Pilot Study on Agricultural Water Conservation and Efficiency Measures

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ABSTRACT

Globally, we are faced with increasing demand and pressure for reliable ground and surface water resources. Those resources must be recognized as valuable and precious resources. Therefore, everyone on our plant earth is urged to **i)** efficiently utilize, **ii)** willingly conserve, and **iii)** appreciate the value of those resources for present multi-use and future generations. Among several water use sectors the agriculture sector is one of the largest water use sectors in Canada and globally. Subsequently, the introduction and implementation of agricultural water conservation and efficiency measures such as flowmeters are considered to be vital tools. These measures will fulfil the need for a sound knowledge on agricultural water uses in relation to their productivity as performance indicators to benchmark those uses in the future. Agricultural water conservation and efficiency measures also ensure the sustainability and security of water resources.

This paper presents on the first of its kind pilot study on agricultural water conservation and efficiency measures such as flowmeters at more than sixty farms in the Province of Newfoundland and Labrador, Canada. In addition to the need for this pilot study, the partnership and consultation were considered to be core requirements to introduce and implement this pilot study. The implementation of this pilot study was based on farm assessments and visits for the proper selection and installation of flowmeters to ensure their compatibility with **i)** the nature of utilized water sources, **ii)** existing delivery piping systems, **iii)** type of farm (i.e. irrigation or livestock), and **iv)** budget allocated for each participating farm. The acceptability of this pilot study by more than sixty agricultural water users/producers was evidence of its success in promoting the efficient utilization and conservation and appreciation of the value of water resources. It was also encouraging to know that more agricultural water users/producers are willing to participate in similar studies. Such willingness will help expand the introduction and implementation of similar water conservation and efficiency measures such as flowmeters for all agricultural water uses in Newfoundland and Labrador, Canada. It was concluded that this pilot study and similar studies on agricultural water conservation and efficiency measures in Canada or any other country, especially those under water stress or scarcity, will ensure the sustainability and security of water resources throughout the 21st century and beyond. This paper also recommends further monitoring and reporting; assessment and evaluation of functionality of installed flowmeters; and micro scale investigations at participating farms in this pilot study.

RÉSUMÉ

À l'échelle internationale, nous sommes confrontés à la demande et à la pression pour des ressources en eau souterraine et de surface fiables. Il faut reconnaître la valeur et la préciosité de ces ressources. Tous les habitants de la planète sont donc exhortés **i)** à les utiliser de façon efficiente, **ii)** à les conserver volontairement, et **iii)** à comprendre leur valeur pour les générations à utilisateurs multiples actuelle et future. Le secteur agricole est un des plus grands utilisateurs de l'eau au Canada et dans le monde. Par conséquent, il est essentiel d'introduire et d'appliquer des mesures de conservation de l'eau, comme les débitmètres, au sein de ce secteur. Ces mesures répondent au besoin d'une solide connaissance sur l'utilisation de l'eau à des fins agricoles en tant qu'indicateur de rendement pour évaluer l'utilisation future. Elles garantissent également la durabilité et la sûreté des ressources en eau.

Le présent document décrit la première étude pilote en son genre sur l'application de mesures de conservation de l'eau, comme les débitmètres, par plus de soixante exploitations agricoles à Terre-Neuve-et-Labrador, Canada. En plus du besoin d'entreprendre cette étude pilote, le partenariat et la consultation ont été considérés comme des exigences de base de cette dernière. L'étude pilote repose sur l'évaluation des exploitations agricoles et des visites en vue de choisir et d'installer les débitmètres convenables **i)** à la nature des sources en eau utilisées, **ii)** à la tuyauterie de refoulement actuelle, **iii)** au genre d'exploitation agricole (c.-à-d. irrigation ou bétail) et **iv)** au budget alloué à chaque exploitation agricole participante. L'acceptation de cette étude pilote par plus de soixante utilisateurs et producteurs agricoles témoigne de son succès dans la promotion de la conservation et de la valeur de l'eau. Il est aussi réconfortant de savoir que d'autres producteurs et utilisateurs agricoles sont prêts à participer à des études semblables. Cette volonté permettra d'élargir l'introduction et l'application de mesures de conservation de l'eau semblables, comme les débitmètres, relativement à toutes les utilisations de l'eau aux fins agricoles à Terre Neuve-et-Labrador, Canada. Il a été conclu que la présente étude pilote et d'autres études semblables sur les mesures de conservation de l'eau utilisée à des fins agricoles au Canada et dans tout autre pays, notamment ceux frappés par le stress hydrique et la rareté de l'eau, garantiront la durabilité et la sûreté des ressources en eau au cours du 21e siècle et après. Le présent document recommande également des contrôles et des rapports plus fréquents, l'évaluation de la fonctionnalité des débitmètres installés et des enquêtes à petite échelle dans les exploitations agricoles qui participent à la présente étude pilote.

