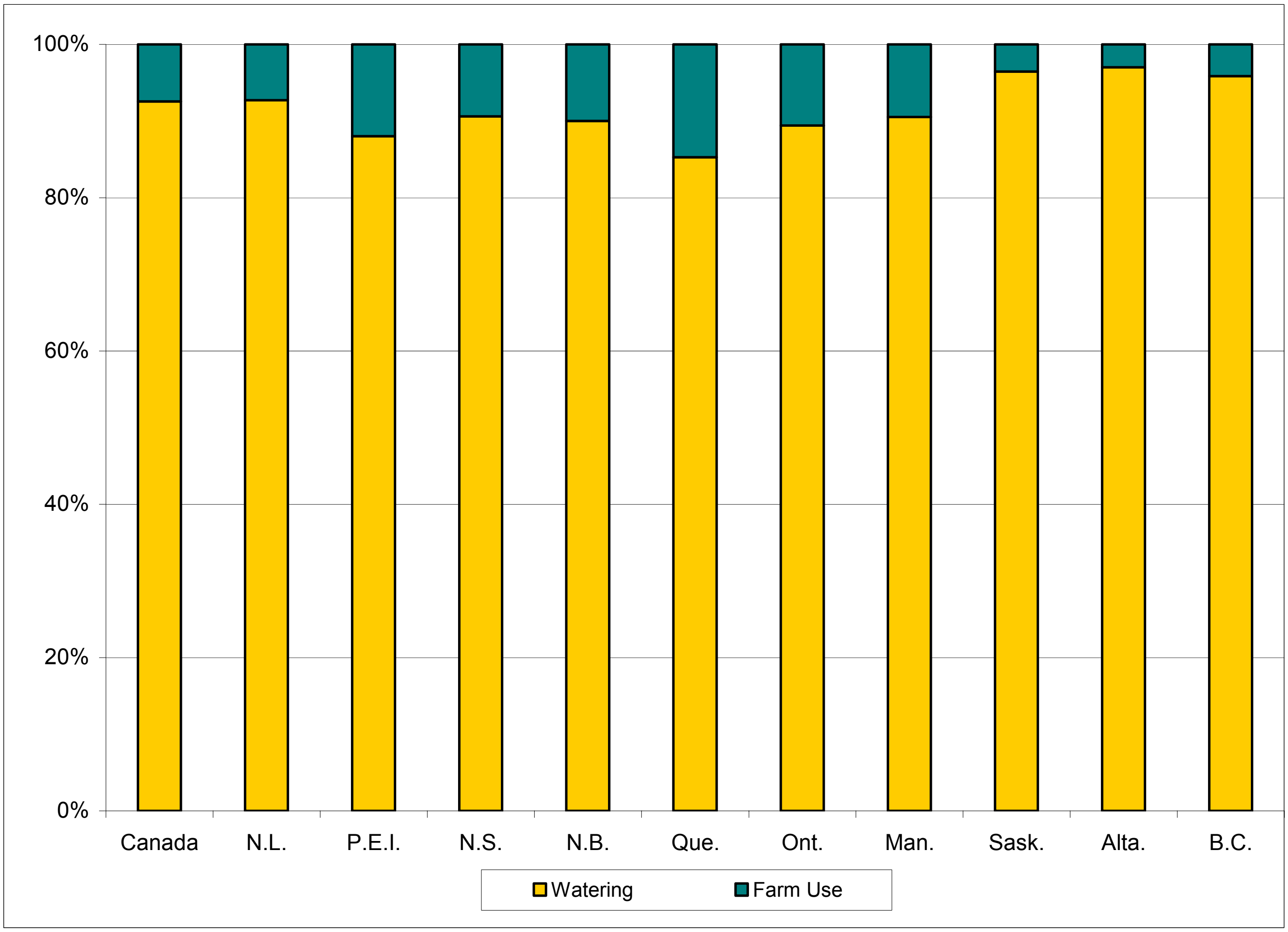
Ontario and Quebec followed Alberta with 19.3% and 17.1% respectively of total water used in livestock farming (Table 3 and Figure 3). Saskatchewan was not far behind Quebec with 14.2% of the total water consumed by livestock farms, attributed to its large cattle population. Manitoba followed with 10.2% mainly due to its large hog population.

Figure 3
Total livestock water use, Canada and provinces, 2001



In Canada, 92.5% of the water was mainly used for watering the animals and 7.5% was used in cleaning facilities or lost to spillage (Table 3 and Figure 4).

Figure 4
Distribution of total livestock water use, Canada and provinces, 2001



2.3.1 Mapping water use for livestock watering

Maps 3 and 4 show where water use for livestock watering was concentrated in 2001. From West to East, the Lower Fraser-Coast SSDA was the location with the highest use of water for livestock watering in British Columbia.

In Alberta, livestock water use was high in several SSDAs: Central Oldman (Belly and Willow), Central Bow-Jumpingpond, Upper Red Deer (Blindman and Little Red Deer), Upper North Saskatchewan (Wabamum and Strawberry), Central and Lower Pembina, Lower Bow (Crowfoot and Mouth), Little Bow, Lower Oldman, Lower Red Deer-Matzhiwin, Central Red Deer (Rosebud and Tail), Headwaters Battle, Sturgeon, Central North Saskatchewan (Redwater, Beaverhill and Big Gully) and Seven Persons SSDAs.

