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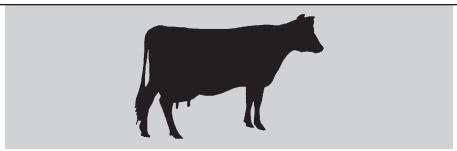

Usage and attitudes of water conservation on Ontario dairy farms

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ABSTRACT

Water use on 17 Ontario dairy farms was studied over 20 mo using continuous-flow water meters to measure cow consumption and milk-house and parlor usage with the goal of quantifying and assessing the amount of water used on dairy farms. The farmers were also interviewed regarding their perspectives on water use on their operations as well as throughout the industry. The goal was to gauge producers' opinions and motivations behind water use as well as future environmental and industrial sustainability. Average water use for a free-stall automated milking operation was greater ($P < 0.01$) than the average usage for a free-stall parlor and a tie-stall operation. Overall, water use was found to be greater ($P < 0.05$) during the summer (June–August) than the winter months (December–February). Producers of free-stall operations were found to implement sustainable water-use strategies on their farms even without government incentive.

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INTRODUCTION

The production demand on the agricultural industry is constantly increasing with the growth of the human population. This is creating pressure on water resources, which then leads to a need for coordinated management considerations (Wall and Marzall, 2006). Water is a vital agricultural resource; therefore, its effective use provides a means to improve the environmental sustainability of the sector. Water is one of the most important factors on a dairy farm because it is essential for cow consumption to support milk production and is heavily used to wash, clean, and cool the dairy facility.

The total water footprint of the dairy industry makes up 19% of the global water use of all animal production, second only to the beef industry at 33% (Mekonnen and Hoekstra, 2012). There are considerations that go into the water footprint calculation that are not wholly controllable by the farmer, including processes such as feed production. However, it has been estimated that the overall water footprint of milk production is 1 m^3/kg of milk (Mekonnen and Hoekstra, 2012). This represents a substantial amount of water that could be partially conserved throughout the production system on farm, which can have a significant effect (House et al., 2014). Water is used in many aspects of dairy production within the dairy barn, including cow consumption, washing of the milking equipment and milking parlor, cleaning of the pipelines, washing down of the holding area, cooling of the milk, and heat abatement (Brugger, 2007).

With the agricultural industry as one of the leading freshwater consumers in Canada, and dairy operations as significant users, it is important to improve dairy farmers' awareness of their direct and indirect water usage (Hoekstra and Chapagain, 2007). Water is abundant throughout Canada, making it seem like an inexhaustible resource. Yet, there have been issues with supply in the past, and it will certainly become a bigger issue in

Table 1. Operational information for 17 Ontario dairy farms used

Farm	Location in Ontario	Herd size	Milking herd size	Housing style[1]	Milking system[2]	Conservation practices employed[3]
A	East	141	126	Free	Rotary	Yes
B	West	160	80	Free	Robot	Yes
C	North	52	40	Tie	Tie	No
D	East	72	65	Free	Parallel	Yes
E	North	44	36	Tie	Tie	Yes
F	North	177	146	Tie	Tie	Yes
G	East	181	155	Free	Robot	Yes
H	South	116	98	Free	Parallel	Yes
I	South	145	125	Free	Parallel	Yes
J	East	85	78	Tie	Tie	No
K	North	47	43	Tie	Tie	No
L	South	125	108	Free	Robot	Yes
M	East	135	118	Free	Swingover	Yes
N	North	151	122	Free	Parallel	Yes
O	East	71	65	Tie	Tie	Yes
P	West	116	104	Free	Parallel	Yes
Q	East	226	187	Free	Rotary	Yes

[1]Free = facilities where cows are free to roam around the stall area, Tie = facilities where cows are constrained to a particular stall.

[2]Rotary, Parallel, and Swingover are particular styles of free-stall parlors, where the cows are milked in a separate parlor area at particular times of the day, and Robot is a method in which the cows choose to go to the robotic milker on their own.

[3]Each producer's response to whether they practiced any water conservation on their farm of their own accord before this study began.

the future (de Loë et al., 2001). This trend may lead to more active regulation and monitoring of water use in all agricultural sectors, which puts a great amount of pressure, especially financially, on farmers.

Agricultural water conservation is an extremely important issue because of greater scrutiny being placed on more effective water resource management (Robinson, 2006). Water is essential for agricultural production; however, monitoring of Ontario's agricultural sector water use has been limited. Increasing our understanding of agricultural water use in Ontario would be a great asset for the industry, individual producers, and provincial water technicians (de Loë et al., 2001). With enhanced awareness of water conservation comes knowledge and, in turn, positive action.