INTRODUCTION

No doubt ground and surface water resources are recognized as valuable and precious resources. Globally, their limited availability in several countries to satisfy various water use sectors led water resources researchers and experts to classify those countries to be under either water stress or scarcity. In Newfoundland and Labrador, Canada or any other country, defining the baseline conditions for an agricultural water use is an important step in a strategic framework for agricultural water conservation and efficiency. In fact, the establishment of baselines and benchmarks are essential for assessing the performance of agricultural water use practices and for modifying future strategies and approaches to properly manage utilized water sources. Such

measures in the agricultural water use sector are compatible with Canadian and global trends and are essential in several aspects including:

1. The need for monitoring and reporting to determine the extent of current uses and forecasting future needs to fill in the lack of benchmarks for agricultural water uses as well as determining the value of agricultural water uses to the economy;
2. The expansion of the use of existing agricultural water supplies for both irrigation and livestock;
3. The need for reducing the effluent and return flows from agricultural water uses into receiving water resources and the environment;
4. The examination of the functionality of this pilot study and the possibility of introducing and implementing similar measures (i.e. flowmeters) for all agricultural water uses in Newfoundland and Labrador, Canada; and
5. Providing researchers, water resources managers, and agricultural water users/producers with reliable figures on how much water is being utilized at farm level and finding ways to conserve it and efficiently utilize it where and when needed.

Those aspects significantly contribute to the sustainability and security of water resources for agricultural and other water use sectors.

The main goal of this pilot study aimed and succeeded in setting the stage for the continuous monitoring and reporting of agricultural water uses that utilize both ground and surface water resources in the Eastern, Central and Western regions of Newfoundland and Labrador. This is considered to be vital to fulfil the need for a sound knowledge on agricultural water uses in relation to their productivity as performance indicators to benchmark those uses in the future. This paper presents a description of the location, area and nature of water resources in the pilot study regions, highlights on agricultural water uses, and the need for this pilot study. Also, the paper presents the partnership and consultation involved in this pilot study. In addition, this paper presents the subsequent implementation of agricultural water conservation and efficiency measures. Moreover, this paper presents figures and graphical presentations of typical daily water uses for monitored periods between 2 to 184 days at more than sixty participating farms in Newfoundland and Labrador, Canada. Furthermore, the author recommends and will pursue **i)** further monitoring and reporting to develop trends of agricultural water uses, **ii)** the assessment and evaluation of functionality of installed flowmeters at participating farms to determine the most successful technologies and operational mechanisms, **iii)** conducting similar studies to include all agricultural water uses, and **iv)** conducting micro scale investigations and comparisons of agricultural water uses at participating farms with similar commodities.

LOCATION, AREA AND NATURE OF WATER RESOURCES IN PILOT STUDY REGIONS

This pilot study on the introduction and implementation of agricultural water conservation and efficiency measures was conducted in the Province of Newfoundland and Labrador, Canada. Figure 1 shows the location of Newfoundland and Labrador in relation to the world and North America. The Province lies between the 46^{th} and 61^{st} parallels with the bulk of its Island portion being below the 50^{th} parallel. The Island portion is located in the Gulf of St.

Lawrence and the larger Labrador portion is on the eastern part of the Canadian mainland. The area of the Province of Newfoundland and Labrador is 405,720 km^2 of which 111,390 km^2 represents the Island portion and 294,330 km^2 represents Labrador portion. The Province's area is more than three times the total area of the Canadian Maritime Provinces (Nova Scotia, New Brunswick and Prince Edward Island). The Province of Newfoundland and Labrador would rank fourth in size behind states of Alaska, Texas and California in the United States of America. In comparison with areas of other countries, the area of the Province is about 63% the area of France, almost one and three quarters times the area of Great Britain, and 41% the area of Egypt.