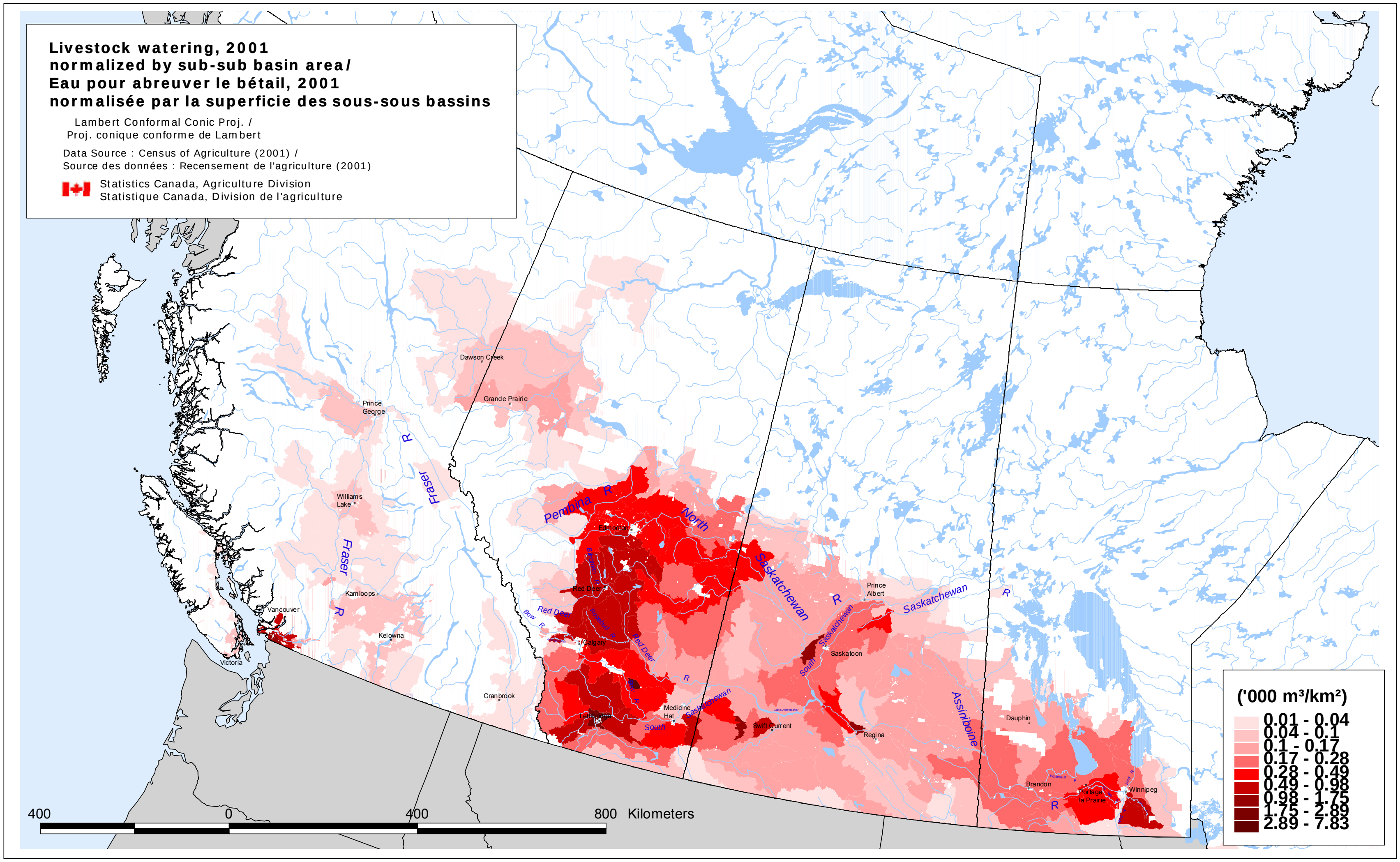
The Lower South Saskatchewan (Happyland, Myri-Antilope, Brightwater), Upper-Qu'Appelle-Thunder and Upper Carrot SSDAs had relatively more water used for livestock watering in Saskatchewan. The Morris, Lower Assiniboine-Mouth, La Salle, Seine and the Rat and Tourond SSDAs were the SSDAs showing relatively more livestock watering use than other areas of Manitoba (Map 3).

Map 4 shows that Ontario had several SSDAs showing important amounts of water used for watering livestock (notably the Scugog, Penetangore, Saugeen, Maitland, Ausable, Upper and Lower Grand, Upper Thames, Niagara and the Big SSDAs).

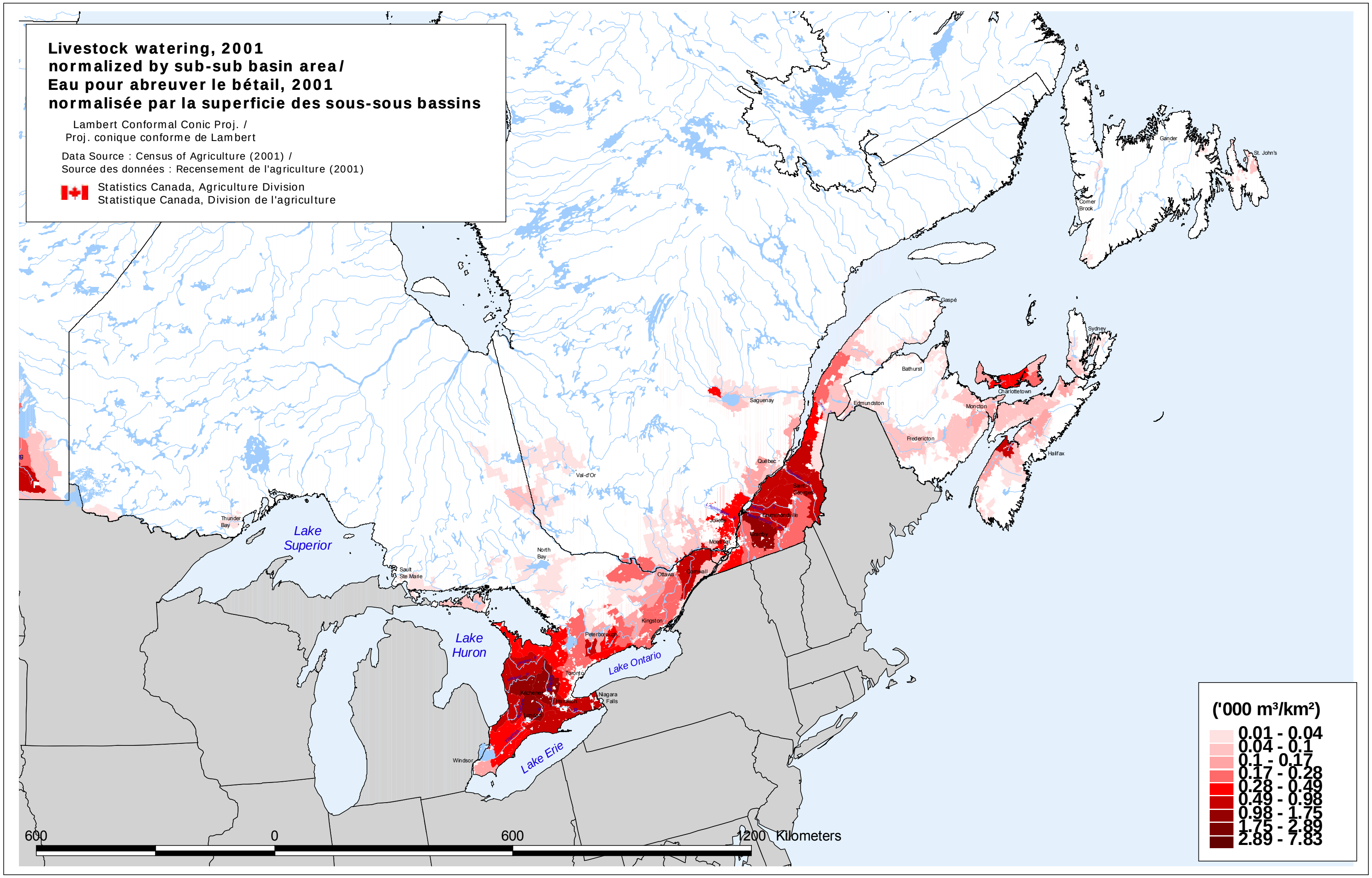
In Quebec, SSDAs with the most significant use of water for livestock watering were located in the SSDAs of the Lower Ottawa-South Nation, Yamaska, Lower Saint-François, Nicolet, Bécancour, Lower St.Lawrence-Chêne, Chaudière and Etchemin).