The goal of this study was to quantify the amount of water used on Ontario-based dairy operations and assess current attitudes around on-farm water conservation. Specific objectives included the following:

- identifying water use for a range of Ontario-based dairy operations and assessing the extent of seasonal and system variations and
- identifying current attitudes of Ontario-based dairy producers around water conservation.

MATERIALS AND METHODS

Study Population and Measurements

This research was carried out over 2 yr, from May 2013 to December 2014 (20 mo), and included 17 dairy farms with details provided in Table 1. Initially, 25 Ontario-based dairy operations were preselected for this study from a previous Ontario Ministry of Agriculture, Food and Rural Affairs; and Dairy Farmers of Ontario project (OMAFRA, 2013). Of these, 8 were excluded because of the farmer's choice not to participate or because the facility's water systems were not able to support the water meters.

Continuous-water-flow meters (Jerman Co. DLJ Water Meters, Hackensack, NJ) were installed on each dairy operation. These meters were purchased with a calibration guarantee, and samples were selected for validation both before installation as well as near the end of the trial. Monthly after the May 2013 installation through December 2014, the farms were contacted to provide the most recent continuous-flow water meter readings. Besides the total water-use values, the rest of the readings were converted into a liters per cow on a daily basis. Total herd size was used to calculate the per cow basis for total water use, and milking herd size was used to calculate the per cow basis for robotic, parlor, or milk-house water-use values. The farms that specifically measured total facility water use were grouped into 3 categories of milking systems: (1) free-stall parlor, (2) free-stall robotic, and (3) tie-stall facilities. "Free-stall," or cubicles, indicates facilities where cows are free to roam around the stall area ["parlor" (in-

cluding rotary, parallel, and swingover parlor styles), where the cows are milked in a separate parlor area at particular times of the day, and "robotic," where the cows choose to go to the robotic milker on their own]. "Tie-stall" indicates facilities where cows are constrained to a particular stall and are milked directly in their stall.

Dairy Farmer Survey

A farmer questionnaire was conducted in September 2014 in which each dairy producer was surveyed about their specific operation, their opinions of the importance of water conservation for their farm as well as the industry as a whole, and other water-use considerations. During the interview, each farmer received a detailed report about their operation's water use since the start of their metering in 2013 with comparisons to the other farms in this study.

Survey questions that involved close-ended or quantitative answers were given coding on a Likert scale (Andres, 2012). Survey questions that involved open-ended or qualitative answers were given coding and categorized according to the Research Project Matrix Tool as described by Odame (2001) using 3 criteria: conservation (positive, neutral, negative), government (positive, neutral, negative), and industry (positive, neutral, negative). All questions from the dairy farmer survey are provided in Table 2.

Statistical Analysis

A total of 10 farms were selected for detailed data analysis, because these farms were measuring water use either for the entire milking barn or strictly for cow consumption, both of which are not on any automated cycles and have the possibility to fluctuate with the season, milking system, or housing style. An ANOVA was run on water consumption (L/d per cow) as the dependent variable and milk production (kg/d per cow) as the independent variable, and no significant differences were detected ($P < 0.05$). This allows for close comparison between these operations without a concern for possible milk production differences.

An ANOVA was performed on average monthly water use (L/d per cow), as the dependent variable, and dairy system type (i.e., tie-stall, free-stall parlor, or free-stall robotic), as the independent variable. All assumptions for the ANOVA were met. All tests were run with a type 1 error of $\alpha = 0.05$. Post hoc analyses were conducted on pairwise contrasts between each of the barn types to determine whether any of the pairs were significantly ($P < 0.05$) different.

An ANOVA was also performed on average monthly water use (L/d per cow), as the dependent variable, and average monthly and seasonal (spring, summer, fall, winter) temperature (°C), as the independent variables. All assumptions for the ANOVA were met. All tests were run with a type 1 error of $\alpha = 0.05$. Post hoc analyses were conducted on pairwise contrasts between each of the seasons' temperature means to determine whether any of the pairs of groups were significantly ($P < 0.05$) different. Temperatures for each season in 2014 were obtained from Environment Canada from the closest weather station to each farm location (EC, 2015).

The survey responses were analyzed to gain insight into the comparisons between farmers' responses and their operation. The quantitative question data were coded either by the Likert scale or by a specific scale per question (for answers that did not have a yes/no, agree/disagree, or significance response). The Pearson Chi-squared test was used to test for a relationship between the 2 variables. All tests were run with a type 1 error of $\alpha = 0.05$.