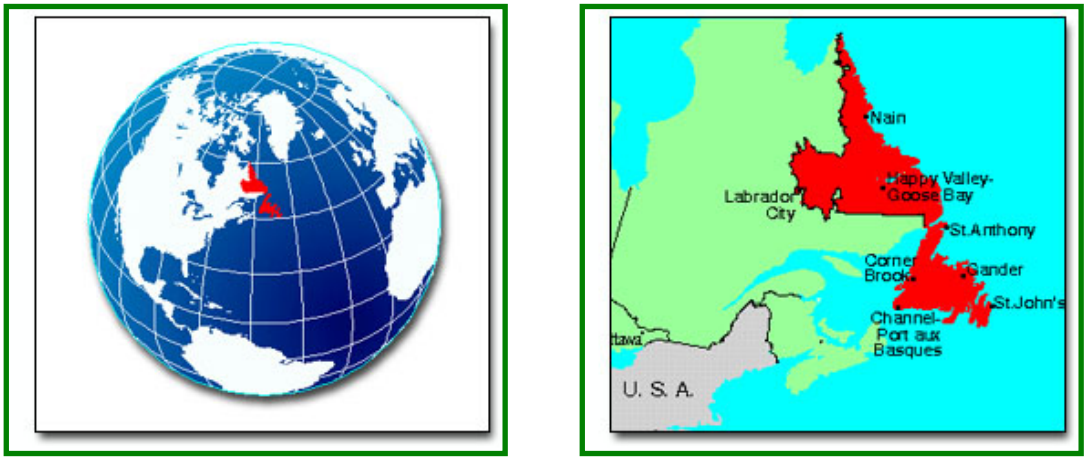

Figure 1 Location of Newfoundland and Labrador, Canada
(Source: Government of Newfoundland and Labrador website - 2008)

The following provides highlights of the physiographic characteristics, runoff and nature of water resources in the Province of Newfoundland and Labrador, Canada:

1. The interior of the Island portion is characterized by an elevated, undulating plateau which generally tilts towards the northeast. Peak elevations range from 200-300 m on the central region up to more than 800 m in the area of the Long Range Mountains that runs from the extreme southwestern region of the Island and up along the Northern Peninsula.
2. Labrador portion is characterized by elevated ranges over 1500 m in the Torngat Mountains with an interior large plateau with elevations ranging between 300 and 650 m.
3. On the Island portion, the mean annual runoff ranges from 700 mm to 900 mm on the north-central region of the Island portion up to 1300 mm to 2100 mm in the southwestern region of the Island portion. The total mean annual runoff volume on the Island portion is about 105,000 million cubic meters. This is about two times Egypt's share of water from the River Nile (Abdel-Razek (1986)).
4. In Labrador portion, the mean annual runoff ranges from 600 mm up to 800 mm with the exception of the extreme southeastern corner where it is over 1000 mm. The total mean annual runoff volume on the Labrador portion is about 190,000 million cubic meters.
5. Up to 20% of the land area of Newfoundland Labrador is covered by bodies of surface water including wetlands.
6. The available data on groundwater indicates a yield of up to more than 40 litres per minute.

HIGHLIGHTS ON AGRICULTURAL WATER USE

Food and Agriculture Organization of United Nations – FAO (2008) indicated that agricultural water use represents 70% of the global water use. In Egypt for example, FOA indicated that the total water withdrawal from all sources in 2000 was estimated at 68,300 million cubic meters of which 59,000 million cubic meters is used for agriculture (i.e. 86% of the total water withdrawal). In Australia, Trewin (2006) of the Australian Bureau of Statistics reported that Australian agricultural farms used 11,147 million cubic meters of water for agricultural production. Irrigation of crops and pastures was found to represent the major water use of 10,085 million cubic meters or 90.5% of total agricultural water use. The agricultural water use for other purposes such as livestock drinking water, and dairy and piggery cleaning was 1,062 million cubic meters or 9.5% of the total agricultural water use. In Canada, Soulard et al (2008) of Statistics Canada indicated that the agricultural sector accounted for 9% of all water used in Canada based on 1996 estimates. They further indicated that irrigation represented 92% of agricultural water use in Canada in 2001, while livestock water use accounted for 5%. In Newfoundland and Labrador, there are no reliable figures on agricultural water uses. However, there is a study proposed and implemented by the author and funded by the Canada-Newfoundland and Labrador Water Supply Expansion Agreement under the National Water Supply Expansion Program to evaluate and provide reliable figures on agricultural water uses.

NEED FOR PILOT STUDY ON AGRICULTURAL WATER CONSERVATION AND EFFICIENCY MEASURES

Canada has less than 1% of the world's population and has about 9% of the world's freshwater resources and is viewed as a rich country in freshwater resources. As stated earlier, the Province of Newfoundland and Labrador, Canada may also be viewed a rich region with water resources. However, Canada faced dry climate conditions and drought watches in recent years which affected both water availability for agriculture industry and its production especially in the Prairie Provinces (i.e. Alberta, Saskatchewan, and Manitoba). Kinkead (2005) highlighted the following realities in relation to Canadian water resources and their reliability for agricultural and other water use sectors:

1. Sixty percent of Canada's water resources flow north while more than 85% of the population and the vast majority of the country's economic activity are located in more southern regions.
2. Many agriculturally important areas have semi-arid climates and face growing competition for limited water supplies. Crop and livestock production and many local communities have become dependent on water diversions and constructed storages to meet their needs.
3. Many other areas exhibit seasonal and more-prolonged patterns where cumulative demand for water results in competition over supplies and threatens aquatic ecosystems.
4. Climate change predictions show that many parts of Canada are likely to experience increasing risks from reduced water availability and increased demand.

