ADOPT Model Predictions in a Canadian Context

Estimating Future Beneficial Management Practice Adoption Rates

Authors: Margot McComb[1], Andrew Hartoford[1], Michael Sydora[1]

Contributors: Tori Waugh[3], Kate Jones[1], Ria Mukherjee[1]

[1] Agriculture and Agri-Food Canada
{margot.mccomb, andrew.hartford}@agr.gc.ca

[3] Ontario Soil Network
tori@ontariosoil.net

Abstract. The main objective of this research is to assess whether the Adoption Diffusion Outcome Prediction Tool (ADOPT) is a useful model for the prediction of cover crop adoption rates in Canada. To meet this objective, data on cover crop adoption from various Agriculture and Agri-Food Canada surveys and recent academic literature were inputted into the ADOPT model. The model results were then compared to historical cover crop adoption rates to assess whether the model is an accurate predictor of the levels of BMP adoption in Canada. The ADOPT model estimations align with adoption rates reported by the Census of Agriculture for Southern Ontario in 2016 and 2021. However, when tested with a different data source, the results were 7% lower at peak adoption. Potential factors that may inhibit or incentivize the adoption of these BMPs are also examined.

Keywords. Beneficial Management Practices, BMP, Adoption, ADOPT model, Cover Crops, Nutrient Management, Peak Adoption, Time to Peak Adoption

1 Introduction

1.1 ADOPT Model Predictions in a Canadian Context

Agriculture and Agri-Food Canada (AAFC) researchers worked with their Ontario Living Lab partner (the Ontario Soil Network or OSN) to test the Adoption Diffusion Outcome Prediction Tool (ADOPT) model developed by Australia's Cooperative Research Centre for Future Farm Industries. Researchers at AAFC applied the ADOPT model to cover crops and then compared the model's outputs with Census of Agriculture data for Southern Ontario. If successful, this model could help predict timelines and uptake rates for new beneficial management practices (BMPs) in Canada.

The aim of this paper is to investigate the accuracy of the ADOPT model as a predictor for BMP adoption rates in Canada and as a test case to determine the primary factors that influence the adoption of cover cropping. The motivation for this research is to better understand the adoption of sustainable agricultural practices that can prevent or reduce non-point source pollution in the context of the Ontario Living Lab in the Lake Erie basin. The report begins with a literature review on cover cropping to investigate the economic and environmental impacts, challenges, incentives, and other factors known to influence adoption. Next, given that the use of the ADOPT model is not well-documented to-date in Canada, the report will turn to an examination of the accuracy of the model in a Canadian context through a comparison of historical BMP adoption rates to preliminary ADOPT predictions for BMP adoption rates. Based on these findings, the advantages and disadvantages of the ADOPT model will be characterized and recommendations will be made as to whether the ADOPT model might be helpful to inform agricultural policy development in Canada.

1.2 Research Questions

In order to meet the objective of this report, we will seek to answer the following research questions:

- Could the ADOPT model be a useful tool for predicting cover crop adoption rates in Canada?

- What are some of the primary factors that influence adoption and non-adoption of cover cropping?
- What are the practical lessons that can be learned from this research and applied to future applications of the ADOPT model?

1.3 Background

Agriculture and Agri-Food Canada (AAFC) launched the Ontario Living Laboratories Initiative (ONLL) in 2018 as part of the broader Living Laboratories Initiative (LLI). The LLI aims to bring together farmers, scientists, and other collaborators to co-develop and test innovative practices and technologies to address agri-environmental issues. ONLL is located in the Lake Erie basin, which is in the southwestern region of the province. On-farm research is conducted at multiple locations on landscapes that reflect the varied geography and agricultural production in the Lake Erie basin (see Figure 1).

