Incentives and disincentives identified by producers and drainage contractors/experts on the adoption of controlled tile drainage in eastern Ontario, Canada
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ABSTRACT
This study investigates incentives and disincentives regarding adoption of controlled tile drainage (CTD) in a region of eastern Ontario, Canada, where CTD could be used proliﬁcally from a biophysical standpoint, but is not. Irrespective of documented environmental and agronomic beneﬁts of CTD, adoption remains low. Surveys and semi-structured interviews with producers and drainage contractors/experts were used to evaluate awareness of CTD and identify producer adoption impediments. Surveys indicated nearly 70% of producer respondents had heard about CTD. Top ranked incentives identiﬁed by producers (who adopted) and drainage contractors/experts combined were: soil water retention beneﬁts, increased crop yields, and gratiﬁcation improving the environment. Top ranked disincentives combined by target groups were: increased farm labor, perceived lack of extension services, and costs. Many producer adopters emphasized motivators grounded in personal or community bearing, such as peer interaction and doing the right thing for the environment. Drainage contractors emphasized adoption impediments tied to a perceived lack of extension support for CTD. Drainage contractors themselves desired more extension support and ﬁrm data/research foundations with respect to advocating CTD to clients. With respect to motivation for producers to adopt CTD, this latter point may be critical given that producers highly valued drainage contractors as an information source on drainage practices.

Key words | BMP adoption, controlled tile drainage, drainage water management, farm behavior, incentives, perceptions

INTRODUCTION
Tile drainage is essential for agricultural production in many parts of the world (Evans & Fausey 1999). However, tiles can act as efﬁcient hydrological pathways by which inorganic and organic ﬁeld constituents can directly and rapidly enter surface water systems (Skaggs et al. 1994; Lapen et al. 2008; Blann et al. 2009). Tile drainage beneﬁcial management practices (BMPs) have been studied extensively in North America and in Europe (e.g., Gilliam et al. 1979; Drury et al. 1996; Lalonde et al. 1996; Tan et al. 1998; Fausey 1999; Weststrom & Messing 2007; Skaggs et al. 2010). Controlled tile drainage (CTD) is one form of drainage water management that regulates the amount of tile drainage that can leave a ﬁeld (Gilliam et al. 1979; Strock et al. 2010). This practice is best suited on ﬂat ﬁelds and where soils below tile are less permeable (American Society of Agricultural & Biological Engineers (ASABE) 1990). This practice can increase water table levels and soil water contents in the ﬁeld thereby allowing crops to more readily access water and nutrients during critical crop growth stages (American Society of Agricultural & Biological...
Engineers (ASABE) 1990; Evans et al. 1995; Lalonde et al. 1996; Sunohara et al. 2014; Kross et al. 2015). The practice has been examined experimentally and is clearly promising for boosting crop yields and reducing net exports of agricultural pollutants to adjacent surface water (Drury et al. 1996; Westrom & Messing 2007; Ciccek et al. 2010; Sunohara et al. 2015). The annual marginal cost of CTD was estimated in eastern Ontario be on the order of $30 CAD ha$^{-1}$ (Crabbe et al. 2012). Crabbe et al. (2012) estimated, based on observed yields as well, that a crude payback period was roughly 3 years for corn and 4 years for soybean. Wossink & Osmond (2002) determined, due to modest yield boosts, a financial benefit of CTD in North Carolina on order of $5 to $25 USD ha$^{-1}$ yr$^{-1}$.

Recently, Que et al. (2015) simulated the effect of CTD for a 4,000 km$^2$ river basin in eastern Ontario Canada that had about 2,000 km$^2$ of cropland on which CTD could be physically employed. That study found that during the growing season only, loads of dissolved nitrogen could be reduced by up to 55%; underscoring the potential importance of this BMP for meeting large-scale environmental pollution targets. Sunohara et al. (2015) found for experimental watersheds in eastern Ontario that CTD significantly reduced growing season fluxes of mineral N and total and dissolved phosphorus over many years of study. Thorp et al. (2008) estimated that for the US Midwest, roughly 50% reductions in nitrate loads could potentially occur if drainage water management practices were adopted across the region. Feser et al. (2010) reported that CTD can reduce edge of field nitrogen and phosphorus loads by over 50%.

Despite these documented environmental and agronomic benefits, CTD is not adopted widely in North America or in Europe. This study asked: Why, within regions where CTD can be employed from a physical standpoint, is CTD not readily adopted by producers? The technology adoption literature suggests that rates of adoption are multifactorial (Rogers 2003), thereby requiring exploratory experimental methods to uncover many of the motivators.

In this exploratory case study, we attempted to identify incentives and disincentives that influenced producer decisions regarding the adoption of CTD on their farms. In addition, views held by drainage contractors/experts on producer decision-making, as well as drainage contractor/ expert understanding and promotion of the technology, were explored. We employed a quantitative survey to assess the familiarity of producers and drainage contractors/experts with CTD and we employed semi-structured key informant interviews to identify factors influencing participants’ views of CTD adoption. Although this study was conducted in eastern Ontario, CTD can be employed in many tile drained areas throughout the world and therefore the findings herein could serve as a basis for research and CTD promotion for a broad range of regions and jurisdictions.

**Motives to adopt a BMP**

The literature on the motivators and barriers for adoption of CTD are limited. Hindsley (2002) focused on economic motivations and found that CTD adoption is more likely to increase with: increasing farm size, when financial assistance and implementation assistance is available, and the percentage of income generated from on-farm activities is significant.