In particular, the Province of Newfoundland and Labrador faced and may face dry summers such as summer 2004 (Abdel-Razek (2005 and 2007)). Such dry climate conditions may be repeated in the future and agricultural water users/producers must be in a position to

properly manage their utilized water sources for ensuring the sustainability of those water sources and agriculture productivity. Obviously, the peak water demand for irrigation and water consumption for livestock occur in low flow or dry periods that directly impact the water availability for agricultural water uses. Meanwhile and in his study on the evaluation of agricultural water uses, the author found that there is presently less than 1% of farms in Newfoundland and Labrador that implement water conservation and efficiency measures such as flowmeters to monitor and record their agricultural water uses from utilized water sources. Perhaps, the main reason in Canada and Newfoundland and Labrador is agricultural water users/producers and other users thinking of the availability of abundance of water resources which may contradict the realities on Canadian water resources as pointed by Kinkead (2005). Globally, FOA (2008) indicated that the experience shows that the number of countries where agricultural water use is monitored with sufficient accuracy is limited. In its metering water extractions policy, the State of Queensland (2005) indicated that the policy is largely concerned with metering of water taken directly from the source such as an aquifer or watercourse. Therefore, it applies more to un-supplemented water users, which includes a large portion of agricultural users.

Therefore, agricultural water conservation and efficiency measures are considered to be vital tools to satisfy the need for reliable data on agricultural water uses, the increasing demand for agri-food production and ensuring the sustainability and security of water resources in Newfoundland and Labrador, Canada and elsewhere especially in countries with water stress and water scarcity. In addition, the agricultural water conservation and efficiency measures help in avoiding water use conflicts especially when agricultural uses are competing with other uses from same water resources or watershed especially in low flow or dry periods. More important those measures are compatible with Canada's notion in promoting itself as world leader in food safety and environmentally sound agri-food production.

PARTNERSHIP

In February 2007, this pilot study was proposed by the author of Newfoundland and Labrador Department of Environment and Conservation. In August 2007, the funding was provided by Canada-Newfoundland and Labrador Water Supply Expansion Agreement under the National Water Supply Expansion Program along with in-kind contribution provided by the Water Resources Management Division, Department of Environment and Conservation, Newfoundland and Labrador of Newfoundland and Labrador, Canada. This represents federal-provincial partnership. This pilot study was implemented by the author. In addition, the overwhelming interest and willingness to participate by agricultural water users/producers of more than sixty was viewed as real partnership in implementing this pilot study on agricultural water conservation and efficiency measures.

CONSULTATION

When the author proposed this pilot study, a sample of more than 10 agricultural water users/producers was consulted to gauge the acceptability of this pilot study and its rationale.

Those agricultural water users/producers immediately agreed to participate in this pilot study. The author initially set a target to involve up to 53 farms in this pilot study (i.e. more than 10% of all farms in the Province of Newfoundland and Labrador, Canada). Upon receiving the initial approval for funding in March 2007, more potential agricultural water users/producers were consulted and agreed to participate in this pilot study. It was also necessary to hold direct discussions with agricultural water users/producers on the nature of this pilot study and the importance of having water conservation and efficiency measures as tools for efficient utilization of on-farm available water sources and the appreciation of the value and sustainability of water resources. In addition, the consultation process aimed towards a strategic selection of participating irrigation and livestock farms to cover not only the Eastern region of the Island portion of Newfoundland but to also cover Central and Western regions of the Island portion of Newfoundland as well as the Labrador portion of the Province of Newfoundland and Labrador.

Figure 2 shows a photo for the author holds a flowmeter that was selected and installed in some small irrigation farms and livestock farms while presenting the need for and advantages of agricultural water conservation and efficiency measures and the value of water resources. The photo also shows anther installed flowmeter for large irrigation systems (bottom right corner) at a participating farm in this pilot study.

Figure 2 Author during Presentation at Participating Farm

IMPLEMENTATION

Selection of Flowmeters

From March up until July 2007, the author conducted extensive research on the best and most economical technologies for flowmeters. This research covered a variety of technologies including turbine, propeller, positive displacement, electromagnetic or insert type flowmeters.

The process considered the following parameters:

1. Nature of utilized water sources at the participating farms;
2. Existing delivery piping system at the participating farms;
3. Type of participating farm (i.e. irrigation or livestock); and
4. Budget allocated in the pilot study for each participating farm.