In Atlantic Canada, the Gaspereau SSDA in Nova Scotia and the Central Prince Edward Island (Wilmot and Hillsborou) used relatively more water for livestock watering than any other SSDA in that four-province region.

Map 3
Water used for livestock watering, Western Canada, 2001



Map 4
Water used for livestock watering, Eastern Canada, 2001



2.4 Total agricultural water use

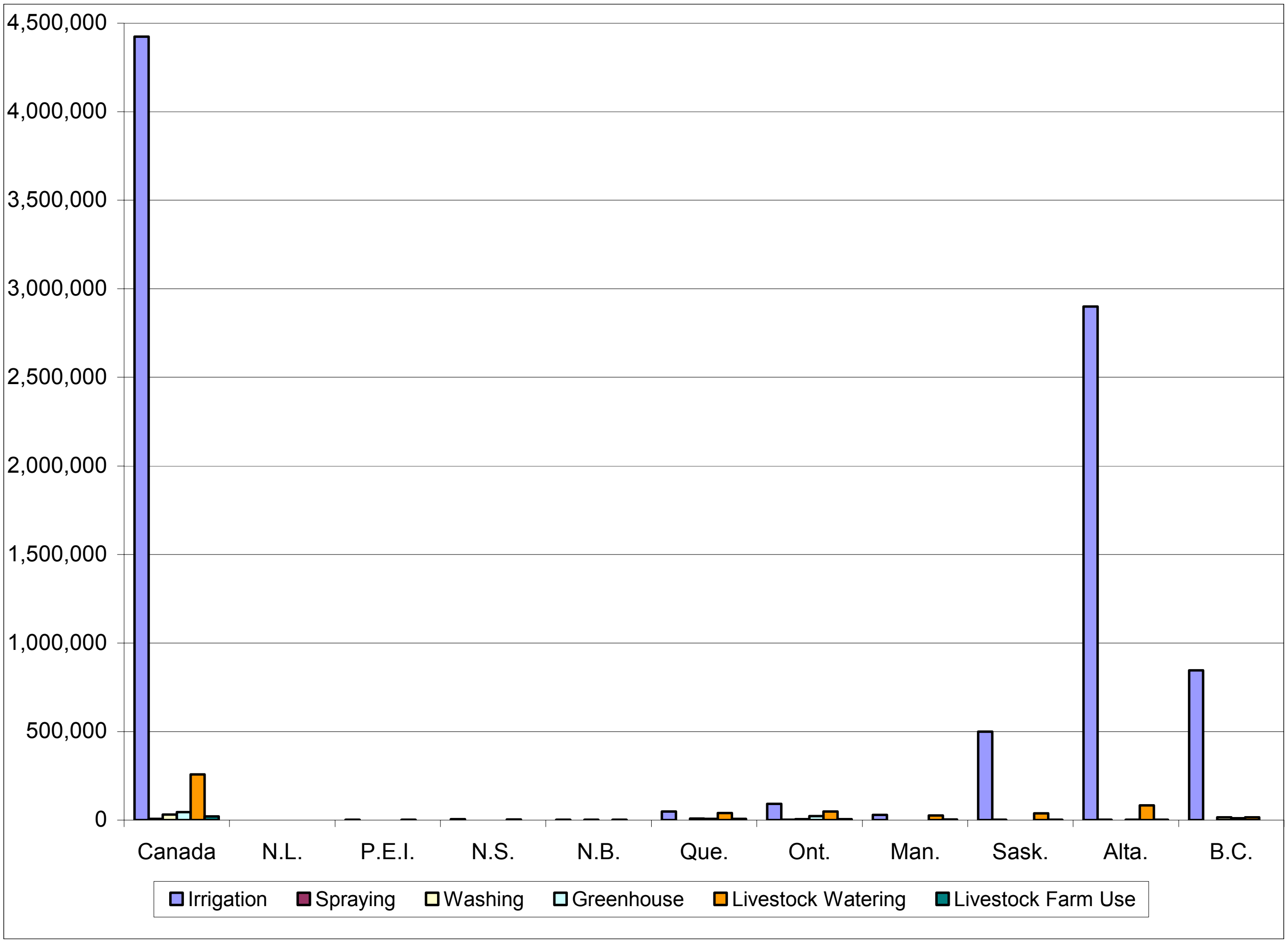
In 2001, Canadian agricultural water use was estimated at 4,786,590 thousand m^3 (Table 4). Alberta represented the highest use at 2,989,670 thousand m^3, followed by British Columbia at 886,190 thousand m^3 and Saskatchewan at 542,630 thousand m^3 (Figure 5). Together these three westernmost provinces accounted for 92.3% of total national agricultural water use.

Table 4
Total agricultural water use, Canada and provinces, 2001

	Crop water use				Livestock water use			
	Irrigation	Spraying	Washing	Greenhouse[1]	Watering	Farm use	Total	
	thousand cubic meters							percent
Canada	**4,424,600**	**6,540**	**31,370**	**44,920**	**258,360**	**20,800**	**4,786,590**	**100.0**
Newfoundland and Labrador	200	0	110	200	510	40	1,060	0.0
Prince Edward Island	1,400	160	230	110	1,620	220	3,740	0.1
Nova Scotia	5,400	70	410	800	2,800	290	9,770	0.2
New Brunswick	1,600	100	1,190	570	2,350	260	6,070	0.1
Quebec	49,000	530	9,380	6,700	40,630	7,000	113,240	2.4
Ontario	92,000	1,220	4,780	22,310	48,120	5,700	174,130	3.6
Manitoba	30,000	770	110	780	25,730	2,690	60,080	1.3
Saskatchewan	500,000	2,230	110	660	38,230	1,400	542,630	11.3
Alberta	2,900,000	1,210	230	2,420	83,260	2,550	2,989,670	62.5
British Columbia	845,000	240	14,820	10,360	15,120	650	886,190	18.5
	percent							
Canada	**92.4**	**0.1**	**0.7**	**0.9**	**5.4**	**0.4**	**100.0**	
Newfoundland and Labrador	18.9	0.0	10.4	18.9	48.1	3.8	100.0	
Prince Edward Island	37.4	4.3	6.1	2.9	43.3	5.9	100.0	
Nova Scotia	55.3	0.7	4.2	8.2	28.7	3.0	100.0	
New Brunswick	26.4	1.6	19.6	9.4	38.7	4.3	100.0	
Quebec	43.3	0.5	8.3	5.9	35.9	6.2	100.0	
Ontario	52.8	0.7	2.7	12.8	27.6	3.3	100.0	
Manitoba	49.9	1.3	0.2	1.3	42.8	4.5	100.0	
Saskatchewan	92.1	0.4	0.0	0.1	7.0	0.3	100.0	
Alberta	97.0	0.0	0.0	0.1	2.8	0.1	100.0	
British Columbia	95.4	0.0	1.7	1.2	1.7	0.1	100.0	

