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Tipping the Balance on Winter Deicing Impacts: Education Is the Key

Michael E. Dietz
University of Connecticut

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Tipping the Balance on Winter Deicing Impacts: Education Is the Key

Abstract

Winter deicing results in substantial export of road salts to fresh waters and causes numerous ecological problems. Extension faculty and other educators at the University of Connecticut implemented New Hampshire's Green SnowPro program, a voluntary training program for salt applicators. University of Connecticut facilities staff applied 3,479 fewer metric tons of salt to campus in the 2 years after the educational training, equating to a cost savings of $459,251. Substantial environmental and economic benefits can be realized in northern climates if Extension and other educators rally behind this program.

Keywords: conductivity, deicing, road salt, Green SnowPro, education

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Michael E. Dietz
Extension Educator
University of Connecticut
Storrs, Connecticut
michael.dietz@uconn.edu
@ctiwr

Introduction

Road salt use in the United States has increased substantially in the past several decades (Mullaney, Lorenz, & Arntson, 2009). Perhaps unsurprisingly, increased salinization of ground and surface waters has been documented in recent years (Cassanelli & Robbins, 2013; Corsi, De Cicco, Lutz, & Hirsch, 2015; Dugan et al., 2017; Kaushal et al., 2005; Kaushal et al., 2018; Mullaney et al., 2009). High concentrations of chloride have documented impacts on aquatic life (Corsi, Graczyk, Geis, Booth, & Richards, 2010; Williams, Williams, & Cao, 1999), vegetation (Bryson & Barker, 2002; Galuszka, Migaszewski, & Podlaski, 2011), and infrastructure (Connecticut Academy of Science and Engineering, 2015). Also at risk are public and private drinking water wells. Shallow overburden wells are obviously vulnerable; however, even deep bedrock wells are showing increases in chloride concentrations over time (Cassanelli & Robbins, 2013). Public drinking water system operators are required to test their source water for salt, but private well owners do not have the same testing requirements, putting public health at risk (Vaughn, 1989). Perhaps of greater concern, high chloride concentrations have been documented even in the low-flow summer months, when water temperatures are higher and aquatic life is more vulnerable to stressors (Cooper, Mayer, & Faulkner, 2014). Currently, no technology exists to efficiently remove chlorides from ground or surface waters at the watershed scale.

Additionally, the financial costs of road deicing are substantial; total expenditures on deicing materials in the United States have been estimated to be more than $1 billion annually (Lilek, 2017). For state departments of transportation and municipalities, these costs can comprise a considerable portion (20%) of annual budgets (Federal Highway Administration, n.d.).

Several states have implemented training programs for public works staff, with the goal of reducing excessive salt applications while still maintaining safe conditions for pedestrian and vehicular travel. For example, New Hampshire recently began its Green SnowPro program (https://t2.unh.edu/green-snowpro-salt-applicator-certification-training), a voluntary program where public works staff and private contractors receive training and become certified salt applicators. Once applicators become certified, facilities they manage receive limited liability protection from slip and fall litigation.

The University of Connecticut (UConn) main campus in Storrs, Connecticut, is a small urbanized area in the middle of a rural landscape. Consequently, the streams that drain campus have been channelized and have caused impairments of aquatic life support and recreation (Connecticut Department of Energy and Environmental Protection, 2017).

Extension professionals can conduct, and/or facilitate with other educators, trainings to assist public sector entities in reducing salt use. Many states have Roads Scholar training programs for municipal public works staff (for example, at UConn these trainings are provided by the Connecticut Training and Technical Assistance Center). Educators in the many Roads Scholar training programs are natural partners for Extension educators already performing public outreach on water quality issues.

The objective of the study reported here was evaluation of the effect of an educational training (based on New Hampshire's Green SnowPro program) for UConn winter operations staff on salt export from the UConn Storrs campus. Impacts of the training were measured via salt export calculations and an operations staff survey. Both the methodology and results can be of use to others in Extension in educating public works employees and private sector contractors on the beneficial impacts of reducing salt use.