Rates of BMP adoption can be influenced by a wide range of factors (Rogers 2003). The perceived attributes of the technology such as the technology’s relative advantage over alternatives, its compatibility with existing production systems, its complexity, its faculty for incremental adoption, and its capacity to demonstrate observationally its effects, are all important. Adoption is also influenced by the communication channels through which information is passed (including how the BMP works and its pros and cons), the social variables such as norms and networks found in the adoption region, and the promotional efforts of change agents (Rogers 2003).

Producers’ motives for participation in conservation programs broadly fall into three areas: economic/financial motives, social motives, and environmental/conservation motives (Morris & Potter 1995; Wilson & Hart 2000; Smithers & Furman 2003; Greiner et al. 2009). Agricultural productivity and efficiency significantly influence producers’ decisions, even when they are sympathetic to conservation (Carr & Tait 1991; Cary & Wilkinson 1997; Chouinard et al. 2008; Greiner et al. 2009). Sheeder (2008) states that financial motives are the most widely cited factor in adoption of conservation measures. Adoption increases if
producers have access to sufficient income to implement conservation practices or to purchase technologies (Lynne et al. 1988; Sheeder & Lynne 2009). In a survey of southwestern Ontario producers, 89% of respondents stated that financial incentives would persuade producers to adopt environmental programs (Lamba et al. 2009). Studies examining conservation practices aimed at reducing emissions of agrochemicals and fertilizers have found that producers were more positive about subsidized conservation versus non-subsidized practices (Lokhorst et al. 2010). In the case with CTD, crop yields can be boosted thereby providing, unlike many purely environmental BMPs, on-farm benefits. Hence, intrinsic financial incentives will no doubt be a critical component in CTD adoption broadly. However, the extent to which on-farm benefits will serve as a ‘financial’ nexus for CTD adoption, irrespective of environmental benefits, will likely depend on degree of yield augmentation, external financial support and incentives, and support for labor (Evans et al. 1988; Hindsley 2002; Nistor & Lowenberg-DeBoer 2007).

A German study found that ‘cost neutrality’ or ‘cost reduction and compatibility with local conditions’ were the most important factors influencing decision-making (Sattler & Nagel 2010). Morrison (2005) suggests that financial factors play a more important role in innovations that provide visible benefits and are easy to implement, whereas sociological factors hold greater influence for innovations that require new skills. Enhancing social standing within peer networks can be an important driver for some producers, particularly those that wish to be progressive (Nassauer & Westmacott 1987).

A positive attitude towards the environment can support practice adoption and is often found to be linked to awareness of environmental issues and to personal involvement in conservation efforts (Michel-Guillou & Moser 2006; Knowler & Bradshaw 2007; Prokopy et al. 2008). Producer perception of responsibility for a pollution problem is also important in the adoption of BMPs. Michel-Guillou & Moser (2006) found that producers felt significantly less responsible for water pollution than industry or households regardless of their practices. Thus, while awareness of environmental impacts may be prevalent among producers, if attribution for water pollution is directed elsewhere there may be less motivation to engage in conservation practices. The presence of a stewardship ethic among producers is another widely cited motivation for engagement in conservation practices and environmental programs (Nassauer 1988, 1989; Sinden & King 1990; VanKooten et al. 1990; Ryan et al. 2003; Ryan 2009).

Regulatory and compliance measures may effectively force producers to adopt BMPs, even though producers may not be supportive of stringent legal controls (Clearfield & Osgood 1986). Frey & Stutzer (2006) indicated, however, that while command and control mechanisms can shift control away from individuals, thereby reducing the motivation for environmental action beyond existing regulatory requirements, legal mechanisms can generate clear expectations of behavior which can reinforce the motivation to adopt a BMP.

This literature suggests that BMPs such as CTD, within a purely environmental context, will likely require a threshold financial benefit in order to initiate voluntary and/or prolific adoption. However, these financially based considerations may be offset to some degree by a strong conservation ethic and/or social pressures.

METHODOLOGY

Study area

The study area is centralized about the South Nation River basin (~4,000 km²) in eastern Ontario, Canada. The landscape is generally flat, tile drainage is ubiquitous, and in 2006, agriculture accounted for ~60% of the region’s land uses with ~70% of the farming area used for crops and ~9% for pasture (Statistics Canada 2006). It was estimated that the vast majority of cropland in the South Nation River basin is suitable, topographically, for CTD (Que et al. 2015). Yet, CTD is extremely rare in the region.

Controlled tile drainage

In-line CTD approaches that have been used in the study region are discussed in depth in Sunohara et al. (2014, 2015). Briefly, tile drainage from fields drain into a main outlet, and the outlet drains into a drainage ditch (stream channel). In-line water level control structures installed on these outlets manage tile drain flow (one example of an in-line system is
given in Figure 1). The control structures in Figure 1 restrict drainage when water levels drop below the stopgate (stoplog, dam, or risers, etc.) height; when water levels are greater than the height of the stopgates, tile drainage occurs. Other forms of in-line structures use float systems to open and close valves to regulate tile flow when certain water levels are achieved. In this region, many of the producers that employ CTD choose to control flow primarily during the growing season, preferring free drainage during the non-growing season (Sunohara et al. 2015).

Generalized research approach

This study used both quantitative survey methods and qualitative interview methods to examine factors affecting CTD adoption in the study region. The qualitative methods employed herein are well established (Rogers 2003; Atwell et al. 2009; Smit et al. 2009; Prokopy 2011). The interviews were directed at current and former CTD adopters as well as drainage contractors/experts. All adopters identified in this study retrofitted CTD to existing tile drainage systems. An emergent qualitative semi-structured interview approach was chosen to help elucidate subjective factors, contextual issues, and themes, potentially missed in a survey-only approach (Patton 2002; Creswell 2007).