RESULTS AND DISCUSSION

Quantification of Water Use

The average daily water use for each of the dairy operations is provided in Table 3. The overall average of each milking system type was calculated and is represented in Table 4. The ANOVA indicates that there is a difference ($P < 0.05$) between the different milking systems. A post hoc Tukey test demonstrated that the free-stall robotic milking systems used more water ($P < 0.05$) than both the tie-stall and free-stall parlor systems. This is comparable to an Ohio-based study (Brugger, 2007) that observed 113 L of water per day per cow in a free-stall parlor operation and an Ontario study that found 135.5 L of water per day per cow in a free-stall system (House et al., 2014). The average milk-house water use across operations was calculated for both the free-stall parlor systems and the tie-stall systems (Table 4). This is similar in average usage to an Ohio study with 24 L of water per day per cow used in a free-stall milk house (Brugger, 2007). The industry has been moving toward free-stall systems for several reasons including animal comfort and welfare, improved manure management, improved milk quality, and animal health. The problem is that these systems inherently use more water. Therefore, determining the exact quantity these farms use as well as the best management practices surrounding water use on these farms should help improve the sustainability of the industry.

An ANOVA was conducted on the seasonal water use and the corresponding average temperatures, which resulted in significant ($P < 0.05$) variations. A post hoc Tukey test demonstrated that the summer months (June through August) significantly ($P < 0.05$) used more water across all dairy farm types than the winter months (December through February). As expected, the peak water-use period coincided with the warm season (June through August) as shown in Figure 1. Beyond greater cow consumption, the amount of water required for cooling the milk would be expected to increase during these hot summer months.

Dairy Farm Water-Use Survey

The questions included in the farmer survey are provided in Table 2. Water reuse was the most com-

mon water conservation strategy used (45%). This could be due to the fact that it is the most easily implemented strategy on the majority of farms, typically with the installation of a storage tank or redirection of a pipeline. The primary reasons behind water conservation strategies in general were wastewater volume reduction at 58% of the responses and cost reduction as the second greatest at 37%.

A fair amount of the farmers disagreed when asked if water conservation was a priority on their operation (47%), although the majority also agreed that possible future water restrictions were a concern (18% strongly agree, 35% agree). Although most farmers were not concentrating specifically on water conservation measures for their operations, they were still concerned about water becoming scarce and may begin placing a greater priority on water-use efficiency in the future. Most producers were still interested in water conservation; it was just not their main concern. Finally, the majority of farmers (70%) agreed that government programs should specifically target on-farm water conservation (11% strongly agree, 59% agree).

There were 3 pairs of quantitative questions with statistically significant ($P < 0.05$) relationships between the variables. These included

(1) Industry*Province (i.e., "The dairy industry collectively places a high enough priority on water conservation," and "The province (Ontario) is do-

Table 2. Farm survey questionnaire

	Question
1	Sex: male, female, other
2	Age: under 35, 35–54, 55 and older
3	Highest level of education: elementary school, high school, college, university, diploma program
4	Involvement in the agricultural industry: PDO, DHI, OFA, NFU, OSCIA, other
5	If applicable, have any of these organizations provided information about water conservation in the past 2 years? yes, no, If yes, which organizations?
6	Area of cropping acreage owned: under 69, 70–129, 130–179, 180–239, 240–399, 400–559, 560–759, 760–1,119, 1,120–1,599, 1,600–2,239, 2,240–2,879, 2,880–3,519, 3,520 and over
7	Water conservation strategies practiced on your farm operation: run-off diversion, nutrient management plan, water reuse, water table management, roof water collection, water conserving devices, other, Water conservation strategies are not applicable on this farm.
8	Main driver for water conservation strategies, if practiced: cost reduction, wastewater reduction, standards compliance, changes in water availability, other
9	Water conservation is a priority on your farm.[1]
10	Why did you volunteer to participate in this water meter study?
11	Have you experienced any water management issues on your farm in the past: yes, no, If yes, what were they related to? quality, quantity, Please describe.
12	How efficiently do you believe you use water in your barn operation compared with the average of farms similar in type and size to yours: significantly less, somewhat less, equivalent, somewhat more, significantly more
13	How efficiently do you believe you use water in your barn operation compared with the average of all farm types: significantly less, somewhat less, equivalent, somewhat more, significantly more
14	Now knowing your actual comparison to the average, does this encourage you to do anything differently with your water use? yes, no, If yes, please describe.
15	What is your opinion of on-farm water conservation as a whole?
16	Has this opinion changed in the past 10 years? yes, no, If yes, in what way?
17	Has your on-farm water use changed in the past 10 years? more efficient, less efficient, unchanged
18	Have you heard of any particular water saving technologies that you think might work on your farm but you do not use? yes, no, If yes, please describe the technology, why you are not using it, and what would encourage you to do so.
19	Is there a relationship between on-farm water efficiency and overall farm productivity? synergy, trade-off, no relationship
20	Is the effect of possible future water restrictions, such as drought, a concern to you?[1]
21	Is the effect of possible future water quality issues a concern to you?[1]
22	The dairy industry, as a whole, places a high enough priority on water conservation.[1]
23	The province of Ontario is doing a sufficient job in assisting dairy producers to better manage on-farm water use.[1]
24	We should have provincial and/or federal programs specifically to support on-farm water conservation.[1] If agree, please give an example. If do not agree, why?
25	In water-stressed countries there are water restrictions and taxes on well water, not just city water. Would you approve of this if it were to be suggested for Ontario?[1]
26	Any other comments?