Educational Training

In December 2017, the Connecticut Training and Technical Assistance Center at UConn and Extension faculty at the Center for Land Use Education and Research administered two 3-hr trainings to UConn winter operations staff and managers. The program followed the New Hampshire Green SnowPro model and included information on how salt works, environmental impacts of salt, brine making, anti-icing, efficient plowing, and equipment calibration.

Methods

To identify tangible evidence of the environmental impacts of behavior changes resulting from the training, I calculated the salt export in stormwater drained from the campus by measuring the discharge rate and electrical conductivity in stormwater drainage. Salt export data for winter seasons from 2011 to 2020 were summarized, along with the total number of storms for each season. Salt costs to the university also were summarized. Feedback from UConn winter operations staff was gathered via a survey.

Site Description

The study site was located in a 91.3-ha subwatershed of Eagleville Brook that drains a portion of the UConn main campus in Storrs (Figure 1). The watershed drains a large section of the core campus and has 41.6 ha (45.6%) of impervious cover (IC). Roughly half of this IC (19.2 ha) is roads, parking areas, and sidewalks.

Figure 1.
Location of Study and Detail at University of Connecticut in Storrs, Connecticut

Note: Location of study is signified by black star; watershed boundary is dashed line; triangle indicates watershed outlet and gauging station.

Salt Loading Calculation

Discharge Measurements

A concrete v-notch weir (dam) was installed on Eagleville Brook in the 1950s. It is located approximately 35 m downstream from the point where the brook discharges to an open channel after traveling under campus for roughly 865 m. Faculty in UConn's Department of Natural Resources and the Environment installed water level measurement equipment in 2009, and I have maintained and updated the datalogger system since that time. The datalogger records average water level in the stream every 10 min. For the study reported here, I calculated discharge using a standard weir equation:

$$\text{Discharge (ft}^3\text{/s)} = 7.578 * [\text{Water level (ft)}]^{2.5} \quad (1)$$

Conductivity Measurements

Specific conductance is a measurement of how much electrical current water conducts; higher salt content will result in higher conductance readings. I installed a specific conductance probe in 2011, and the datalogger records average specific conductance every 10 min. For the purposes of my study, I used an established regression relationship (R^2 = 0.95; see Equation 2) developed from previous sampling (n = 71) of shallow groundwater wells on campus (Dietz, Angel, Robbins, & McNaboe, 2016; McNaboe, 2017) to predict chloride concentrations from specific conductance. Based on analysis of several grab samples from Eagleville Brook, Equation 2 is very conservative and underestimates chloride concentrations from high specific conductance values. I then calculated salt export for each season by taking specific conductance at each 10-min time step that was above 3,500 µS/cm (highest baseflow concentration not associated with winter salting) and converted it to chloride (mg/L) using the regression. I then divided the chloride concentration by 0.39 (the ratio of the molecular weight of chloride to sodium chloride) to obtain the concentration of salt. Lastly, I multiplied the concentration of salt (mg/L) by the discharge (L) for each time step to calculate the mass of salt and summed the values for each winter season (2011–2020).

$$\text{Chloride concentration (mg/L)} = 0.39 * [\text{specific conductance } (\mu\text{S/cm})] - 247.79 \quad (2)$$

Storm Data

As winter storm activity is associated with salt use, data on the number of storms per winter season were relevant. Those data were obtained from the Connecticut Department of Transportation.