CTD adoption survey questionnaire

A short questionnaire was distributed among Ontario Soil and Crop Improvement Association (OSCIA) producer members in the study region to gather information on the nature of their farms and drainage systems (size, number of cultivated fields, field slope, nature of drainage network, tile depth, headers), preferred sources of information on tile drainage/management, general awareness of CTD, and if they would or had adopted CTD. The OSCIA distributed the questionnaire to 425 producer members in March of 2011 through two mail-outs in the Eastern Valley and Ottawa/Rideau regions (areas broader than the South Nation River basin, but within the same general region). Data analysis of results followed the approach outlined by Dewalt & Dewalt (2002).

Semi-structured interviews

At the outset of the study it was unknown how much non-adopters knew about CTD, thus interviews were focused on producers who had adopted CTD at one time, as well as drainage contractors/experts who have worked with adopters and/or were familiar with the practice. A literature review was employed to define the generalized content of the semi-structured interviews. Since there is limited literature specific to CTD adoption motivators and constraints, the review largely consisted of studies on adoption factors for agricultural innovations, but professional judgment based on research experience with CTD by the research team was used to help contextualize the interviews on the basis of CTD practices.

Semi-structured interviews were conducted from September 2010 to April 2011 with a total of 21
informants: 10 producer adopters, eight drainage contractors in the region familiar with the technology, and three engineers with drainage expertise that were affiliated with the provincial government and/or had extension experience. Considering the common positioning of both drainage experts and drainage contractors in the context of information flow to producers regarding BMP technology transfer, we lumped drainage contractor and drainage expert opinions together when we tallied and summarized generalized adoption incentives and disincentives in Figure 2. Nevertheless, it should be noted that there are clear differences among experts and contractors with respect to business-industry perspectives (the former do not rely directly on on-farm drainage installation for business livelihood); and we consider this primary difference in the framework of specific discussion points herein. Drainage contractors in the region were identified via the Land Improvement Contractors of Ontario’s (LICO) database of drainage contractors for the Eastern region (LICO n.d.). A total of 12 contractors were identified in the study region. Of these, eight were interviewed. The sample of producer adopters was obtained from drainage contractor interviews and South Nation Conservation (www.nation.on.ca). Of the 10 producers interviewed, two had adopted CTD as part of an experimental study of CTD impacts at the watershed scale (Sunohara et al. 2015). These two producers had CTD systems installed by researchers, but no other financial incentives were provided. With respect to the other producers interviewed, none had any form of financial assistance to adopt CTD. Drainage contractors, researchers, and South Nation Conservation believe that a majority of adopters in the South Nation watershed were invited to participate. The key informant interviews ranged from 20 to 70 minutes in length.

Interviewees were asked open-ended questions addressing the benefits and challenges of CTD, and what motivated producers to adopt or not adopt the practice. Prompts were provided to ensure that interviewees covered topical areas including, but not limited to: environmental factors, agronomic factors, social factors, technical elements, reliability of information, and management and feasibility. Interviewees were further asked about their sources of information on drainage management and the external drivers they perceived as influential from a producer’s decision to adopt CTD. Producers were asked to describe their farm operation, the time and area of installation, and the series of events and the decision-making process that resulted in adoption of CTD. Drainage contractors, who typically install tile and other drainage infrastructure for producers, were asked to describe how they have encouraged or discussed CTD with their clients. Likewise, similar questioning as described above, was aligned for drainage experts since they provide prescription, technical provision for installation, and up-to-date information on regulations and drainage optimization for both producers and contractors.

Data collected from the semi-structured key informant interviews were digitally recorded as audio files and then transcribed. Qualitative data from the interviews were coded and categorized using NVivo 7 software (QSR International Pty Ltd, Doncaster, Australia). The coding largely followed a deductive approach based on the pre-identified categories that emerged during the literature review. However, a number of themes emerged from the interviews that were unanticipated.

RESULTS

Survey questionnaire

A total of 102 questionnaires were returned out of the 425 questionnaires distributed among OSCIA members for a response rate of 24%. This response rate is consistent with the 20–30% response rates reported in the survey literature (Yammarino et al. 1991). Eighty-six percent of the respondents were from the South Nation River basin, the rest from primarily the Raisin River basin to its east.

Results indicate that producers use a variety of sources to get information on drainage and drainage water management (Table 1). Drainage contractors and other producers were considered the most important sources of information on tile drainage/management among producers. As well, information from producer organizations (e.g., OSCIA) and industry publications on drainage were also viewed as important information sources. The former is not a surprising result since the mail-out was to OSCIA members, but
Incentives (I) and disincentives (D) regarding adoption of CTD that were identified via semi-structured interviews with producers who have adopted CTD ($n = 10$) and with drainage contractors/experts ($n = 11$).

**Figure 2** | Incentives (I) and disincentives (D) regarding adoption of CTD that were identified via semi-structured interviews with producers who have adopted CTD ($n = 10$) and with drainage contractors/experts ($n = 11$).
it does underscore the influence of such organizations in disseminating farm practice information. As these sources are viewed as most important, their stance towards the technology will greatly impact the nature and perception of CTD, and by extension, adoption by producers.