[1]Answer on the Likert scale of strongly agree, agree, neutral, disagree, strongly disagree.

Table 3. Average daily water use on 17 Ontario dairy operations from August 2013 through December 2014 with a comparison to average milk production

Farm	Housing style[1]	Milking system[2]	Measurement	Milk production (kg/d per cow)	Average usage (L/d)	Average usage[3] (L/d per cow)
A	Free	Rotary	Total	29.5	25,147.5	178.4
B	Free	Robot	Total (excluding robot)[4]	34.5	13,083.2	81.8
C	Tie	Tie	Milk house	27.9	2,703.4	67.6
D	Free	Parallel	Total	31.2	8,374.0	116.3
			Milk house		1,190.5	18.3
E	Tie	Tie	Total	21.1	4,485.1	101.9
			Milk house		932.2	25.9
F	Tie	Tie	Milk house	31.5	2,674.0	18.3
G	Free	Robot	Total	34.1	31,815.4	175.8
H	Free	Parallel	Total	35.4	22,735.2	196.0
I	Free	Parallel	Total	33.0	11,419.6	78.8
			Parlor wash		2,673.0	21.4
			Plate cooler		7,467.5	59.7
J	Tie	Tie	Milk house	38.3	1,639.2	21.0
K	Tie	Tie	Total	15.9	4,733.9	100.7
L	Free	Robot	Total	32.5	20,218.4	161.8
			Total (excluding robot)[4]		13,308.9	106.5
M	Free	Swingover	Total	29.1	18,366.9	136.1
			Consumption		14,625.9	108.3
N	Free	Parallel	Milk house	29.8	2,768.6	22.7
O	Tie	Tie	Milk house	31.6	1,162.0	17.9
P	Free	Parallel	Total	30.0	14,250.9	122.9
Q	Free	Rotary	Total	36.3	25,674.4	113.6

[1]Free = facilities where cows are free to roam around the stall area, Tie = facilities where cows are constrained to a particular stall.

[2]Rotary, Parallel, and Swingover are particular styles of free-stall parlors, where the cows are milked in a separate parlor area at particular times of the day, and Robot is a method in which the cows choose to go to the robotic milker on their own.

[3]Total, Total (excluding robot), and Consumption were calculated using herd size; Milk house, Parlor wash, and Plate cooler were calculated using milking herd size.

[4]Total (excluding robot) includes all other aspects of the farm (cow consumption, milk house, toilet use).

Table 4. Average daily water use on 17 Ontario dairy operations grouped by milking system from August 2013 to December 2014

Milking system	Measurement	Average Usage (L/d)	Average Usage[1] (L/d per cow)
Free-stall parlor	Total	17,995.5	134.6
Free-stall robot	Total	26,016.9	168.8
Tie-stall	Total	4,609.5	101.3
Free-stall parlor	Milk house	1,979.5	20.5
Tie-stall	Milk house	1,822.2	30.2
Free-stall robot	Total (excluding robot)[2]	13,196.0	94.1
Free-stall robot	Robot	12,820.9	74.7

[1]Total and Total (excluding robot) were calculated using total herd size; Robot and Milk house were calculated using milking herd size.