Farm Visits and Assessments

In addition to direct discussions and consultations with agricultural water users/producers, it was necessary to conduct the following:

1. One or two farm visits to each participating farm;
2. Farm assessment to confirm the nature of utilized water sources utilized, delivery piping system and proper flowmeter(s);
3. Installation and testing selected flowmeter(s); and
4. Hands on for agricultural water users/producers on the nature and the operation of installed flowmeter(s), records keeping, and an agreed upon reporting mechanism.

Participating Farms

More than sixty irrigation and livestock farms participated in this pilot study including some farms with two or more sub-farms within one mixed farm (i.e. irrigation and livestock) and one relatively large irrigation farm. The farms were located in the Eastern, Central and Western regions of the Island portion and one participating farm in Labrador portion of the Province Newfoundland and Labrador.

Commodities in participating farms included greenhouses, strawberries, blueberries, raspberries, blackcurrants and small fruits, cranberries, vegetables, sweet corn, sod, beef, dairy, growing dairy, broilers, layers, pullets, egg grading, sheep, turkey, horses, fur and hogs. Figure 3 shows participating irrigation farms by commodities. Mixed commodities included strawberries, raspberries, blueberries, vegetables, sweet corn, blackcurrants, cranberries, small fruits, greenhouse, and sod.

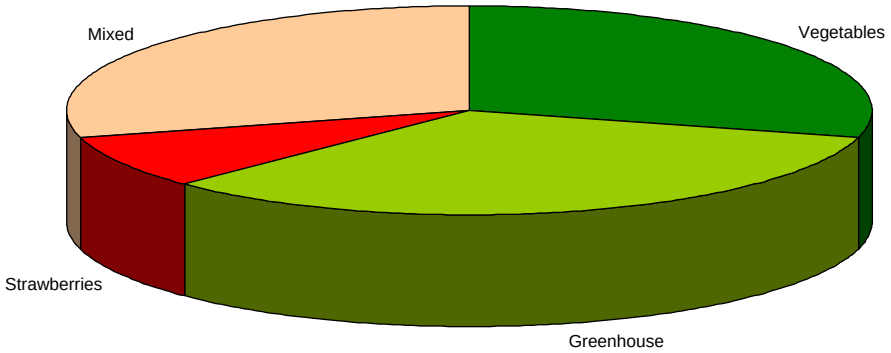

Figure 4 Participating Irrigation Farms by Commodities

Figure 4 shows participating livestock farms by commodities. Mixed commodities included sheep, turkey, layers, pullets, egg grading, horses and hogs.

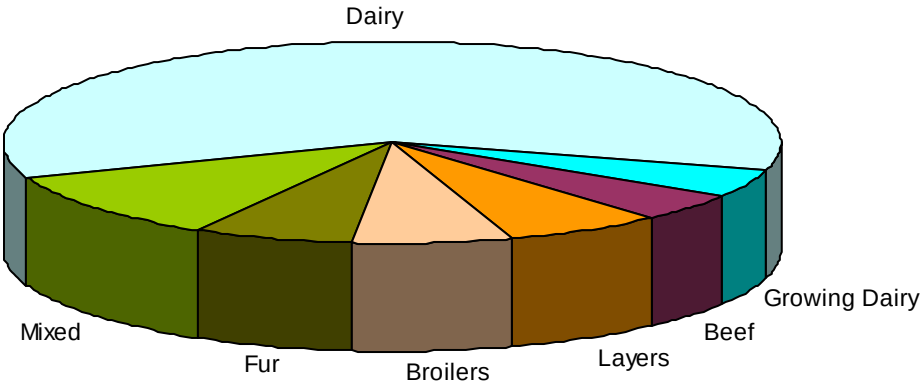

Figure 4 Participating Livestock Farms by Commodities

Monitoring and Data Collection and Analysis

Irrigation Farms

In most of participating irrigation farms, test runs were conducted for flowmeters due installation in March 2008. Water use data will be collected in the next irrigation season (May to October). However in some farms, it was possible to monitor water uses from installed flowmeters for periods from 2 up to 169 days. The average daily water use ranged between 0.0565 cubic meters in greenhouse up to 215.400 cubic meters at a selected location of one participating farm. Figure 5 shows typical daily water use at a participating irrigation farm. It can be seen that irrigation trends were affected by mild climate conditions during the monitoring period.