Salt Cost Data

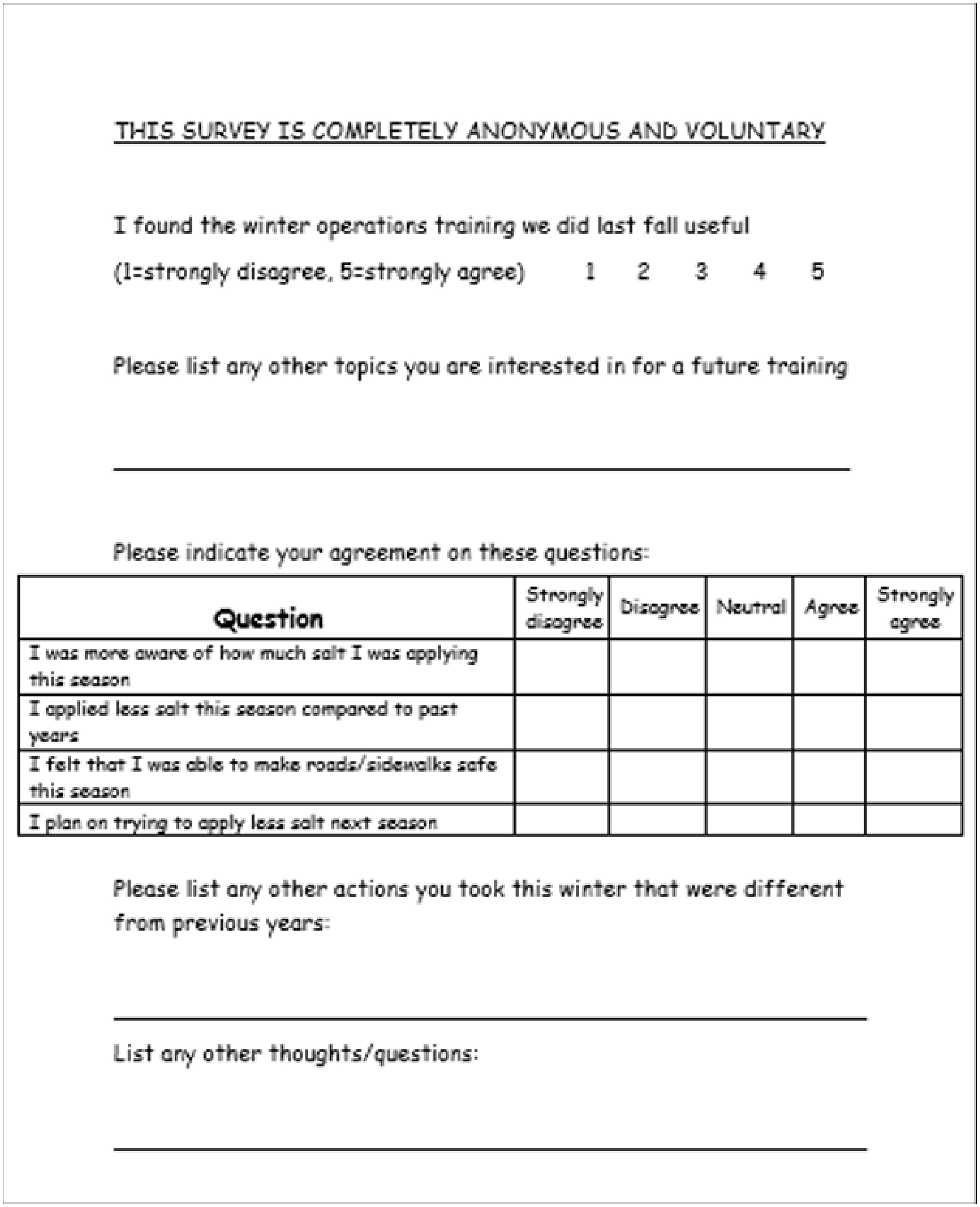
Salt costs ($/metric ton) were obtained from the director of landscape operations at the University of Connecticut.

Survey of Facilities Operations Workers

After winter operations had ceased for the season in May 2018, I convened a meeting with winter operations staff, where I presented monitoring results showing how much salt had run off campus into Eagleville Brook for the 2017–2018 season as compared to the previous season. I solicited feedback from staff in the form of a one-page survey (Figure 2). As I was not quantifying how much salt each participant applied before versus after the survey, these self-reported data are still useful. This "post-then-pre" evaluation approach can actually provide a more realistic representation of program effectiveness in situations such as this (Rockwell & Kohn, 1989).