[2]Total (excluding robot) includes all other aspects of the farm (cow consumption, milk house, toilet use).

ing a sufficient job in assisting dairy producers to better manage on-farm water use") (n = 6, df = 16.037, $P = 0.014$),

(2) Taxes*Future (i.e., "In water-stressed countries, there are water restrictions and taxes on well water, not just city water. Would you approve of this if it were to be suggested for Ontario?" and "Is the impact of possible future water restrictions, such as drought, a concern to you?") (n = 8, df = 15.867, $P = 0.044$), and

(3) Priority*Efficiency (i.e., "Water conservation is a priority on your farm," and "How efficiently do you believe you use water in your barn operation compared to the average

of all farm types") (n = 6, df = 14.044, $P = 0.029$).

The main relationship between Industry and Province was that farmers who disagreed that the dairy industry is not placing a sufficiently high enough priority on water conservation also disagreed that the province of Ontario is also not doing a sufficient job in assisting farmers with on-farm water management. Also, those that agreed the Industry placed a high enough priority on water conservation also agreed that the Province was doing a sufficient job in assisting farmers. Therefore, many farmers do not view these 2 groups as being independent of one another. The main relationship between Taxes and Future was that farmers who believed that water should not be taxed were also concerned about possible future water restrictions. Therefore, dairy farmers are concerned about future water access but do not want to be taxed as an inducement to use less water. The main relationship between Priority and Efficiency was that the producers who disagreed that water is a priority on their farm predicted that they used an equivalent amount of water in comparison to other farms. Also, the producers who agreed that water is a priority on their farm predicted that they use somewhat less water in comparison with other farms. Therefore, farmers who see water conservation as a priority are already consciously taking action to reduce water use but are not fully aware of how much they presently use.

Qualitative questions were also assessed and categorized into 3 classes of responses including conservation (C+, C, C−), government (G+, G, G−), and industry (I+, I, I−). Notably, the farmers did not express any negative industry statements. There were a wide range of opinions, but overall most farmers were quite open to water conservation as a current or potentially future priority on their operation, with the bulk of the responses (36%) in the C+ category. The government is frequently seen as being too restrictive with many of their programs, guidelines, and regulations. With this information, the government could improve their programs and possibly improve the sustainability of the dairy industry.

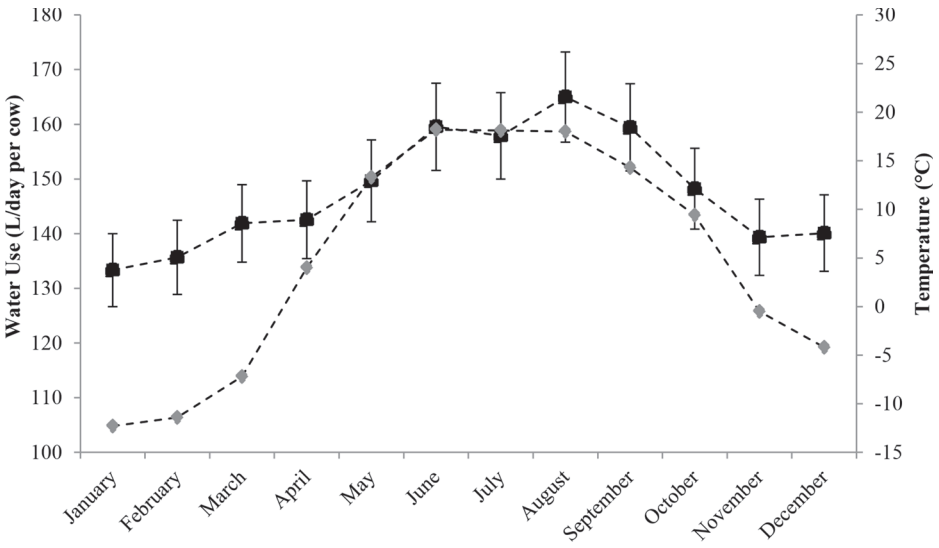

Figure 1. Average monthly water use on 10 Ontario dairy farms (■) from January through December 2014 with SE, and daily average Ontario temperature on the secondary y-axis (◆).

IMPLICATIONS

This study indicates that free-stall dairy automated milking systems use more water on a daily basis than tie-stall and free-stall parlor operations. Significantly more daily water-use fluctuations occurred during summer months. This leads to reasoning that seasonality is a key factor in water use. With the knowledge that robotic facilities use a greater amount of water and are also becoming a more common milking system, the industry can target efficient water-use strategies for these systems. There is a positive movement toward water conservation. There is still a lack of knowledge of many water conservation strategies that could be used on farm. But, there is a positive trend toward this, and there will most likely be improvement in the coming years. The exact potential savings for water reuse on a dairy farm are still unknown and would most likely vary between facilities. Further investigations into comparisons and opinions with additional farms would be useful in expanding upon this research.

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