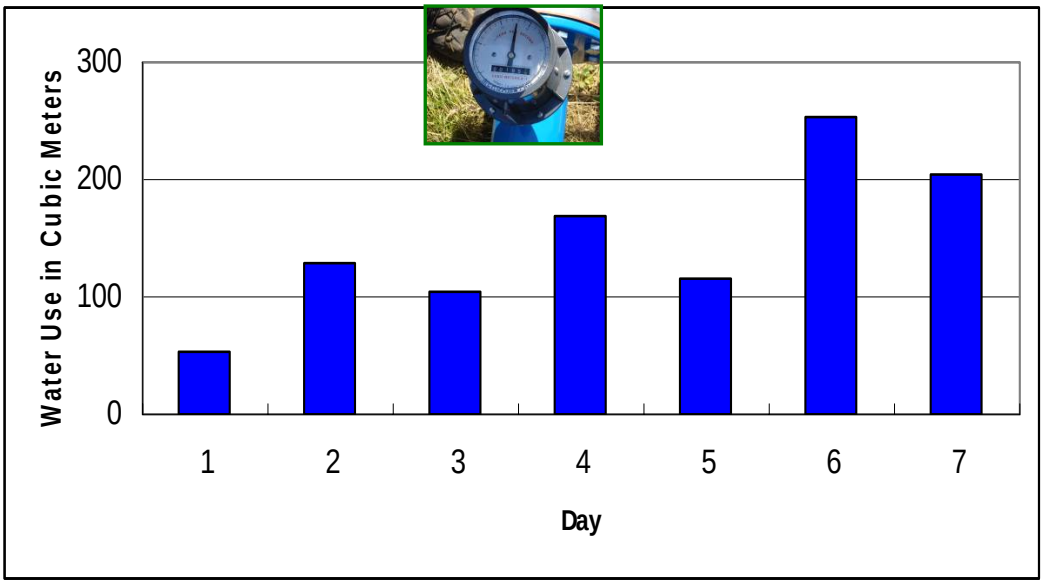

Figure 5 Typical Daily Water Use and Installed Flowmeter at Location # 1 of Participating Mixed Farm

Livestock Farms

In most of participating livestock farms, it was possible to monitor water uses from installed flowmeters for periods from 7 up to 184 days. In some participating livestock farms, only test runs were conducted for flowmeters due installation in March 2008.

Table 1 presents the average daily water use at participating livestock farms. Also, Figures 6 to 8 shows typical daily water uses at participating livestock farms.

Table 1 Average Daily Water Use at Participating Livestock Farms

Livestock Farms by Commodity	Average Daily Water Use (Cubic Meters)
Two Mixed farms (sheep, turkey and horses)	0.241 to 0.824
Most dairy farms	4.000 to 45.770
Two broilers farms	7.692 to 15.492
One fur farm	0.490

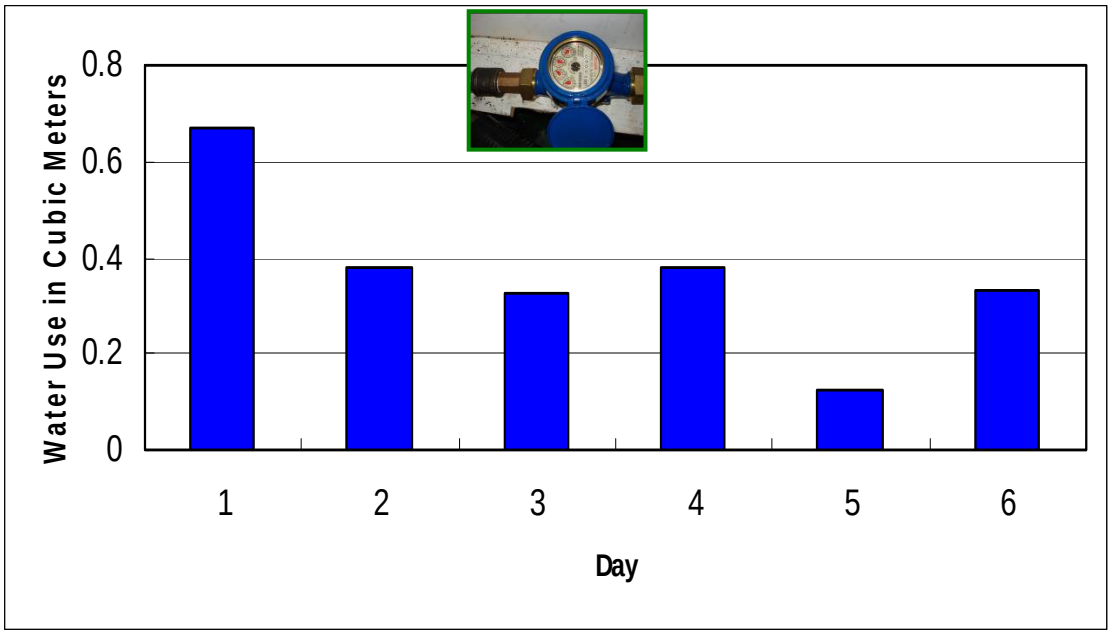

Figure 6 Typical Daily Water Use and Installed Flowmeter at Participating Mixed Livestock Farm