Figure 2.

Survey Soliciting Feedback from University of Connecticut Facilities Staff



THIS SURVEY IS COMPLETELY ANONYMOUS AND VOLUNTARY

I found the winter operations training we did last fall useful

(1=strongly disagree, 5=strongly agree) 1 2 3 4 5

Please list any other topics you are interested in for a future training

Please indicate your agreement on these questions:

Question	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I was more aware of how much salt I was applying this season					
I applied less salt this season compared to past years					
I felt that I was able to make roads/sidewalks safe this season					
I plan on trying to apply less salt next season					

Please list any other actions you took this winter that were different from previous years:

List any other thoughts/questions:

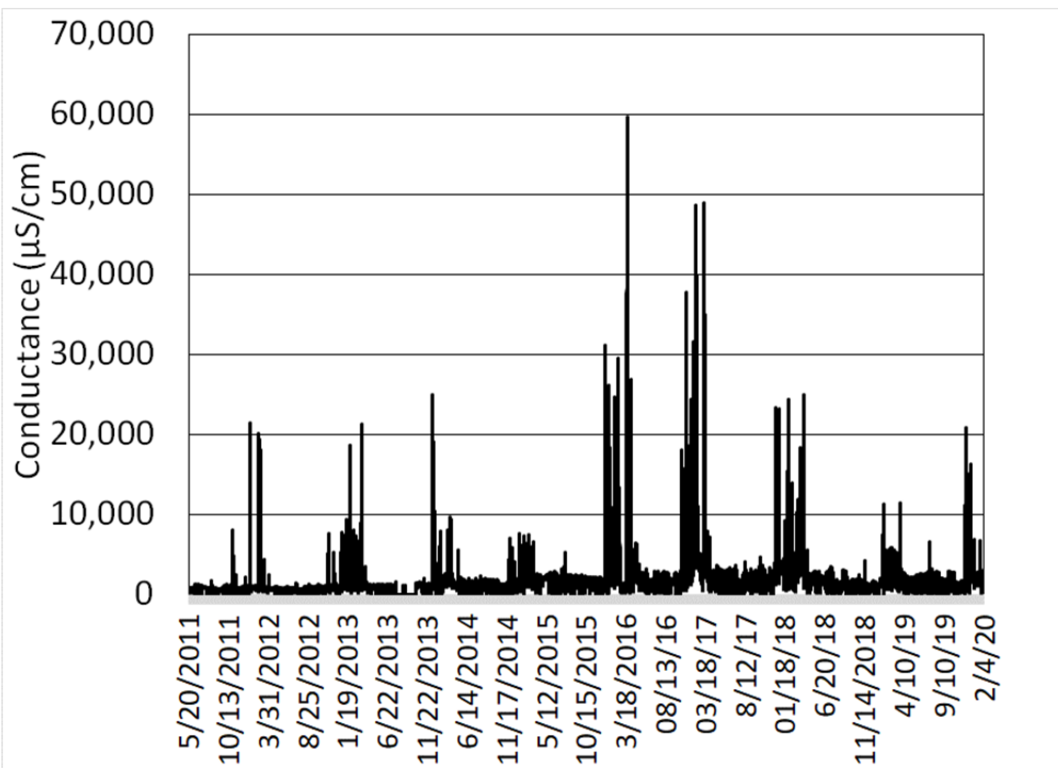
Results and Discussion

Conductance

High conductance was observed in Eagleville Brook during winter seasons from 2011 to 2020 (Figure 3). Conductance in baseflow (flow in the stream not associated with a rain event) during low-flow conditions of late summer/early fall increased from ~1,000 μS/cm in August 2011 to over 3,000 μS/cm in August 2017 (Figure 3). This phenomenon occurs because some of the road salt applied during the winter months runs off paved areas and sidewalks and percolates through pervious soils to the shallow groundwater table. The shallow groundwater supplies baseflow to streams in the region during periods when it is not raining. This situation has been documented in other areas (Cooper et al., 2014) and can be extremely stressful to aquatic life and streamside vegetation when flows are at their lowest and temperatures are high. Streams in this area with less developed watersheds would be expected to have conductance between one and two orders of magnitude lower than those found in Eagleville Brook in 2017 (Brown, Mullaney, Morrison, & Mondazzi, 2011).