Regarding farm suitability for CTD, the survey found that out of 99 respondents, 52% said 80–100% of their cultivated cropland was flat (e.g., less than ∼1–2% slope) (8% respondents for 60–79% of flat cropland; 16% for 40–59%); 6% for 20–39%; and 18% for 0–19%). Moreover, out of 99 respondents, 78% indicated 80–100% of their land was tile drained (8% respondents for 60–79% of land tile drained; 1% for 40–59%; 5% for 20–39%; and 7% for 0–19%) with, on average, 0.92 m tile drain depth and, on average, 2.4 tile header systems per running field (query results regarding number of fields cultivated may have been misinterpreted by respondent and is not included here). Farm sizes of the 102 respondents were found to average 206 ha and tile drainage networks on farms were nearly all of parallel design. Overall, the above findings suggest a vast number of farms are readily suitable for CTD from a biophysical (most soils are suitable for CTD in the region (Que et al. 2015)) and tile drainage-retrofit perspective.

Of 100 respondents, 67% stated that they were aware of CTD while 20% indicated they were unaware. Our initial expectation was that the level of awareness would be much lower given the low degree of adoption in the study region. Hence non-adoption of CTD may not in this case be as strongly related to simple ‘unfamiliarity’ with the technology as initially thought. Yet out of 67 respondents, 87% indicated that they would not employ CTD (12% would/did; 1% unsure). Of those that indicated they would/did adopt, ∼88% (n = 7/8) of them were interviewed herein. Some concerns regarding adopting CTD that were provided voluntarily by respondents included: too much slope on farm; not sure how to manage CTD; difficulty finding contractors to install; questions regarding CTD structure suppliers (who? where?); increases in labor; crops grow well enough already sans CTD; perceived increases in runoff/erosion if used during the non-growing season; perceptions that information from extension was lacking; and excessive P mobilization and losses when used in spring and winter.

Table 1 | Ranking of information sources regarding drainage water management information (survey results)

<table>
<thead>
<tr>
<th>Information source</th>
<th>Ranking of information source (%)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Not applicable</td>
</tr>
<tr>
<td>News, television, local media (n = 90)</td>
<td>28.9</td>
</tr>
<tr>
<td>Internet (n = 90)</td>
<td>20.0</td>
</tr>
<tr>
<td>Industry publication (n = 88)</td>
<td>6.8</td>
</tr>
<tr>
<td>Government and/or academic publication</td>
<td>5.6</td>
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<tr>
<td>Other producers (n = 93)</td>
<td>1.1</td>
</tr>
<tr>
<td>Conservation authority (n = 91)</td>
<td>14.3</td>
</tr>
<tr>
<td>Producer organization (n = 91)</td>
<td>9.9</td>
</tr>
<tr>
<td>Drainage contractor (n = 96)</td>
<td>4.2</td>
</tr>
<tr>
<td>Federal government (n = 86)</td>
<td>16.3</td>
</tr>
<tr>
<td>Provincial government (n = 86)</td>
<td>12.8</td>
</tr>
</tbody>
</table>

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Semi-structured interviews with producers and drainage contractors/experts

Among producers and drainage contractors/experts, a total of 44 different incentives and disincentives for adoption of CTD were classified (Figure 2). For producers, as an individual group, the top three ranked disincentives were: (1) increased on farm labor to operate; (2) perceived lack of extension services to support CTD use; and (3) concern over legitimacy of research results, perceived increases in regulatory burden if they adopt CTD, lack of awareness of breadth of environmental impacts and, perceived increase in cost to overall farming inputs. For drainage contractors/experts, the top three ranked disincentives were: (1) cost of control structures and installation on multiple fields; (2) increased on farm labor to operate and, lack of awareness of existing research on CTD pros and cons; and (3) perceived lack of extension services to support CTD and, topographic constraints to CTD use. The top three
incentives for producers were: (1) increased soil water retention related to agronomic benefits; (2) CTD reduces tile effluent loading and, overall perception of benefiting the environment and resulting personal gratification; and (3) (several ties) including boosts in crop yield, perceived increase in nutrient use efficiency and, focus on long term not just short-term investment. Top incentives for drainage contractors/experts included: (1) increased soil water retention related to on-farm benefits; (2) increased crop yields and, capacity to retrofit CTD to existing tile drainage systems; and (3) perceived benefits for higher value cropping systems and, perceived increase in nutrient use efficiency.

The top ranked concerns by both producers and drainage contractors/experts combined, revolved around perceptions that CTD would be a labor burden to the producer managing the practice. This is in the context that most farmers have multiple tile drained fields, and that managing them all was perceived as a considerable time sink for them in concert with their other farming activities. The second most important combined issue(s) are related to lack of extension support as a disincentive, and agronomic benefits of CTD as an incentive. Cost of control structures and installation for multiple fields was ranked third overall by producers/drainage contractors and experts alike, but was a much bigger issue for drainage contractors than it was for producers (the highest ranking of all factors for drainage contractors/experts alone). The fourth ranked factor for combined target groups was based on lack of awareness of existing research on CTD pros and cons. The drainage contractors felt this was much more important than producers felt in terms of this being a disincentive for adoption. The fifth ranked issue(s) were based on topographic constraints to CTD employment (ranked much higher by drainage contractors/experts than producers), concerns over research legitimacy (among the drainage contractor/experts group, this was more of a contractor-based perception), potential for increased yields, and perceptions of benefiting the environment and resulting personal gratification (this latter factor was expectedly ranked much higher by producers than drainage contractors/experts). Overall, environmental benefits of CTD appeared more of a positive issue for producers than it did for drainage contractors. Generally, producers emphasized more strongly factors that had personal or community bearing, such as ‘being exemplary in their community’, peer interaction, community-based networking, and basically ‘doing the right thing for the environment’. Drainage contractors identified disincentives that were more tied to ‘lack of’ quantitative evidence/research/extension support for the practice; factors they have affinity for given that they want firm ‘data’/research’ foundations before promoting and installing the practice on producer farms. This impediment was reinforced by drainage engineer viewpoints as well. In other words, drainage contractors desired firm research findings to solidify their position for promoting the practice and implementing it properly in the context of not wanting to incur liabilities/blame and loss of credibility and business if the practice failed in some way. In the sections below, we attempt to discuss more succinctly some of the incentives and disincentives identified by producers and drainage contractors/experts.