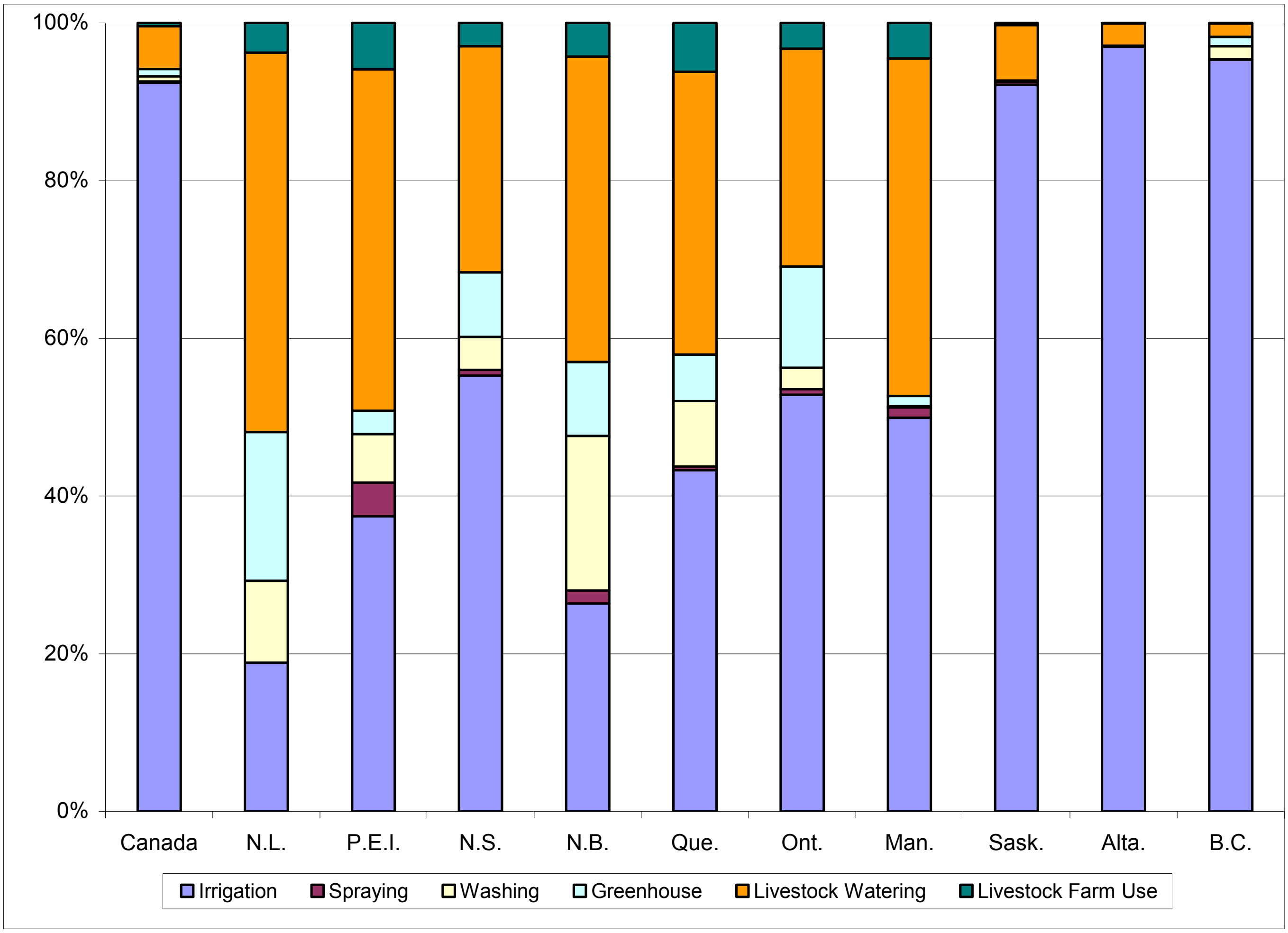
Notes:
Due to rounding, figures may not add up to totals.
1. Includes water used for greenhouse irrigation, spraying pesticides and washing equipment.

Figure 5
Total agricultural water use, Canada and provinces, 2001



At the national level, 92.4% of total agricultural water was used for irrigating crops while 5.4% was used for watering livestock (Table 4 and Figure 6). The three westernmost provinces had similar distributions as irrigation water use is so important in these provinces. Together, they heavily influenced the national percentages of the different types of water use.

Figure 6
Distribution of total agricultural water use, Canada and provinces, 2001



For the other central and eastern provinces, the distribution among the different types of water use within each province varied. For example, water used for watering livestock accounted for almost half (48.1%) of total farm water use in Newfoundland and Labrador. It accounted for around 43% of total farm water use in Manitoba and Prince Edward Island and about one-third of total farm water use in the remaining four provinces (Table 4).

2.4.1 Mapping total agricultural water use

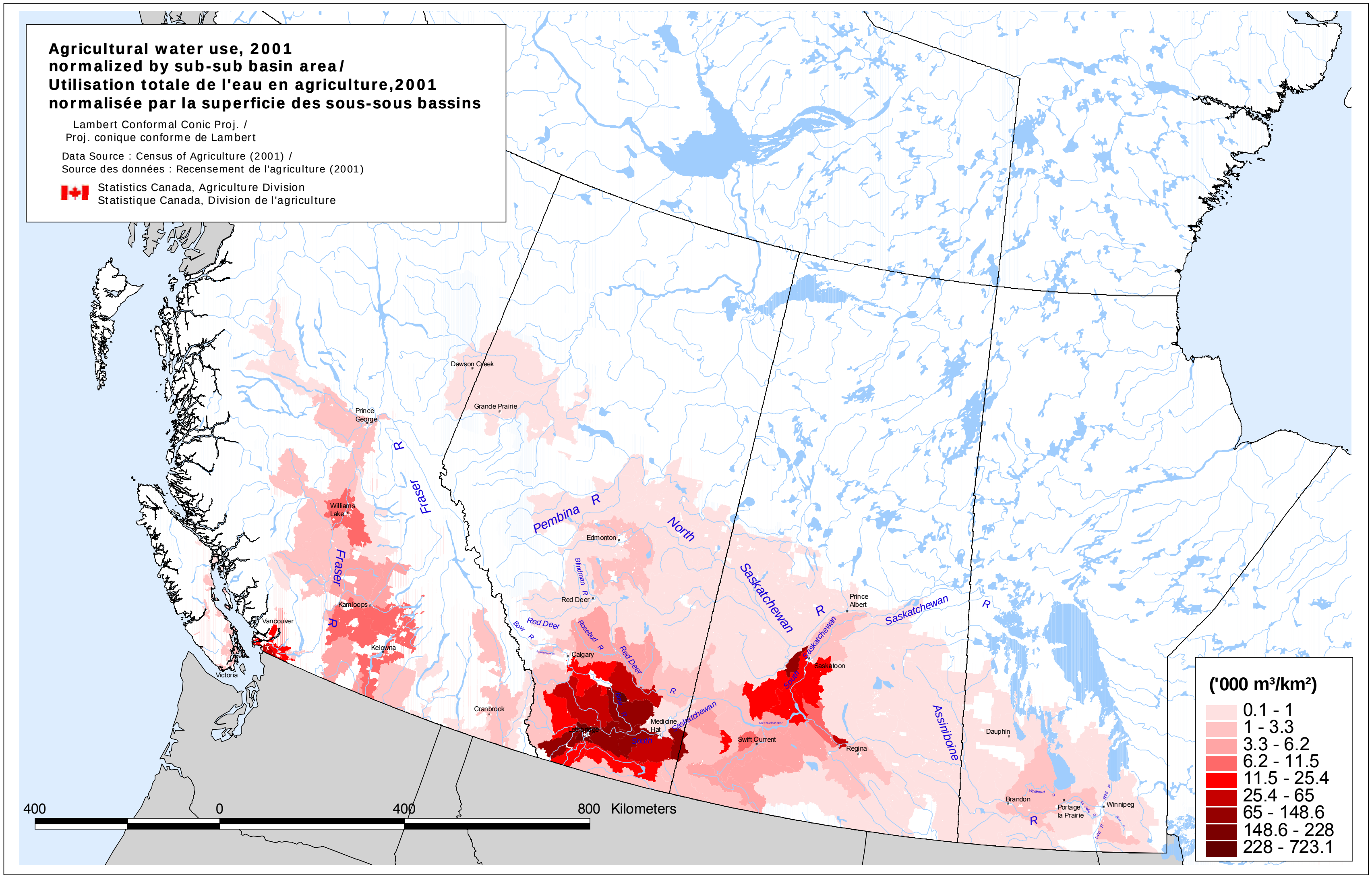
Based on these results, Map 5 shows where total agricultural water use was most concentrated in 2001 in Western Canada while map 6 shows the distribution in Eastern Canada.

