Adoption of Beneficial Water Management Practices by Fruits and Vegetable Farms in Eastern Canada

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Outline

1. Agricultural Production and GHG Emissions
2. On-farm Reduction of GHG Emissions
3. Study Background
4. Adoption of BMPs
5. Objectives
6. Research Design
7. Data collection
8. Results and Discussion
Agricultural Production and GHG Emissions

- In 2016, GHG emissions 704 Mt of CO$_{2\text{EQ}}$
- Under the Paris Accord, Canada has made a commitment of reducing GHG emission by 30%

Canada is committed to meeting its 2030 target. To do so, Canada is investing in public transit, clean technology, and innovation, and working with provinces and territories to develop further measures. We also expect additional reductions from increases in carbon sequestered in forests, soils, and wetlands.

Canada's target (517 Mt)
Agricultural Production and GHG Emissions

- Agricultural sector accounts for 10% of the total GHG balance - highest contributor in terms of $N_2O$ emissions, accounting for 70% of the national balance and is a significant contributor to the national $CH_4$ balance, with a share of 27% (Environment Canada, 2016)

- To help meet targets (517 Mt $CO_{2EQ}$), several supporting programs
  a) In Ontario, the provincial Ministry of Agriculture and Food (OMAFRA) implements cost share programs through the Ontario Soil and Crop Improvement Association (OSCIA). OMAFRA recognizes six categories of BMPs focused on protecting Ontario’s natural resources: environment and climate change adaptation, food safety, and traceability amongst others (OSCIA, 2016).
  b) Quebec has the same categories for their cost-share program, however, their agri-environmental program is delivered through MAPAQ's local advisors
On-farm Reduction of GHG Emissions

- The agricultural sector can help support by reducing emissions, increasing retention of emissions, or by providing offsetting alternatives.

- More efficient water use technologies and practices, improved application of fertilizer, and a reduction of chemical application, are some of the on-farm strategies for mitigating emissions.

- On-farm adaptation strategies can reduce producers’ vulnerability to the effects of climate change.

- With increased evidence of changing climatic conditions throughout the world, many mitigation strategies are no longer sufficient as climate change policy responses. Increasingly, attention has been given to adaptation strategies.
Agricultural producers and BMP Adoption

- Agricultural producers can influence the impact their farm has on the environment

- The outcome depends on the production process decisions made by farmers

- Farmers are key potential agents of change within a given landscape, however their agency is bounded by the structural elements that surround them

- Understanding the components of their decision-making can inform policy and in return, help devise efficient policy instruments to reach a common social goal

- Modelling farmers’ behaviour allows us to understand the factors that contribute to or hinder the adoption of innovations
Study Background

- Eastern Canada is one of the country's fruit and vegetable production hubs

- Ontario, SW region tomato production; Central Québec - cranberry production in the region has seen a rapid expansion in the last decade and Southern Québec is where most of the onion production takes place

- These regions benefited from suitable climatic, soil and socio-economic conditions which were conducive to pursuing high value crop production

- Region is starting to face water shortages

- Under climate change, this issue would be more severe

- Improvement in water use efficiency and reducing greenhouse gas emissions are important issues
Objectives of research

1. Identify main determinants of adoption

2. Identify the role of BMP perceptions in adoption

3. Evaluate adoption models based on their performance
Agricultural producers and BMP Adoption

Figure 1. Roger's Diffusion of Innovations Five Stage Model
Source: Rogers (2003)
Agricultural producers and BMP Adoption

Figure 2. Reasoned Action Approach by Fishbein and Azjen
Source: Fishbein and Azjen (2010)
Agricultural producers and BMP Adoption

Figure 3. Finding Common Ground: Diffusion of Innovations and Reasoned Action Approach
Source: Adapted from Reimer et al. (2012), Fishbein and Azjen (2010), and Rogers (2003)
Determinants of Adoption

- Farmer Characteristics
  - Age
  - Education
  - Farming Experience
  - Status
  - Membership
  - Past Experiences
  - Attitude
  - Awareness

- Farm Characteristics
  - Size
  - Type
  - Soil type
  - Slope
  - Resource condition
  - Income/profitability
  - Land tenure
  - Ownership status

- BMP Characteristics
  - Relative advantage
  - Complexity
  - Compatibility
  - Observability
  - Triability
  - Risk

- Context Characteristics
  - Policies and programs
  - Extension/technical assistance
  - Regional biophysical conditions
  - Social networks
  - Commodities prices
Research Design

- Conduct case studies to evaluate on-farm effects of BMP adoption (Leamington, Sherrington and St. Louis de Blandford)

- Recruit and survey regional producers
  - Surveyed tomato, cranberry and onion growers in Ontario (Essex and Chatham Kent) and Quebec
  - Approximately 150 growers completed a part of the survey, but only 70 respondents completed the survey
  - The survey was distributed through the main growers’ association, advertised on the government website and throughout the growers’ annual meetings

- Understand adoption decision through the means of regression models.
Research Sites
Data collection

- Web-based surveys

- Respondents were presented the results of previous studies, after which adoption, perception and socio-demographical questions were asked.