**Environmental quality factors**

Seventy percent of the producers interviewed brought up as positive incentives to adopt CTD: (1) reducing tile effluent loading to the broader environment; and (2) personal gratification knowing they are benefiting the environment. When asked if they would adopt an agricultural technology that had limited return on investment overall, but a major environmental benefit, some producers pointed to a need for financial support via public interventions. For example, Producer 7 stated: ‘If [the government] see[s] that it would be worthwhile from an environmental standpoint, [the government] will certainly have to give out grants and have to prove to producers that the portion that the producer invests in will produce a return …’ Most drainage contractors/experts felt environmental motivations would not offset financial concerns. As Drainage Contractor 11 pointed out: ‘For most producers, [environmental motivation is] minimal … The driver from a business view point is profitability …’ This viewpoint was echoed by other drainage contractors who suggested that profitability is a primary motivation with environment being a secondary benefit. The economic angle taken by most drainage contractors, and echoed by some drainage experts, is founded on a business bottom line, as most, if not all contractors would likely install CTD on farms irrespective of any
environmental benefit, if their services were paid for. This bottom line was not as firmly expressed by producers interviewed in the context of pure environmental benefits of the practice, as several raised positive incentive factors associated with reducing effluent impact on wildlife, and being exemplary environmental stewards in the eyes of the community. But these are perspectives from adopters or former adopters who may have had an intrinsically stronger stewardship ethic to begin with.

Agronomic factors

Producers indicated that the perceived ability of CTD to augment crop production (yield) via increased soil water retention (top ranked incentive to adopt by producers) and improved nutrient use efficiency (fourth ranked by producers) helped motivate them to employ CTD, particularly for water deficit conditions. Three of the producers stated that any nutrients lost to tile drains and waterways were ‘lost revenues’. One producer indicated: ‘That’s less nitrogen going down the drain… Nobody wants fertilizer moving into the ditch because it’s costing money.’ Producers who continue to use CTD and are aware of potential nutrient retention benefits resulting from reduced N losses, have not reduced application rates of mineral and/or organic fertilizer, preferring not to accept the risk of potential yield reductions. While six drainage contractors/experts highlighted water retention benefits as critical positive incentives, only four felt improved nutrient use efficiency was a positive motivator. Thus nutrient use efficiency as a supportive motivator could be limited by concerns over research legitimacy, perceived lack of education on pros and cons, and identified and perceived gaps in research (Figure 2). However, CTD is not a new practice, and a plethora of literature supporting many positive nutrient/water-based agronomic benefits has been around for decades (Gilliam et al. 1979; Drury et al. 1996). What appears critical in this context by primarily drainage contractors/experts, is that despite the literature, there is a general ‘lack of provision of locally contextualized data’ to support positive agronomic claims. If viewed in this manner, information diffusion, stemming from localized demonstrations (e.g., Sunohara et al. 2015), might be an important adoption vehicle for the practice.

Some producers indicated waterlogging potential is a perceived barrier to CTD adoption. One producer stated: ‘…if [CTD] really worked well and [soils stayed] dry enough, I would have put hay on that field and then I would have had a yield increase…’ Three producers pointed out that they believed alfalfa crops would be unsuitable for this technology given their rooting characteristics. Such perceptions are not entirely unfounded since it has been documented that field water benefits for forages will vary (Buscaglia et al. 1994). An additional concern of producers is that there is little research indicating which crops or cultivars are best suited for CTD. In fact, recently, Kross et al. (2015) found that corn growth properties (leaf area index) responded more favorably to CTD during drier growing seasons, relative to conventional drained systems; whereas for soybean, growth properties responded more favorably to CTD during wetter years.

Structure and installation cost factors

Interestingly, few producers specifically identified structure and installation costs for multiple fields being a disincentive to adoption, even when prompted (3/11), whereas it was a top disincentive identified by drainage contractors/experts. Increases in overall costs to farming operations were considered modest disincentives for producers interviewed (5/11). Even though this disincentive is not entirely unrelated to structure/installation on multiple field disincentives identified above, CTD lifespan labor requirements were considered implicitly by producers as a tangible farming cost implication. Five producers indicated that the comparative cost of the initial investment versus its return over a period of time had an influence on their decision to adopt and to continue to use the technology. For example, Producer 7 noted: ‘There has to be a return in the relatively short term … Farms are so much in debt that it’s not feasible to tell producers to install 25 or 30 water trap systems on their land … If there is some assistance and if there is a return on investment, say 50%, perhaps they will be interested.’ This producer stressed that yield increases needed to be demonstrated at significant levels over the short term. Typically over the longer-term representing many different climates, soil conditions, and degree of drainage management intervention, a ~5% yield improvement is more reasonably achieved on average.
These long-term average values may not be motivation enough for producers to adopt CTD on the basis of crude payback periods of 3–4 years (based on 2006 prices) (Crabbe et al. 2012). Yet, higher commodity prices, for example, could markedly reduce this payback period.