Water is heavily used for agricultural purposes in south central Alberta and Saskatchewan. This is particularly true in Albertan SSDAs like the Central Oldman (Belly and Willow), St. Mary, Upper South Saskatchewan, Little Bow, Lower Oldman, Lower Bow (Crowfoot and Mouth), Lower Red Deer – Matzhiwin and the Seven Persons.

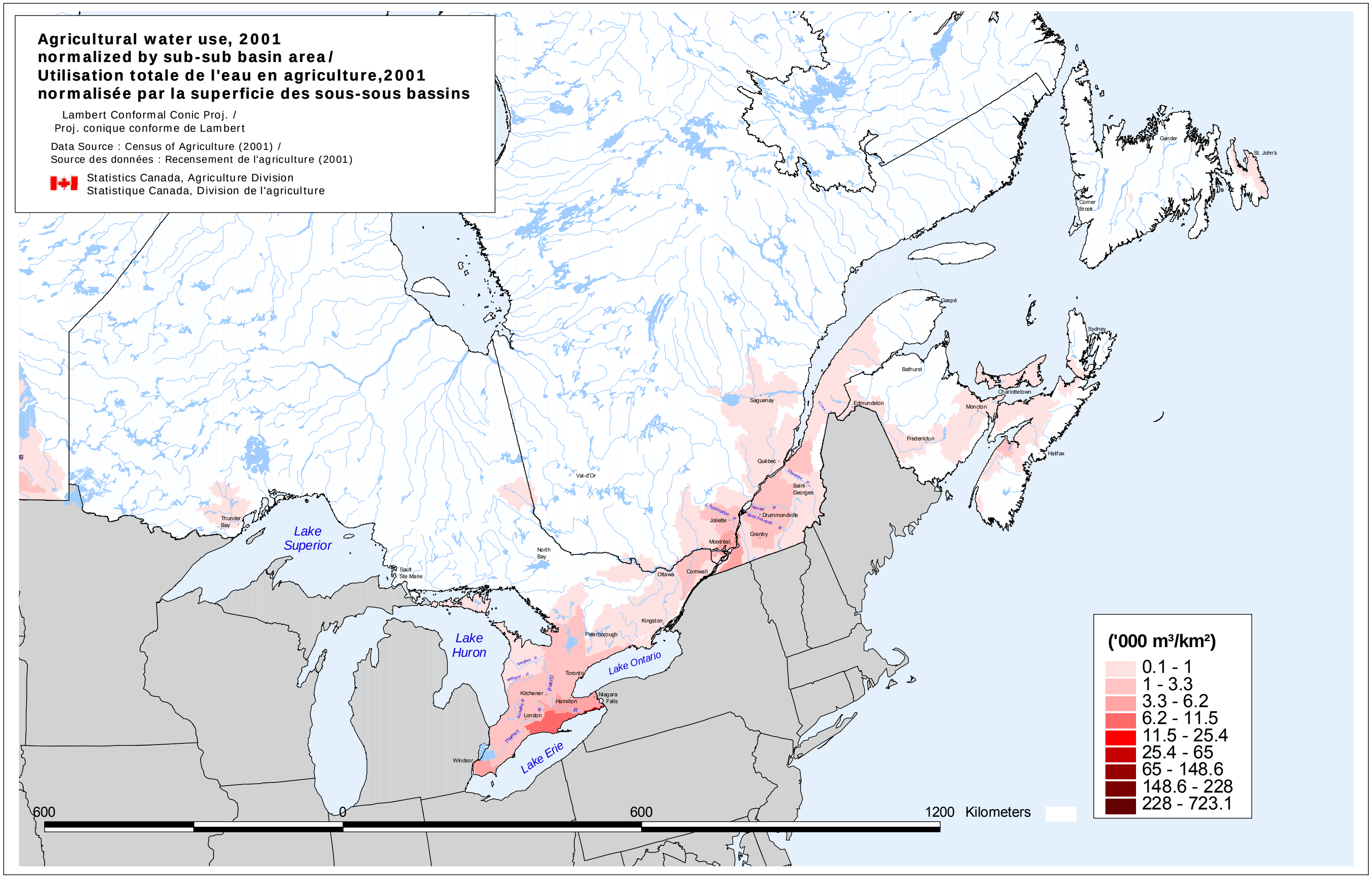
In Saskatchewan, water was mainly used in the Lower South Saskatchewan (Miry-Antelope, Diefenbaker and Brightwater), and the Upper-Qu'Appelle Thunder SSDAs.

In Eastern Canada (Map 6), water used for agricultural purposes is far less than in Alberta. For example, the quantity of water used in (or pumped from) SSDAs located on the north shore of Lake Erie, the heaviest consuming area in the East, averages between 3,300 – 6,200 m^3/km^2. By comparison, in south central Alberta the average of water use for agricultural purposes varies from 148,600 to 228,000 m^3/km^2.

Map 5
Total agricultural water use, Western Canada, 2001



Map 6
Total agricultural water use, Eastern Canada, 2001



II. Conclusion: Estimation of agricultural water use in 2001

The main objective of this study was to produce Canadian agricultural water use statistics for the reference year 2001 through different methods. Water use was estimated for several farming activities including irrigation; spraying herbicides, insecticides and fungicides; frost protection, sanitation washing, and harvesting; on-farm processing; livestock watering, livestock sanitation and other miscellaneous uses.