- Regional recruitment:
  a) Ontario - Chatham Kent and Essex
  b) Quebec – Centre-du-Québec, Montérégie
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Costs and Benefits¹</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capital investment cost</strong></td>
<td>• Depending on your farm the investment could involve²:</td>
</tr>
<tr>
<td></td>
<td>o Tensiometers: 128 – 362 $/acre</td>
</tr>
<tr>
<td></td>
<td>o Sprinkler irrigation system: 1,400 $/acre</td>
</tr>
<tr>
<td></td>
<td>o Water reservoir 150-300 $/acre</td>
</tr>
<tr>
<td><strong>Life expectancy</strong></td>
<td>• 15 years³</td>
</tr>
<tr>
<td><strong>Onion yields</strong></td>
<td>• A significant increase was obtained under optimal irrigation conditions for the jumbo size compared to unirrigated plots – irrigation triggered based on tensiometer readings. Under sprinkler irrigation yield average of nearly 17 mg/acre compared with the unirrigated plots an average of 5 mg/acre⁴.</td>
</tr>
<tr>
<td><strong>Energy costs</strong></td>
<td>• An increase of 67.5% in annual energy costs related to irrigation under sprinkler irrigation as compared to no irrigation⁴. Tensiometers were used for triggering irrigation.</td>
</tr>
<tr>
<td><strong>Water use</strong></td>
<td>• Water use was increased by 67.5% as well when onions were irrigated as compared to no irrigation⁴. Tensiometers were used for triggering irrigation.</td>
</tr>
<tr>
<td><strong>Greenhouse gas emissions</strong></td>
<td>• There are no significant differences between greenhouse gas emissions from onion fields whether irrigated or not</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td>• More labor needed for irrigation when compared to no irrigation</td>
</tr>
<tr>
<td></td>
<td>• Increased managerial decision making related to irrigation</td>
</tr>
<tr>
<td></td>
<td>• Frost protection</td>
</tr>
<tr>
<td></td>
<td>• Increased onion quality with irrigation</td>
</tr>
<tr>
<td></td>
<td>• Prevent soil erosion</td>
</tr>
</tbody>
</table>

¹Details are only for reference; they vary greatly depending on the characteristics of your own farm;
²Based on CRAAQ 2008 and Jabet (2014), research of economic profitability of different water management practice in cranberry production, St. Louis de Blandford, Quebec;
³Based on the most expensive part to replace from the system;
⁴Based on Rekika (2014), case study including 2008 and 2009 growing seasons, in Sherrington, Quebec;
⁵Based on Grant (2014), case study including 2011 and 2012 growing seasons, in Sherrington, Quebec;
Sample Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Frequency (N)</th>
<th>Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Farm Size</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under 500 acres</td>
<td>31</td>
<td>44.29%</td>
</tr>
<tr>
<td>500 to 1,000 acres</td>
<td>13</td>
<td>18.57%</td>
</tr>
<tr>
<td>Over 1,000 acres</td>
<td>25</td>
<td>35.71%</td>
</tr>
<tr>
<td><strong>Crop Size</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under 100 acres</td>
<td>23</td>
<td>32.86%</td>
</tr>
<tr>
<td>100 to 200 acres</td>
<td>33</td>
<td>47.14%</td>
</tr>
<tr>
<td>200 acres and over</td>
<td>14</td>
<td>20.00%</td>
</tr>
<tr>
<td><strong>Owned Land</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under 50%</td>
<td>11</td>
<td>15.71%</td>
</tr>
<tr>
<td>50% to 75%</td>
<td>23</td>
<td>32.86%</td>
</tr>
<tr>
<td>Over 75%</td>
<td>36</td>
<td>51.43%</td>
</tr>
<tr>
<td><strong>Average Annual Gross Sales</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than $99,000</td>
<td>7</td>
<td>10.00%</td>
</tr>
<tr>
<td>$100,000 to $249,000</td>
<td>4</td>
<td>5.71%</td>
</tr>
<tr>
<td>$250,000 to $499,000</td>
<td>6</td>
<td>8.57%</td>
</tr>
<tr>
<td>$500,000 to $1,000,000</td>
<td>17</td>
<td>24.29%</td>
</tr>
<tr>
<td>Over $1,000,000</td>
<td>36</td>
<td>51.43%</td>
</tr>
<tr>
<td><strong>Percentage Crop Sales Annually</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under 25%</td>
<td>14</td>
<td>20.00%</td>
</tr>
<tr>
<td>Between 25% and 50%</td>
<td>25</td>
<td>35.71%</td>
</tr>
<tr>
<td>Over 50%</td>
<td>29</td>
<td>41.43%</td>
</tr>
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</table>
Respondents by Age Group