Figure 3.

Specific Conductance in Eagleville Brook, Storrs, Connecticut, 2011–2020



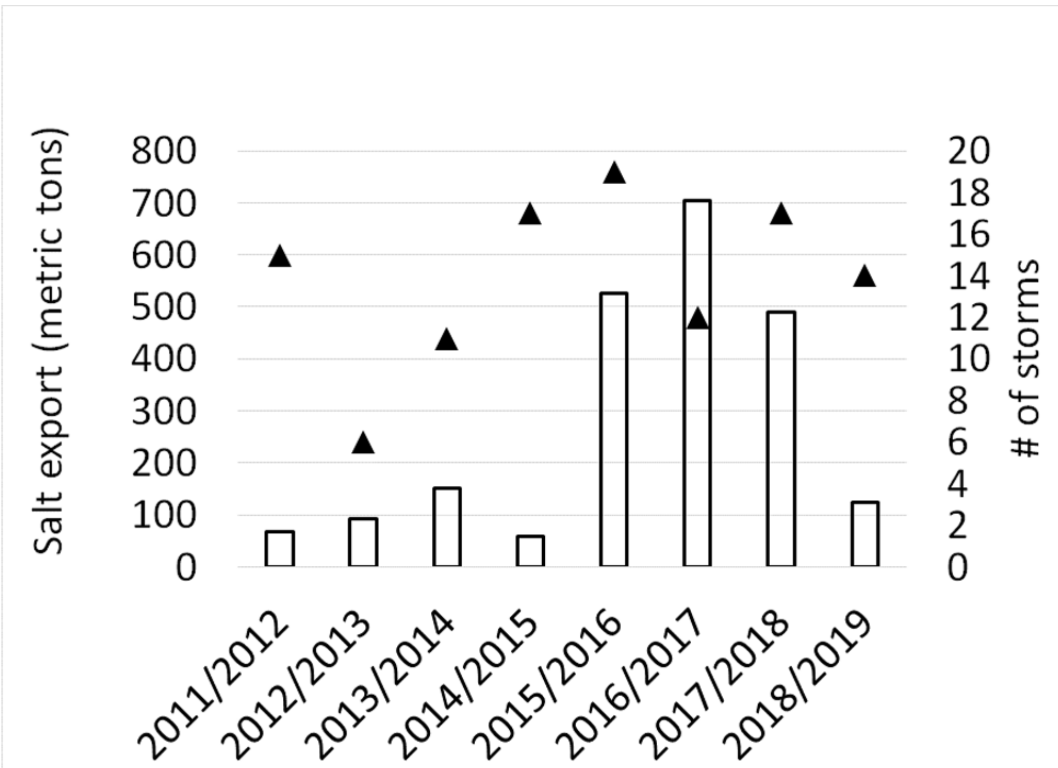
Salt Export

Based on the equation from the regression, salt export for the period of study was found to vary between 68 and 704 metric tons per winter season (Figure 4). A substantial increase in salt export rates can be seen after 2014–2015 (Figure 4). Discussions with the previous facilities landscape operations director indicated that much more salt was applied subsequent to that season due to concerns over slip and fall litigation.