The interviews documented variation in perceptions about the cost of CTD installation among producers and drainage contractor/experts. Two out of the 10 producers who adopted CTD indicated installation expenses are desired to be around $10 CAD ha$^{-1}$ yr$^{-1}$. However, as noted previously, the literature suggests this value is somewhat low. Some adopters pointed to higher values in the range of $15 to 30 CAD ha$^{-1}$ yr$^{-1}$ on their fields (usually <5 ha). Unlike the producers, nearly all of the drainage contractors/experts interviewed discussed cost of installation to some degree (within the context of cost being a disincentive for producer adoption, but in the framework of environmental BMPs, CTD costs on a treatment field area basis can be considered an incentive). They gave estimates of $150 to $250 CAD ha$^{-1}$ for installation of CTD (for fields of around <4 ha), with costs varying due to complexity of the terrain and the desired level of control over the water table. These costs were not annualized. They were the direct immediate costs which include water flow control structure costs plus installation. Crabbe et al. (2012) estimated an immediate investment cost of around $207 CAD ha$^{-1}$ for field systems generally <4 ha. Producers that perceived direct and immediate installation costs of CTD at $250 CAD ha$^{-1}$ saw it as being prohibitively expensive and felt other producers would be unwilling to adopt the practice on that basis alone (not considering financial incentives). A breakpoint value for adoption was not identified. As Feder et al. (1985) suggest, with higher capital investments, a higher credit constraint impedes adoption of BMPs. Producer estimates of direct and immediate costs of retrofitting a conventional tile drainage system with drainage control was noted in the same cost range. This price per hectare was viewed as prohibitive for the producer by drainage contractors, especially since installation costs can increase considerably for more complex terrain. However, flat terrain is more suitable for the practice generally (American Society of Agricultural & Biological Engineers (ASABE) 1990), and a majority of producers in the region would probably not endeavor to install CTD on topographically complex terrain to begin with.

**Biophysical factors**

The design and installation of sub-surface drainage is heavily influenced by existing biophysical features. As noted, eight of the drainage contractors/experts interviewed believed that topography or slope of the land strongly influences the motivation of drainage contractors/experts to promote the installation of CTD, and for producers to adopt it (within a CTD retrofitting context). One drainage contractor pointed out: ‘If you have excessive grades, to control that water table is very, very difficult. We do have some low-grade fields where you have a hundred acres which is very flat, those are ideal situations obviously, but there are fields that just won’t allow you to use it… and a lot of farms, [the grade] changes so much.’ In the South Nation River basin, it was estimated very roughly ∼50% of the total land base or ∼80% of cropland would be suitable (from a topographic perspective) for CTD without excessively customized water level control associated with topographically complex terrain (Que et al. 2015). Topographic constraints regarding this BMP are understood by drainage contractor/experts intuitively. Thus, this may be one reason why topographic impediments to CTD adoption in a region largely suitable for the practice from a topographic perspective was highlighted as a primary disincentive by contractors.

Additional biophysical factors that were raised by both drainage contractor/experts and producers were related to climate in the region and soil properties (the latter only a concern raised by drainage contractors/experts). Three of the drainage contractors and two of the producers interviewed stated that the climate in the last few years (prior to interview) has been too wet to warrant any interest in using CTD to retain water. These perceptions suggest that some producers and drainage contractors are influenced by recent, short-term conditions (perhaps revolving around spring and/or fall time periods when field trafficking predominates), although specificity of the issue was not explored in depth herein.

**Innovation and management factors**

The main factors that influenced drainage contractor preference of control structures were: simplicity, flexible control, durability/robustness, functionality, and capacity to easily retrofit. Drainage Contractor 1, when describing the control
structures, states: ‘I like the [stopgate system] because it has a good reputation. It has a good structure, didn’t leak, was simple to use, and durable.’ This suggests that contractors seek to understand producers’ experiences with drainage technologies in order to promote control structures to other clients. It remains unclear to what extent drainage contractors and producers compare different CTD technologies and their appropriateness for farming operations. Interestingly, most producers and a few drainage contractors interviewed were familiar with either the float or the slot stopgate systems, but not both.

Of the 10 producers interviewed, two had specific issues with their float systems and both were no longer using them due to them malfunctioning. CTD structures with stopgates were viewed by several producers as easy to manage. In this region, most producers adjust their systems once during the spring and once during the fall.

Increased labor managing the structures was the top disincentive to adoption identified among both drainage contractors/experts and producers collectively. Labor to operate CTD systems was a key factor in cost–benefit analyses of CTD, as discussed in Nistor & Lowenberg-DeBoer (2007). Increasing the number of structures (accounting for drainage on multiple fields) was seen as critically increasing workloads. Producers looking at installation of CTD on a large scale would want it to fit into their existing operations with minimal time commitments. While each individual control structure was perceived to take less than 5–10 minutes (depending on the system) to adjust, the additional time constraints of getting to each control structure, particularly in poor weather conditions, was emphasized by producers (even under the two stopgate adjustments per year approach). Automation was perceived as beneficial to manage drainage for large operations to minimize labor requirements, but only a few producers and drainage contractors/experts identified this as a positive incentive given expense and maintenance requirements. One producer suggested that even sparing a short amount of time to operate a structure is perceived as a disincentive, particularly during busy periods that coincide with additional management of fields. Nistor & Lowenberg-DeBoer (2007) indicated that adoption of CTD could decrease as available labor becomes more limited. Yet some drainage contractors/experts who support CTD suggested its management is not too demanding.