In 2001, Canadian agricultural water use was estimated at 4,786,590 thousand m^3. The geographic distribution of water use varied greatly from one region to another. Together the three westernmost provinces accounted for 92.3% of total national agricultural water use. In these provinces, most of the agricultural water was used for irrigating crops (96.1%) and the remaining part was mainly used for watering livestock (3.1%).

For the other provinces, the distribution of the different types of water use within each province varied. In Newfoundland and Labrador, Manitoba and Prince Edward Island, water used for watering livestock accounted for more than 42% of total farm water use. It accounted for about one-third of total farm water use in remaining four provinces

Within each province, agricultural water use varied greatly. Among the 477 SSDAs that contained farms in 2001, there were few that had important amounts of water used for agriculture. Most of these watersheds were concentrated in southern Alberta and Saskatchewan, where irrigation was intensively practiced.

Census of Agriculture data was the main source of data used to derive different water use estimates. Some information is already collected such as the land areas of different crops, the inventories of livestock and the total irrigated land area. Combining Census data on irrigated land, crop areas and livestock inventories with crop and livestock water use coefficients made it possible to derive estimates of the amount of water used for several farming activities. However, these estimates are as good as the limitations of the original data, the methods used and the assumptions taken.

One main limitation is the use of coefficients that are not necessarily uniformly up-to-date, that reflect average climatic conditions, expert opinion, or that are based to some extent on experimental field research originally calculated at a relatively much smaller scale.

Even if certain data gaps can be filled with new survey estimates, there are clear advantages to continuing to develop and improve various non-survey methods for estimating agricultural water use. Non-survey indicator estimates represent a valuable source of information for water specialists to calibrate survey results as well as to develop benchmark statistics immediately following every new Census of Agriculture in which some irrigation questions are asked.

Several areas could be improved for improving water use estimates such as converting Census livestock stock values into flows within 12 months of Census collection; improving the allocation of results from administrative geographies to precise hydrological geographies; improving livestock and crop water use coefficients to account for climatic conditions, technology used and genetic changes; using alternative data sources to adjust the effect of the lag between the seeded crop areas in the Census year and the irrigation area reported for the year preceding the Census reference year.

This research has produced agricultural water use estimates at a relatively small scale (i.e. the sub-sub-drainage area). With the limitations about the exact location of irrigated areas and livestock on the Census data and the obligations to protect confidential data, an analysis at this scale was deemed relevant to identify areas but insufficient to derive any conclusions about potential for conflicting uses of the water resources. This type of analysis will need to consider other water uses (residential, commercial and industrial water uses), variation of water intake during the year and the water available from different sources. Furthermore, in order to be complete, these analyses will need to vector in water quality.

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Appendix A

Table A.1
Irrigation crop requirement coefficients

Crops	B.C.	Alta.	Sask.	Man.	Ont.	Que.	N.B.	N.S.	P.E.I.	N.L.
	mm of water per ha									
Alfalfa	680 [12]	500 [4]	500 [4]	..	..	..	..	..	..	..
Barley	..	390 [10]	..	..	..	..	..	..	..	..
Chick peas	..	380 [12]	380 [12]	..	..	..	..	..	..	..
Corn	384 [8]	510 [12]	510 [12]	117 [13]	..	..	..	..	..	..
Dry white beans	..	380 [12]	380 [12]	..	..	..	..	..	..	..
Fall rye	..	..	390	117 [13]	..	..	..	..	..	..
Flaxseed	..	410 [12]	..	..	..	..	..	..	..	..
Forage seed	..	410	..	..	..	..	..	..	..	..
Ginseng	19 [7]	..	..	..	19 [7]	..	..	..	..	..
Mixed grains	..	..	330	..	..	..	..	..	..	..
Other dry beans	..	380 [12]	380 [12]	..	..	..	..	..	..	..
Other tame hay	..	..	500 [4]	..	..	..	..	..	..	..
Potatoes	500 [11]	560 [12]	500 [11]	82 [13]	225 [7]	143 [6]	..	..	143 [6]	..
Spring rye	..	..	..	..	0	..	..	..	..	..
Sugar beets	..	560 [10]	..	..	..	..	..	..	..	..
Tobacco	..	..	..	..	75 [7]	75 [7]	..	..	..	..
Winter wheat	..	480 [12]	..	..	..	..	..	..	..	..
Durum wheat	..	460 [12]	460 [12]	..	..	..	..	..	..	..
Spring wheat	..	..	..	..	..	..	..	..	..	..
Nursery	175 [1,7]	175 [1,7]	175 [1,7]	67 [1]	175 [1,7]	175 [1,7]	175 [1,7]	175 [1,7]	175 [1,7]	175 [1,7]
Sod	544 [2,7]	544 [2,7]	544 [2,7]	102 [2]	544 [2,7]	544 [2,7]	544 [2,7]	..	..	..
Apples	420 [5]	..	..	..	140 [7]	140 [7]	..	140 [7]	..	..
Apricots	420 [5]	..	..	..	..	140 [7]	..	..	..	..
Blueberries	672 [5]	..	..	..	224 [7]	224 [7]	..	..	..	..
Cherries	420 [5]	..	140 [7]	..	..	..	..	..	..	..
Cranberries	.. [3]	..	..	..	.. [3]	.. [3]	.. [3]	.. [3]	.. [3]	..
Grape	258 [5]	..	..	..	86 [9]	..	..	..	86 [9]	..
Pears	672 [5]	..	..	..	..	..	224 [7]	..	..	..
Peaches	420 [5]	..	..	51 [13]	..	140 [7]	..	140 [7]	..	..
Raspberries	672 [5]	..	..	..	224 [7]	224 [7]	..	224 [7]	224 [7]	224 [7]
Saskatoons	672 [5]	224	224	51 [13]	..	224	..	..	..	..
Strawberries	672 [5]	224 [7]	224 [7]	51 [13]	224 [7]	224 [7]	224 [7]	224 [7]	224 [7]	..
Other fruits	672 [5]	224	..	..	224	..	..	..	..	..