<table>
<thead>
<tr>
<th>Age</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 to 24 years</td>
<td>4</td>
<td>6%</td>
</tr>
<tr>
<td>25 to 34 years</td>
<td>9</td>
<td>13%</td>
</tr>
<tr>
<td>35 to 44 years</td>
<td>13</td>
<td>19%</td>
</tr>
<tr>
<td>45 to 54 years</td>
<td>26</td>
<td>37%</td>
</tr>
<tr>
<td>55 to 64 years</td>
<td>12</td>
<td>17%</td>
</tr>
<tr>
<td>65 and over</td>
<td>6</td>
<td>9%</td>
</tr>
</tbody>
</table>
Respondents by Education

Respondents by Education (N = 70)

<table>
<thead>
<tr>
<th>Education</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>High School</td>
<td>9</td>
<td>13%</td>
</tr>
<tr>
<td>College</td>
<td>7</td>
<td>10%</td>
</tr>
<tr>
<td>Technical Degree</td>
<td>24</td>
<td>34%</td>
</tr>
<tr>
<td>Bachelor Degree</td>
<td>16</td>
<td>23%</td>
</tr>
<tr>
<td>Graduate or Professional Degree</td>
<td>14</td>
<td>20%</td>
</tr>
</tbody>
</table>
Respondents by Income from Farming

- No income from farming: 4%
- 25% of income from farming: 6%
- 50% of income from farming: 10%
- 75% of income from farming: 31%
- 100% of income from farming: 49%

<table>
<thead>
<tr>
<th>Household Income from Farming</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>No income from farming</td>
<td>3</td>
<td>4%</td>
</tr>
<tr>
<td>25% of income from farming</td>
<td>4</td>
<td>6%</td>
</tr>
<tr>
<td>50% of income from farming</td>
<td>7</td>
<td>10%</td>
</tr>
<tr>
<td>75% of income from farming</td>
<td>22</td>
<td>31%</td>
</tr>
<tr>
<td>100% of income from farming</td>
<td>34</td>
<td>49%</td>
</tr>
</tbody>
</table>
Respondents by Farming Experience

(N = 70)

- **Over 30 years**: 21% (21 respondents)
- **Under 10 years**: 22% (15 respondents)
- **Between 10 and 20 years**: 24% (17 respondents)
- **Between 21 and 30 years**: 24% (17 respondents)
- **Over 30 years**: 30% (21 respondents)
Respondents by Membership

Respondents by Membership in Agricultural Organizations (N = 70)

<table>
<thead>
<tr>
<th>Membership in Farming Organizations</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Membership</td>
<td>21</td>
<td>30%</td>
</tr>
<tr>
<td>Membership in an Organization</td>
<td>31</td>
<td>44%</td>
</tr>
<tr>
<td>Membership in Multiple Organizations</td>
<td>18</td>
<td>26%</td>
</tr>
</tbody>
</table>
Other Characteristics

Respondents by Environmental Farm Plan (N = 70)
- Yes: 91%
- No: 9%

Respondents by Prior Adoption of BMPs (N = 70)
- Yes: 40%
- No: 60%
Farmers' Perceptions of Proposed BMPs

- Benefit society at large: 7% strongly disagree, 26% disagree, 54% neutral, 10% agree, 3% strongly agree
- Benefit local community: 9% strongly disagree, 13% disagree, 63% neutral, 13% agree, 3% strongly agree
- Better alternative than the current one: 19% strongly disagree, 39% disagree, 27% neutral, 16% agree, 3% strongly agree
- Improve crop yields: 27% strongly disagree, 46% disagree, 20% neutral, 6% agree, 1% strongly agree
- Reduce water use: 16% strongly disagree, 39% disagree, 16% neutral, 7% agree, 3% strongly agree
- Reduce production risks: 11% strongly disagree, 46% disagree, 33% neutral, 9% agree, 3% strongly agree
- Reduce fertilizer or chemical run-off: 11% strongly disagree, 31% disagree, 39% neutral, 14% agree, 4% strongly agree
- Expensive: 21% strongly disagree, 54% disagree, 16% neutral, 9% agree, 3% strongly agree
- Profitable: 30% strongly disagree, 50% disagree, 13% neutral, 4% agree, 3% strongly agree