Knowledge and learning factors

Three drainage contractors indicated that guidelines and standards for installation and management of CTD are lacking (a point not raised by producers); at least within the framework of the region of their business. Past studies found that there were few specific guidelines regarding CTD in the literature (Pitts et al. 2004), but more recently, some prescription/guideline specific documentation exists regarding installation, management, and maintenance that could be drawn upon (e.g., American Society of Agricultural & Biological Engineers (ASABE) 1990; USDA 2001, 2008, 2010). However, this underscores a lack of Canadian-derived (even regionally contextualized) guidelines, as identified, by some contractors (as a disincentive to promote the practice); since most existing materials of this sort were sourced from the United States where climatic conditions in particular are different. There was mutual agreement that developing the capacity to retrofit CTD to existing tile drained systems would be an incentive. As one drainage contractor indicated, retrofitting would be less of a concern if retrofit prescriptions were well documented and disseminated. Retrosfits were perceived by one drainage contractor to be prohibitively expensive, in part due to additional design and installation requirements he felt were necessary for optimal drainage network design (something he felt would be important to consider). This kind of retrofitting must be placed in context, since producers that would significantly alter their field drainage networks could do so in a way that optimizes CTD benefits (Frankenberger et al. 2006); but, the expense of such efforts would be seen for many in the study herein, to be prohibitive. Retrofits in a more conventional sense rely on placing water flow control structures on outlets of existing tile networks irrespective of network disposition (e.g. Sunohara et al. 2014, 2015). Clearly, perceptions regarding retrofitting need to be contextualized properly, so that potential adopters do not think they need to reinstall or reconfigure an existing tile drainage network significantly, at great expense, for the purpose of operationalizing CTD; hence, knowledge translation and transfer regarding these aspects would appear to be
important (e.g., guideline support). Design and installing a tile drainage network that optimizes the effects of CTD and sub-irrigation would enhance benefits for cropping systems, but considerations on prospective engineering design/install were not raised en masse by producers or drainage contractors/experts. The lack of specific standards for CTD installation and operation in Canada (and the issue of local context) appears to constitute one barrier to promotion of the practice by drainage contractors/experts. None of the producers interviewed discussed any informational materials or resources that they were exposed to from government agencies or drainage contractors.

Many drainage contractors/experts explained that they rely on scientific publications to glean insights on CTD pros and cons. One of the drainage contractors obtained his primary knowledge at drainage conventions where researchers presented their findings. Drainage contractors/experts (5/11), unlike producers (0/10), touched upon the issue of perceived and existing gaps in research, the need for locally contextualized data on benefits (both producers and drainage contractors felt an issue), and data on the environmental impacts on deeper groundwater. One drainage contractor stated that localized research was necessary for promoting CTD among his client base. Interestingly, two of the drainage contractors interviewed had no knowledge of benefits or issues associated with CTD. For example, some of the drainage contractors could not identify studies or resources providing information on CTD, notwithstanding scientific studies published nearly two decades ago with regional and supra-regional context on CTD benefits and approach (e.g., Drury et al. 1996; Lalonde et al. 1996; LICO http://www.drainage.org/). Also, for many contractors, demand for tile drainage installation as a primary revenue maker may have muted the impetus to take-up and disseminate new information on drainage water management science and technologies to producers. In the past few years in the region there has been a very high demand for installing drainage systems.

Attention must also be paid to the perceived validity and legitimacy of research/extension material among those making the decisions about CTD adoption (one of the highest ranking collective producer and drainage contractor/expert concerns). Some producers and contractors remain skeptical of research findings. One drainage contractor stated that when evaluating the research, the specific interests of whoever conducts the research are important to consider. There is some perception that some researchers are biased or unduly influenced by stakeholders. That is, institutions are viewed differently by producers and drainage contractors depending on their affiliation, history, and mandate. The concerns over perceived lack of extension services that would help support or bring to light credible research, is very noteworthy here considering it was raised as the second most important overall disincentive for CTD adoption by producers and drainage contractors/experts (mainly contractor viewpoint) alike.

The plethora of factors governing variable CTD effects in fields (Cicek et al. 2010; Kross et al. 2013) and variable seasonal-commodity on-farm benefits (Skaggs et al. 2012), perhaps contribute to uncertainty, or reduced confidence in the technology. Controlled tile drainage equates in many ways to a passive form of irrigation (water trapping), and in that way both environmental and agronomic responses will vary depending on weather, cropping practice, and antecedent soil conditions. Yet, on the longer-term average there are modest yield boosts that are well documented, notwithstanding immediate environmental benefits associated with CTD. Drainage contractors/experts, who are in an excellent position to promote CTD, may seek to prioritize promotion of drainage practices that demonstrate more immediate and consistent cost-benefits to producers.

Institutional factors

Many producers are interested in achieving public good benefits, but several of those interviewed believed that there should be funding available to help support the installation and, perhaps more importantly, implementation of some of the practices that improve environmental quality beyond the farm. However, some cost-share programs were/are available to farmers to support CTD; such as the Canada-Ontario Farm Stewardship Programs (COFSP) (http://ofa.on.ca/issues/fact-sheet/canada-ontario-environmental-farm-plan) and South Nation Conservation Clean Water Program (http://www.nation.on.ca/water/grant-programs/clean-water-program), for example. No producer interviewed indicated they had applied to these programs.
Three producers interviewed believe that monies designated for programs such as these are overhead heavy, thereby reducing funding to farmers. Several others felt that the ‘paperwork’ required to apply to such programs outweighed the benefits. Overall, cost-share for CTD has not been utilized significantly by farmers in the region (personal communication with South Nation Conservation 2012).