Table A.1
Irrigation crop requirement coefficients (continued)

Crops	B.C.	Alta.	Sask.	Man.	Ont.	Que.	N.B.	N.S.	P.E.I.	N.L.
	mm of water per ha									
Asparagus	90 [5,7]	..	..	..	90 [7]	90 [7]	..	..	..	..
Beans, green or wax	150 [5,7]	..	..	..	..	..	..	..	..	..
Beets	150 [5,7]	..	..	..	..	..	..	..	..	..
Broccoli	210 [5,7]	..	..	..	..	..	210 [7]	..	..	..
Brussel sprouts	210 [5,7]	..	..	..	..	..	..	..	..	..
Cabage	210 [5,7]	..	..	..	210 [7]	210 [7]	210 [7]	..	..	..
Carrots	150 [5,7]	..	..	..	150 [7]	150 [7]	..	150 [7]	..	..
Cauliflower	210 [5,7]	..	..	79 [13]	..	210 [7]	..	210 [7]	..	..
Celery	210 [5,7]	..	..	79 [13]	210 [7]	210 [7]	..	..	..	..
Chinese cabbage	210 [5,7]	210 [7]	..	..	210 [7]	210 [7]	..	..	..	..
Cucumbers	150 [5,7]	..	..	..	..	150 [7]	..	..	..	..
Green peas	150 [5,7]	..	150 [7]	79 [13]	..	..	..	..	..	..
Lettuce	210 [5,7]	..	..	..	..	210 [7]	..	210 [7]	210 [7]	..
Onions	210 [5,7]	..	..	..	210 [7]	210 [7]	..	..	..	..
Peppers	150 [5,7]	150 [7]	..	..	..	150 [7]	..	..	..	..
Radishes	210 [5,7]	..	..	..	..	..	210 [7]	..	..	..
Rhubarb	150 [5,7]	..	..	..	..	..	..	..	..	..
Rutabagas	150 [5,7]	150 [7]	..	..	..	..	..	..	..	..
Shalots	210 [5,7]	..	..	79 [13]	..	..	..	..	..	..
Spinach	210 [5,7]	..	..	..	..	..	..	..	210 [7]	..
Squash, pumpkins, zucchini	150 [5,7]	..	150 [7]	..	150 [7]	150 [7]	..	150 [7]	..	..
Sweet corn	90 [5,7]	90 [7]	..	..	..	..	..	90 [7]	..	..
Tomatoes	90 [5,7]	..	..	79 [13]	90 [7]	..	..	..	..	..
Other vegetables	150 [5,7]	150 [7]	150 [7]	79 [13]	150 [7]	150 [7]	150 [7]	150 [7]	150 [7]	..

Notes:

Irrigation requirement = crop requirement - (average growing season precipitation and available soil moisture)

1. Based on the assumption that only irrigate 25% of area which are new stocks and plants in containers.
2. Based on the assumption that 37% of the sod area is harvested in a year. Harvested area received an additional 50 mm per ha.
3. Flooding water used at harvest is included in "other" crop water use.
4. Better local coefficients will likely help getting more precise results. Even using lower coefficients, Saskatchewan and Alberta estimates may be over-estimated.
5. Better local coefficients will likely help getting more precise results. Assumption is that fruit water requirements are three times as much as Ontario coefficients due to drier conditions.

Sources:

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Appendix B

Table B.1
Irrigation odd ratios, Canada and provinces, 2001

Crops	B.C.	Alta.	Sask.	Man.	Ont.	Que.	N.B.	N.S.	P.E.I.	N.L.
Alfalfa	2.2	2.1	2.8	..	..	..	..	..	..	..
Barley	..	1.7	..	..	..	..	..	..	..	..
Chick peas	..	2.1	1.8	..	..	..	..	..	..	..
Corn	2.3	9.5	4.4	1.9	..	..	..	..	..	..
Dry field peas	..	..	..	..	..	..	..	..	..	..
Dry white beans	..	9.3	7.5	..	..	..	..	..	..	..
Fall rye	..	..	1.6	4.3	4.7	10.2	..	..	..	..
Flaxseed	..	2.3	..	..	..	..	..	..	..	..
Forage seed	..	2.0	..	..	..	..	..	..	107.5	..
Ginseng	9.5	..	..	..	4.0	..	..	..	..	..
Lentils	..	..	..	..	..	..	..	..	..	..
Mixed grains	..	..	1.5	..	..	..	..	..	..	..
Oats	..	..	..	..	..	..	..	..	..	..
Other dry beans	..	18.8	16.8	..	..	..	..	..	..	..
Other tame hay	..	..	1.8	..	..	..	..	..	..	..
Potatoes	2.0	5.8	30.5	168.1	2.0	4.4	1.9	2.3	5.1	..
Spring rye	..	..	..	..	4.5	..	7.8	10.9	..	..
Sugar beets	..	59.8	..	..	..	..	..	..	..	..
Tobacco	..	..	..	..	15.5	193.7	*	..	..	..
Winter wheat	..	2.2	..	..	..	2.9	..	5.3	..	..
Durum wheat	..	4.2	1.7	..	..	..	..	..	..	..
Spring wheat	..	..	..	..	..	1.5	..	..	..	..
Nursery	3.6	6.4	47.4	32.1	6.2	10.5	1.9	11.9	108.6	4.6
Sod	3.5	31.9	626.6	34.1	5.4	7.4	9.5	..	..	..
Apples	7.1	..	..	..	1.6	3.6	..	2.3	..	..
Apricots	2.0	..	..	..	..	*	..	..	..	..
Blueberries	1.3	..	..	..	6.6	4.9	..	..	..	..
Cherries	3.0	..	4.0	..	..	..	..	..	..	..
Cranberries	10.3	..	..	..	6.8	189.1	549.4	135.2	666.8	..
Grape	7.0	..	..	..	1.5	..	..	..	168.4	..
Pears	..	..	..	..	..	..	10.8	..	..	..
Peaches	3.1	..	..	192.5	..	*	..	5.7	..	..
Raspberries	2.9	..	..	..	2.0	1.9	..	3.7	24.4	6.7
Saskatoons	..	5.0	18.2	25.7	..	10.7	..	..	..	..
Strawberries	..	4.6	10.4	122.2	6.0	15.4	23.0	15.5	11.6	..
Other fruits	..	2.9	..	..	2.1	..	..	..	..	..
Asparagus	2.0	..	..	..	1.6	4.0	..	..	..	..
Broccoli	..	..	..	..	..	..	6.9	..	..	..
Brussel sprouts	2.0	..	..	..	..	..	..	..	..	..
Cabage	..	..	..	..	1.4	2.7	15.4	..	..	..
Carrots	..	..	..	..	2.1	2.2	..	2.3	..	..
Cauliflower	..	..	..	32.9	..	3.3	..	23.5	..	..
Celery	..	..	..	>999.9	5.4	3.7	..	..	..	..
Chinese cabbage	..	6.4	..	..	8.4	2.5	..	..	..	..
Cucumbers	..	..	..	..	..	3.0	..	..	..	..
Green peas	..	..	8.3	6.1	..	..	..	..	..	..
Letuce	..	..	..	..	..	3.9	..	3.2	354.6	..
Onions	1.6	..	..	..	1.4	2.0	..	..	..	..
Pepper	2.5	4.4	..	..	..	2.3	..	..	..	..
Radish	..	..	..	..	..	..	12.1	..	..	..
Rutabagas	..	2.9	..	..	..	..	..	..	..	..
Shalot	2.1	..	..	9.6	..	..	..	..	..	..
Spinach	..	..	..	..	..	..	..	..	493.8	..
Squash, pumpkins, zucchini	..	..	8.1	..	1.6	1.5	..	2.9	..	..
Sweet corn	1.8	3.5	..	..	..	..	..	2.4	..	..
Tomato	..	..	..	4.2	1.8	..	..	..	..	..
Other vegetables	2.1	1.8	2.7	13.4	2.2	3.9	3.9	2.8	293.3	..