Legend:
- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree
Perceived Barriers to BMPs Adoption

The diagram illustrates various perceived barriers to BMPs adoption, categorized as follows:

- **Market stability (i.e. assurance of contracts)**: 36% not at all important, 31% somewhat important, 23% important, 3% very important.
- **Steep learning curve**: 9% not at all important, 19% somewhat important, 51% important, 10% very important.
- **Low profit margins**: 30% not at all important, 33% somewhat important, 24% important, 6% very important.
- **Low prices**: 29% not at all important, 36% somewhat important, 19% important, 9% very important.
- **Risk of investment**: 24% not at all important, 30% somewhat important, 37% important, 4% very important.
- **Available investment capital**: 21% not at all important, 29% somewhat important, 30% important, 10% very important.
- **Initial cost of the system**: 26% not at all important, 41% somewhat important, 20% important, 9% very important.

The colors represent the levels of importance:

- **Blue**: Not at all important
- **Red**: Very important
- **Orange**: Important
- **Gray**: Neutral
- **Dark Red**: Somewhat important
Models

Model 1

\[ ADOPT = \beta_0 + \beta_1 EXPERIENCE + \beta_2 BETTER_{NEUTRAL} + \beta_2 BETTER_{DISAGREE} + \beta_3 GOALS \]

Model 2

\[ ADOPT = \beta_0 + \beta_1 CROP SIZE + \beta_2 CROP SALES SHARE + \beta_3 EDUCATION_{MID} + \beta_4 EDUCATION_{LOW} \]

Model 3

\[ ADOPT = \beta_0 + \beta_1 CROP SIZE + \beta_2 CROP SALES SHARE + \beta_3 EDUCATION_{MID} + \beta_4 EDUCATION_{LOW} + \beta_5 BETTER_{NEUTRAL} + \beta_6 BETTER_{DISAGREE} + \beta_7 GOALS \]
Findings - Model 1

- Farmers with more experience are less likely to adopt an improved water management systems

- Farmers with a positive perception of the BMP are more likely to adopt

- Farmers with primarily financial goals, are more likely to adopt

<table>
<thead>
<tr>
<th>Variables in the Equation</th>
<th>B</th>
<th>S.E.</th>
<th>Wald</th>
<th>df</th>
<th>Sig.</th>
<th>Exp(B)</th>
<th>95% C.I. for EXP(B)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower</td>
</tr>
<tr>
<td>Step 1^a</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Upper</td>
</tr>
<tr>
<td>Experience</td>
<td>-.077</td>
<td>.031</td>
<td>6.076</td>
<td>1</td>
<td>.014</td>
<td>.926</td>
<td>.871</td>
</tr>
<tr>
<td>Be a better alternative than the current one</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Be a better alternative than the current one(1)</td>
<td>-22.059</td>
<td>12791.261</td>
<td>.000</td>
<td>1</td>
<td>.999</td>
<td>.000</td>
<td>.000</td>
</tr>
<tr>
<td>Be a better alternative than the current one(2)</td>
<td>-2.116</td>
<td>.820</td>
<td>6.665</td>
<td>1</td>
<td>.010</td>
<td>.120</td>
<td>.024</td>
</tr>
<tr>
<td>Goals(1)</td>
<td>2.196</td>
<td>.822</td>
<td>7.134</td>
<td>1</td>
<td>.008</td>
<td>8.992</td>
<td>1.794</td>
</tr>
<tr>
<td>Constant</td>
<td>2.054</td>
<td>.879</td>
<td>5.463</td>
<td>1</td>
<td>.019</td>
<td>7.803</td>
<td></td>
</tr>
</tbody>
</table>
Findings – Model 1

• Correctly predicts 78.1% of non-adoption cases, and 88.2% of adoption – high specificity and sensitivity

• EXPERIENCE, GOALS & BETTER help to correctly predict whether the farmer will adopt a BMP 83.3% of the time

• Pseudo model fit statistic 1- (-2 log L_{Reduced} / -2 log L_{Full}) = 1 – (43.79 / (43.79 + 47.65) = 0.5211