Research by McCallum (2003) examining producer BMP adoption in Southwest Ontario found that current subsidy levels were insufficient to promote voluntary adoption. In the case of CTD, appropriate subsidy levels are partially dependent on expected economic benefits. For example, Nistor & Lowenberg-DeBoer (2007) modeled the profitability of CTD in the Mid-Western United States and found that if ‘yield advantage due to controlled drainage is below 2.3% (4.5% without subsidy), controlled drainage drops out of the solution and is more profitable to choose free flowing whole farm field drainage’.

Marketing by drainage contractors and organizations

The many disincentives identified in Figure 2 contribute to the lukewarm, if not non-existent marketing of the practice by contractors in particular. One drainage contractor suggested that there is a lack of awareness of the many incentives on the part of producers and a lack of promotion on the part of contractors although he believed that CTD is applicable to many farming systems in the area and in more southern portions of the province. Additionally, he suggested that there is no ‘buzz’ about CTD currently; drainage contractors and producers are not talking about the practice and its production and environmental benefits. Finally, he mentions that contractors largely do not contact their clients to determine how well an installation has worked out. There is an absence of evaluation and redesign of marketing approaches, in general, in the region of study.

Other drainage contractors noted that the trade-off between generating revenues and marketing a product must be considered. Although CTD potentially generates a moderate return, drainage contractors do not want to be liable for a technology that fails (or is perceived to fail) to produce in practice, or is of such risk to cropping outputs if managed improperly. Fear of being unable to guarantee a consistently positive high impact on crop performance, for example, reduces emphasis on marketing and promotion of CTD by contractors. There is little desire to promote a practice for which the contractor is uncertain of the benefits and local applicability, at a minimum.

Extension support

Many producers and drainage contractors/experts indicated that extension support for CTD was lukewarm. This could translate as an adoption impediment given how valued extension organizations are in terms of providing information to producers on drainage practices and BMPs overall. Vanclay & Lawrence (1994) suggest much extension work can be top-down and may not be as sensitive as it can be to producers’ needs and experiences. Whether or not this is the case here is uncertain. However, many interviewees pointed to the need for industry, producer organizations, government (provincial and federal), and suppliers to become more involved in extension and knowledge/technology transfer. Some interviewees suggested that branches of the federal and provincial government and producer associations could play a key role in moving CTD extension forward through existing programs and resources. Others suggest that suppliers should better market their product to drainage contractors and producers, which via diffusion of technology transfer by industry, could help boost confidence in the practice at the producer and contractor level in much the same way formal extension services would endeavor (Table 1).

CONCLUSIONS

This exploratory study has attempted to identify the range of incentives and disincentives influencing producer adoption of CTD in an area in eastern Ontario, Canada where the potential for use of CTD, from a physiographical standpoint, is relatively high. Interviews with both producers who have adopted the practice and drainage contractors/experts (primarily composed of drainage contractors), indicated a suite of incentives and barriers they felt influenced producer adoption of CTD. The relative importance of the incentives and disincentives identified varied somewhat among the target groups, but there were some commonalities: increased farm
labor and lack of extension services to support CTD use were viewed as the most important disincentives for adoption as indicated by both producers and drainage contractors/experts rankings together. However, drainage contractor/experts highlighted more succinctly than producers, costs of structure/install on multiple farm fields as an impediment to producer adoption. Adoption motivators that were common to producers and drainage contractors/experts revolved around agronomic benefits. Environmental benefits, however, appeared to have more bearing for producer adopters than contractors/experts. In this context, there was the indication that some financial incentives (likely beyond on-farm benefits due to yield boosts from CTD alone) would need to be provided to producers to impart greater uptake. Unlike some BMPs that require an effective one-time investment/implementation, CTD requires pulse seasonal labor to manage, and this would occur over the lifespan of the practice. Thus, one-time financial incentives to pay for structures and install might not tip the bucket for producer adoption, and perhaps longer-term financial incentive solutions need to be explored, such as labor resources paid by multiple stakeholders to manage CTD systems on multiple farms. Considering potential watershed-scale benefits of CTD (Que et al. 2015; Sunohara et al. 2013), BMP implementation within nutrient trading or stewardship programs for example, could help financially support such initiatives.

The role of drainage contractors in supporting and/or promoting CTD can be seen as pre-emptive regarding, at a minimum, more producer confidence in the practice. As an information source regarding tile drainage/management, drainage contractors were (as well as industry publications) found by producers to be most important. Supportive organizations/associations/taskforces focused specifically on drainage water management could be seen as a primary means to funnel credible drainage water management information to contractors/experts and other extension and supporting organizations alike. The Land Improvement Contractors of Ontario is an enormously credible and successful association of drainage professionals in Ontario, Canada. They deal with a breadth of drainage issues, including but not dedicated specifically to, drainage water management. In the United States, the ADMS Task Force (http://hostedweb.cfaes.ohio-state.edu/usdasdru/ADMS/ADMSIndex.htm) was developed as an advocacy group to promote a national effort to ‘implement improved drainage water management practices and systems that will enhance crop production, conserve water, and reduce adverse offsite water quality and quantity impacts’. This task force provides a coalition of industry, government, academics, and producers that help address many issues and concerns highlighted in this study. A task force such as this in Canada, dedicated principally to drainage water management, could be an important step towards broader adoption of drainage water management practices in the country.

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