Appendix C

Table C.1
Spraying and other crop water use coefficients for selected crops

	Crop spraying	Equipment washing	On-farm processing	Other
	L/ha	percent of spray water	L/ha	percent of spray water
Alfalfa	29	0.1	.	0.5
Barley	149	0.1	.	0.5
Chick peas	450	0.1	.	0.5
Canola	225	0.1	.	0.5
Corn	338	0.1	.	0.5
Dry field peas	225	0.1	.	0.5
Dry white beans	450	0.1	.	0.5
Fall rye	23	0.1	.	0.5
Flaxseed	225	0.1	.	0.5
Forage seed	225	0.1	.	0.5
Ginseng	8,550	0.3	.	.
Lentils	169	0.1	.	0.1
Mixed grains	149	0.1	.	0.1
Oats	149	0.1	.	0.1
Other dry beans	450	0.1	.	0.1
Other tame hay	16	0.1	.	0.1
Other field crops	169	0.1	.	0.1
Potatoes	3,188	2,300 [2]	.	0.1
Spring rye	23	0.1	.	0.1
Soybeans	338	0.1	.	0.1
Sugar beets	680	1,820 [2]	.	0.1
Tobacco	940	0.1	.	3,000,545 [1]
Winter wheat	113	0.1	.	0.1
Durum wheat	169	0.1	.	0.1
Spring wheat	149	0.1	.	0.1

Table C.1
Spraying and other crop water use coefficients for selected crops (continued)

	Crop spraying	Equipment washing	On-farm processing	Other
	L/ha	percent of spray water	L/ha	percent of spray water
Asparagus	1,020	1,820 [2]	.	135 [3]
Beets	680	1,820 [2]	.	.
Broccoli	2,250	1,820 [2]	2,400	.
Brussel sprouts	2,250	1,820 [2]	.	.
Cabage	2,250	1,820 [2]	.	110 [3]
Carrots	4,760	1,820 [2]	.	3,300 [3]
Cauliflower	3,600	1,820 [2]	.	.
Celery	2,250	1,820 [2]	475	75 [3]
Chinese cabbage	2,700	1,820 [2]	.	75 [3]
Cucumbers	1,350	1,820 [2]	.	450 [3]
Green peas	450	0.2	.	20 [3]
Green or was beans	1,020	0.2	.	120 [3]
Lettuce	2,040	1,820 [2]	.	75 [3]
Onions	3,920	1,820 [2]	.	.
Peppers	2,700	1,820 [2]	.	570 [3]
Radishes	560	1,820 [2]	240	520 [3]
Rutabagas	1,350	1,820 [2]	.	2,330 [3]
Rhubarb	450	1,820 [2]	.	320 [3]
Shalots	2,240	1,820 [2]	.	.
Spinach	680	1,820 [2]	.	75 [3]
Squash, pumpkins, zucchini	900	0.2	.	.
Sweet corn	675	0.1	.	.
Tomatoes	2,250	0.2	.	.
Other vegetables	1,350	1,820 [2]	.	.

Notes:
1. Litres per farm.
2. Litres per day at harvesting time.
3. Litres per hectare.

Source:
Ivey, 1998.

Table C.2
Spraying and other crop water use coeeficients for selected fruit crops

		Herbicides	Fungicides and insecticide [3]	Frost protection	Harvesting/ Transport	On-farm processing	Other
		L/ha	L/ha		L/ha	L/ha	percent of spray water
Apples	with ground cover	125 [2]	12,000 [4]	.	693	11,252	5,594 [1]
	without cover	1,000 [2]	12,000 [4]	.	693	11,252	5,594 [1]
Apricots	with ground cover	188 [2]	8,000 [4]	.	.	.	0.5
	without cover	1,500 [2]	8,000 [4]	.	.	.	.
Blueberries	without cover	600	2,225	.	.	.	0.5
Cherries	with ground cover	125 [2]	9,000 [4]	.	5,390	.	0.5
	without cover	1,000 [2]	9,000 [4]	.	.	.	.
Cranberries		300	1,335	.	10,000,000	.	0.5
Grape	without cover	600	1,780	.	.	.	0.5
Plums	with ground cover	125 [2]	5,000 [4]	.	.	.	0.5
	without cover	1,000 [2]	5,000 [4]	.	.	.	.
Pears	with ground cover	125 [2]	5,000 [4]	.	.	.	0.5
	without cover	1,000 [2]	5,000 [4]	.	.	.	.
Peaches	with ground cover	188 [2]	8,000 [4]	.	342	.	0.5
	without cover	1,500 [2]	8,000 [4]	.	.	.	.
Raspberries	without cover	900	2,800 [4]	.	.	.	0.5
Saskatoons	without cover	600	2,800 [4]	.	.	.	0.5
Strawberries	without cover	900	2,670 [4]	60 [5]	.	.	0.5
Other fruits	without cover	600	2,800 [4]	.	.	.	0.5

Notes:

1. Litres per hectare.
2. Assumption that 85% of fruit orchard had ground cover.
3. Assumption that insecticides are applied with fungicides where compatible.
4. On bearing crops.
5. mm/ha.

Source:

Ivey, 1998.

Table C.3
Spraying and other crop water use coeeficients for greenhouses and nurseries

	Irrigation	Pesticides	Equipment washing
	m/m^2	L/m^2	percent of spray water
Greenhouse			
Vegetables	1.375	1.25	0.3
50% flower (pots)	4.5	9.00	0.3
50% flowers	1.18	9.40	0.3
Other products	0.80	0.75	0.3
Nursery	.	27,000	0.3
Sod	.	.	0.4
Sod before harvesting	.	600 [1]	.

Note:

1. Assumption that 37% of sod area is harvested in a year.

Source:

Ivey, 1998.

Appendix D

Table D.1
Livestock water use coefficients

Livestock waterering coefficients	L/animal/day
Dairy cows	90.0
Beef cows	45.0
Heifers	25.0
Steers	30.0
Calves	15.0
Bulls	36.0
Boars	12.5
Growing pigs	9.0
Other pigs (less than 20 Kg)	1.0
Other pigs (20-60 Kg)	4.5
Sows	20.5
Rams	7.4
Ewes	7.4
Lambs	4.0
Laying hens, 19 weeks and over	0.3
Pullets under 19 weeks, intended for laying	0.2
Turkeys	0.5
Broilers, roasters and Cornish	0.5
Other poultry	0.5
Goats	4.0
Horses & ponies	42.0
Rabbits	0.2
Mink	0.2
Fox	0.2
Bison	10.0
Deer	10.0
Llamas and alpacas	10.0
Wild boars	4.5
Elk	10.0
Other livestock water use	**L/animal/day**
Sows (cleaning)[1]	1,100
Pigs less than 20 Kg (spillage)	0.2
All other pigs (spillage)	3.5
Broiler (cleaning)[1]	1.7
Dairy cow[2]	18.0

Notes:

1. L/animal/year.
2. Includes equipment washing and sanitizing, floor spraying and udder rinsing.

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