• EXPERIENCE, GOALS & BETTER explain 52% of ADOPT
Findings - Model 2

- Farmers with **higher acreage** of tomato, onion, cranberry are more likely to adopt

- Farmers with **higher crop sale share** are more likely to adopt

- Farmers with **higher levels of education**, are **less likely to adopt**

### Variables in the Equation

<table>
<thead>
<tr>
<th>Step 1a</th>
<th>B</th>
<th>S.E.</th>
<th>Wald</th>
<th>df</th>
<th>Sig.</th>
<th>Exp(B)</th>
<th>95% C.I. for EXP(B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop Size (no. of acres)</td>
<td>.030</td>
<td>.008</td>
<td>12.634</td>
<td>1</td>
<td>.000</td>
<td>1.031</td>
<td>1.014 - 1.048</td>
</tr>
<tr>
<td>Crop Sales Share</td>
<td>.062</td>
<td>.020</td>
<td>9.249</td>
<td>1</td>
<td>.002</td>
<td>1.064</td>
<td>1.022 - 1.107</td>
</tr>
<tr>
<td>Education</td>
<td>7.512</td>
<td></td>
<td>2</td>
<td></td>
<td>.023</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education(1)</td>
<td>-5.301</td>
<td>2.028</td>
<td>6.831</td>
<td>1</td>
<td>.009</td>
<td>.005</td>
<td>.000 - .266</td>
</tr>
<tr>
<td>Education(2)</td>
<td>-2.057</td>
<td>1.036</td>
<td>3.942</td>
<td>1</td>
<td>.047</td>
<td>.128</td>
<td>.017 - .974</td>
</tr>
<tr>
<td>Constant</td>
<td>-6.275</td>
<td>2.079</td>
<td>9.114</td>
<td>1</td>
<td>.003</td>
<td>.002</td>
<td></td>
</tr>
</tbody>
</table>

a. Variable(s) entered on step 1: Crop Size (no. of acres), Crop Sales Share, Education.
Findings – Model 2

- Correctly predicts 91.21% of non-adoption cases, and 86.2% of adoption – high specificity and sensitivity

- EDUCATION, CROP SIZE & CROP SHARE help to correctly predict whether the farmer will adopt a BMP 88.9% of the time

- Pseudo model fit statistic 1- (-2 log L_{Reduced} / -2 log L_{Full}) = 1 – (43.79 / (43.79 + 47.65) = 0.5229

- EDUCATION, CROP SIZE & CROP SHARE explain 52% of ADOPT
Findings - Model 3

- Farmers with higher acreage of tomato, onion, cranberry are more likely to adopt
- Farmers with higher crop sale share are more likely to adopt \((not\; sig)\)
- Farmers with higher levels of education, are less likely to adopt
- Farmers with a positive perception of the BMP are more likely to adopt
- Farmers with primarily financial goals, are more likely to adopt \((not\; sig)\)
Findings – Model 3

• Correctly predicts 88.2% of non-adoption cases, and 87.5% of adoption – high specificity and sensitivity

• CROP SIZE, CROP SHARE, EDUCATION, BETTER & GOALS help to correctly predict whether the farmer will adopt a BMP 87.9% of the time

• Pseudo model fit statistic 1- \((-2 \log L_{\text{Reduced}} / -2 \log L_{\text{Full}}) = 1 - (43.79 / (43.79 + 47.65) = 0.7187\)

• CROP SIZE, CROP SHARE, EDUCATION, BETTER & GOALS explain 72% of ADOPT (BETTER explains 26%)
Findings in a Nutshell

• Specialized farmers (higher crop acreage) are more likely to adopt

• Farmers with higher levels of education, are less likely to adopt

• Farmers with a positive perception of the BMP are more likely to adopt
Findings in a Nutshell

- Demographic variables are proxies which can help understand adoption decision-making, however these variables only explain a small percentage of adoption, and they tend to vary across studies.

- Farmers’ perceptions of the BMPs represents an important determinant of adoption, explaining a large portion of the outcome variable.

- Using a sociological psychology theoretical lens that explicitly conceptualizes the role perceptions play in adoption can provide useful insights into farmers’ decision-making process.
Way Forward

- Mixed methods approaches can help investigate in more depth perception formation, the role information sources play in adoption decision-making, map out the information exchange network of farmers.

- Survey based approaches has been one of the main standards in the field, used to help uncover adoption decisions, however other approaches might provide additional insights (i.e. experimental research methodology).

- Theories from sociological psychology and social networks, might allow this field of study to expand beyond its current state.
References:


ACNOWLEDGEMENTS

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