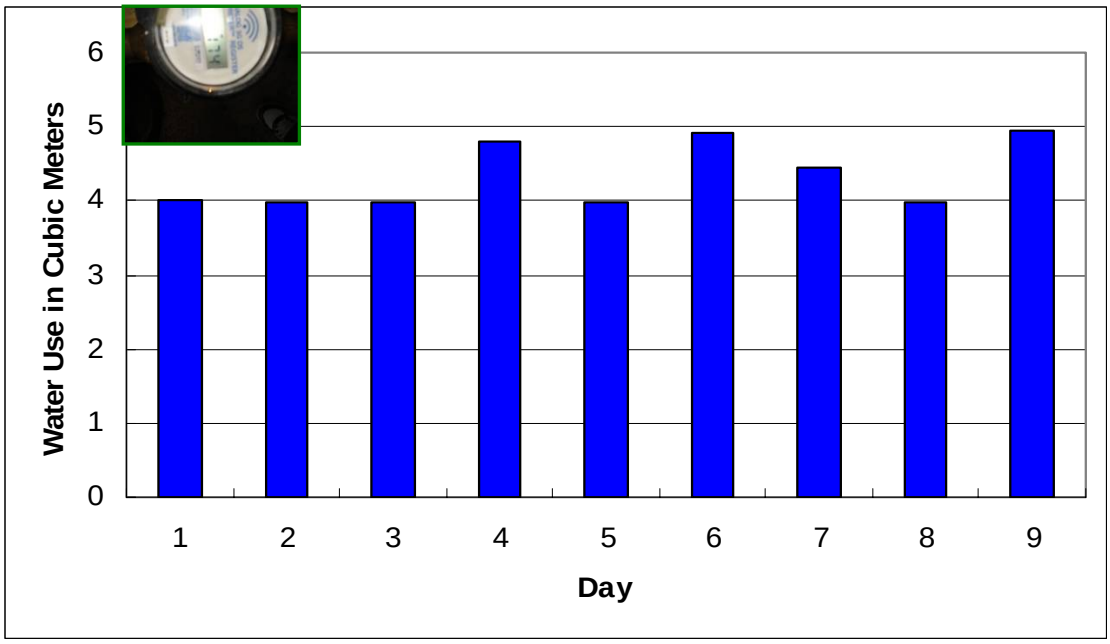

Figure 7 Typical Daily Water Use and Installed Flowmeter at Participating Dairy Farm

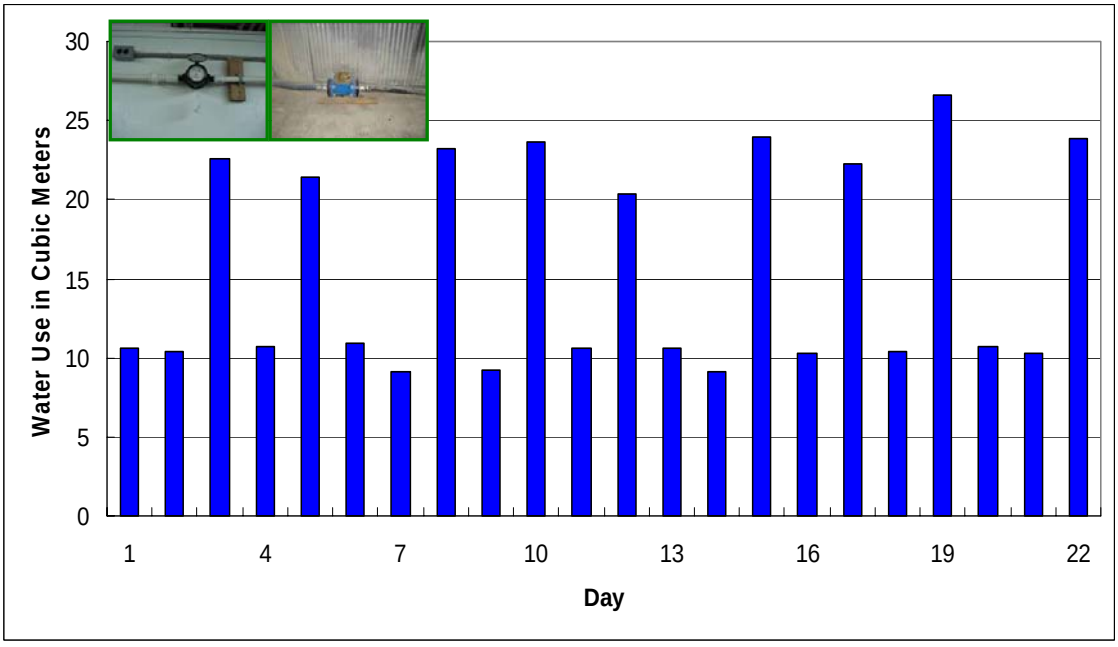

Figure 8 Typical Daily Water Use and Installed Flowmeters at Participating Layers Farm