Salt export decreased by 215 metric tons in 2017–2018 and by an additional 365 metric tons in 2018–2019, despite an increase in the number of storms (17 and 14 during the 2017–2018 and 2018–2019 seasons, respectively, vs. 12 during the 2016–2017 season) (Figure 4). In the 2017–2018 and 2018–2019 seasons, UConn facilities staff applied approximately 1,468 and 2,012 *fewer* metric tons of salt, respectively, to the entire campus (Table 1), when export from paved Eagleville Brook watershed was generalized to the paved areas in the entire campus (the monitoring watershed is roughly 35% of the campus area). If the 2016–2017 season is used as a reference, substantial reductions in salt export were observed in both years following the training, with over $450,000 in cost savings to the University of Connecticut (Table 1).

Figure 4.

Salt Export (Metric Tons per Season) in Eagleville Brook, Storrs, Connecticut



Note: Triangles represent number of storms for which Connecticut Department of Transportation mobilized.

Table 1.

Salt Export and Cost Savings Following Educational Training

Winter season	Predicted salt export (metric tons)	Actual salt export (metric tons)	Difference (metric tons)	Campus-wide reduction (metric tons)	Cost savings ($)
2017–2018	998.0	489.3	508.8	1,467.6	$193,729
2018–2019	821.9	124.6	697.3	2,011.5	$265,521
Total	1,820.0	613.9	1206.1	3,479.2	$459,251

Note. Predicted salt export was calculated from the 2016–2017 season metric tons/storm application rate.

Survey

Survey results (Table 2) indicate a strong positive response to the training in general as well as strong awareness of how much salt was being applied and strong participation in efforts to reduce salt applications. Another important finding was that staff reported that they were able to make roads/surfaces safe (Table 2), indicating that there was no sacrifice in level of service for the reduced salt applications. The current facilities landscape director confirmed this finding anecdotally; no increase in callbacks occurred for the 2017–2018 season (A. Ristau, personal communication, May 5, 2018). The director has expressed a commitment to being more efficient with salt applications while still optimizing safety. This outcome also highlights another key role for Extension educators to fill: Cultivating relationships with key people has the potential to make an enormous difference. Identifying and cultivating a relationship with a key local champion has been recognized as a critical piece to creating successful Extension efforts (Gallardo, Collins, & North, 2018).

Table 2.

Median Responses to Winter Operations Staff Survey Questions

Question	Median response
I found the winter operations training we did last fall useful	5
I was more aware of how much salt I was applying this season	5
I applied less salt this season compared to past years	5
I felt that I was able to make roads/sidewalks safe this season	5
I plan on trying to apply less salt next season	5

Note. Scale for response choices was 1 (*strongly disagree*) to 5 (*strongly agree*). n = 25.

Conclusions

Sharp increases in specific conductance in Eagleville Brook, a small stream in eastern Connecticut, were observed during winter periods from 2011 to 2020. Annual salt export in Eagleville Brook increased from 2011 to 2017, with liability concerns being the primary driver of increased salt application. Two educational trainings for facilities winter operations staff were performed prior to the 2017–2018 winter season. Following the trainings, salt export in Eagleville Brook decreased by 215 metric tons in 2017–2018, and by an additional 365 metric tons in 2018–2019, despite an increase in the number of storms. When generalized to the entire campus, facilities staff applied 3,479 fewer metric tons of salt to campus in the 2 years after the educational training, which equates to a $459,251 cost savings as compared to the 2016–2017 season.

Results of this work indicate that with a fairly modest investment in education, substantial reductions in salt applications can be realized, leading to reduced environmental impacts and monetary savings. No technology or product currently exists that melts ice efficiently. Therefore, the only clear way to reduce the harmful environmental effects of road salts is to educate those who are applying the materials. This is a call to action for Extension educators and others working on water quality issues in northern climates: Adopt the Green SnowPro program in your state as soon as possible. No other option has the potential to reduce environmental harm and save money while still keeping roads safe for travel. Extension educators are ideally situated to enhance relationships with local champions and cultivate new relationships with other partners in education. Readers also can help educate their municipal representatives by directing them to these findings, communicating the value of education in providing both environmental and financial benefits.

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