CONCLUDING COMMENTS

This paper presented the first of its kind pilot study on the introduction and implementation of agricultural water conservation and efficiency measures at more than sixty participating irrigation and livestock farms in Newfoundland and Labrador, Canada. The following are the main concluding comments:

1. The sustainability of our valuable and precious water resources for multi-use including the agriculture water use sector and future generations, requires that they must be **i)** efficiently utilized, **ii)** willingly conserved, and **iii)** value appreciated.
2. The partnership and consultation were core requirements for the success of this pilot study.
3. The selection of participating farms at various locations and with various commodities is very important to ensure a strategic representation and coverage of the agriculture industry in selected regions such as those selected in this pilot study.
4. A variety of technologies for flowmeters in relation to specific farm conditions were selected and installed at participating farms in this pilot study including turbine, propeller, positive displacement, electromagnetic or insert type flowmeters.
5. In this pilot study and similar studies on agricultural water conservation and efficiency measures, it is important to select and install flowmeters with a variety of technologies and operational mechanisms to enable examining their functionality and avoid widespread problems that may result from the selection of a single technology and operational mechanism.
6. The acceptability of this pilot study by more than sixty agricultural water users/producers was evidence of its success in promoting the efficient utilization and conservation and appreciation of the value of water resources. It was also encouraging to know that more agricultural water users/producers are willing to participate in similar studies. This in itself is considered to be an outreach and education that helps the sustainability and security of water resources throughout the 21st century and beyond.
7. The monitoring of daily water use for periods from 2 up to 169 days at participating irrigation farms revealed that the average daily water use ranged between 0.0565 cubic meters in greenhouse up to 215.400 cubic meters at a selected location of one participating farm with mixed commodities.
8. The monitoring of daily water uses for periods from 7 up to 184 days at participating livestock farms revealed that the range of average daily water use of 0.241 to 0.824 cubic meters for two mixed livestock farms; 4.000 to 45.770 cubic meters for most dairy farms; 7.692 to 15.492 for two broilers farms; and 0.490 cubic meters for one fur farm.
9. Agricultural water users/producers of participating farms were very pleased to know "for the first time" reliable figures on how much water is being utilized at their farms.
10. This pilot study aimed and succeeded in setting the stage for the monitoring and reporting of agricultural water uses at participating farms that utilize both groundwater and surface water resources in the Eastern, Central and Western regions of Newfoundland and Labrador, Canada for years to come. This will fulfil the need for a sound knowledge on agricultural water uses in relation to their productivity as performance indicators to benchmark those uses in the future.

Recommendations and Future Research

Based on this pilot study, its success and overwhelming participation by agricultural water users/producers as well as the willingness of more agricultural water users/producers to participate in similar studies on agricultural water conservation and efficiency measures, the author recommends and will pursue the following:

1. Further monitoring and reporting of agricultural water uses at participating farms for monitoring periods of full year or more. This will help to develop a sound knowledge on trends of current agricultural water uses and forecasting future needs to fill in the lack of performance indicators to benchmark for those uses in the future;
2. Assessment and evaluation of functionality of installed flowmeters at participating farms to determine the most successful technologie(s) and operational mechanism(s);
3. Similar studies to expand the introduction and implementation of agricultural water conservation and efficiency measures such as flowmeters for all agricultural water uses in Newfoundland and Labrador, Canada; and
4. Micro scale investigations and comparisons of monitored agricultural water uses at participating farms with similar commodities including, but is not limited to, the development of water use coefficients specific to the Province Newfoundland and Labrador's agriculture industry. This will be valuable for the agriculture industry in Canada and any other country.

ACKNOWLEDGEMENTS

This pilot study was funded by Canada-Newfoundland and Labrador Water Supply Expansion Agreement under the National Water Supply Expansion Program along with in-kind contribution provided by the Water Resources Management Division, Department of Environment and Conservation, Newfoundland and Labrador of Newfoundland and Labrador, Canada.

The author greatly appreciated the overwhelming participation and cooperation of agricultural water users/producers of participating irrigation and livestock farms in this pilot study. Also, the author was encouraged by the agricultural water users/producers' consciousness of the importance of introducing and implementing agricultural water conservation and efficiency measures on their farms. This is considered an important indicator for the appreciation of the value of water resources and willingness to conserve and efficiently utilize those resources. These factors significantly contributed to the success of this first pilot study on the introduction and implementation of agricultural water conservation and efficiency measures at more than sixty farms in the Province of Newfoundland and Labrador, Canada.

DISCLAIMER

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