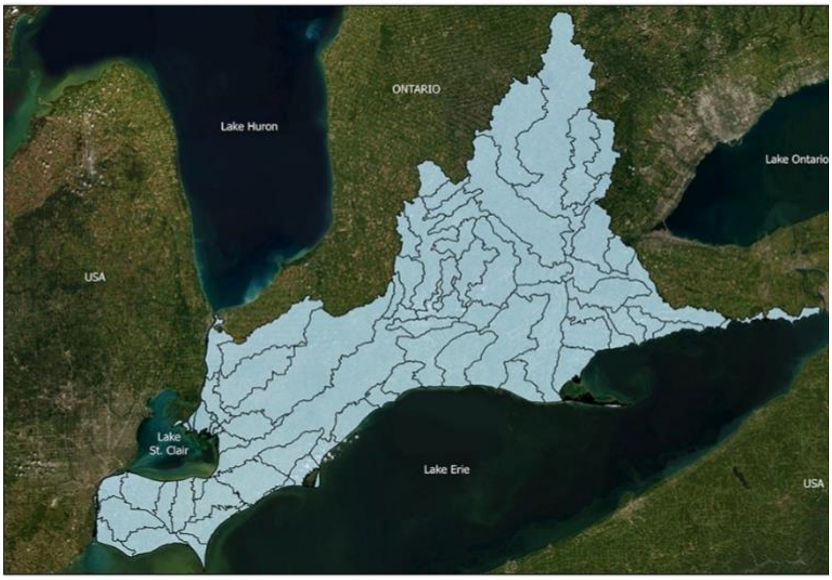

Fig. 1. Ontario Lake Eerie Living Lab Map

Lake Erie is one of the five Great Lakes, which are some of the largest freshwater resources for the world, accounting for approximately twenty percent of the world's freshwater supply, and are used for drinking, irrigation, fishing, and recreation by more than forty million people. Lake Erie is the smallest and shallowest of the Great Lakes, which makes it particularly susceptible to the effects of nutrient runoff from human activity. The Erie Basin's warm climate and fertile soils make it ideal grounds for agriculture. The diverse climate, soils, landscape, and agriculture in the area also make it an ideal location for on-farm trials to take place. Reducing the loss of nutrients from agricultural landscapes is important for improving long-term environmental health since soil and water quality are interconnected and vital for agricultural sustainability. Adopting BMPs is therefore in the best interest of producers and consumers (Living Lab – Ontario, 2021).

BMPs are methods that are believed to be effective and practical means of preventing or reducing non-point source pollution to help achieve environmental goals. BMPs include but are not limited to measures that prevent and mitigate pollution. BMPs can help promote agricultural resilience and adaption to climate change by improving soil health and water quality, increasing biodiversity, and improving watershed management. Currently, Living Labs scientists are focused on evaluating the environmental impacts of adopting these practices, while socio-economic researchers are examining the farm-level economic impact of adopting these practices and studying the socio-economic factors that may influence the decision to adopt them (Living Lab – Ontario, 2021).

1.4 ADOPT Model

The ADOPT model methodology was published in 2017 by seven Australian economists (Kuehne et al, 2017). The tool predicts the speed and peak level of adoption by farmers of new practices. The methodology is based on Roger's Theory of Diffusion of Innovation and meta-reviews of relevant literature (Rogers, 1962). ADOPT's conceptualized framework is categorized into four Quadrants:

Relative Advantage of the Practice, Learning of the Relative Advantage, Time to Peak Adoption, and Peak Adoption Level. These quadrants incorporate a range of socioeconomic variables. Within the quadrants are twenty-two variables related to the practice such as risk aversion, characteristics of the farmer, ease and convenience of the practice, profit maximization, farmer networks, and environmental concern. ADOPT is used by research and development funders, extension agents, scientists, and policy advisors as a way to develop a deeper understanding of the adoption process. ADOPT aims to create predictive quantitative models of adoption for use by those planning agricultural research, development, extension, and policy (Kuehne et al., 2017). A key element of the ADOPT model is that it incorporates human dimensions, which are sometimes lacking in the biophysical and economic models that are often used in guiding investment priorities (Bradford et al., 2020).

In this report, we will compare historical BMP adoption rates with results from the ADOPT model to determine the accuracy of the model in a Canadian agricultural setting. The direct comparison between historical BMP adoption rates and the ADOPT estimate of peak adoption is an indicator for whether researchers and economists can use the ADOPT model to help predict future adoption rates in Canada. BMPs vary by type and by location; therefore, for this study we examined cover crop adoption in Southern Ontario. This is because the data we collected was in Southern Ontario and cover cropping is one of the main BMPs that are currently being implemented in this region.

2 Cover Crops

Cover crops are planted during the off-season between cash crops planting seasons to cover and protect the soil. They enhance agricultural resilience and adaption to climate change by increasing soil organic matter content, which improves agricultural soil. Cover crops contribute to carbon sequestration by removing carbon dioxide from the atmosphere and storing it in the soil. Maintaining ground cover year-round also provides greater protection for soil from water and wind erosion and provides food for soil organisms and microbes during periods when they may otherwise have been undernourished. The plants capture solar energy and fix carbon from the atmosphere that can be returned to the soil, building soil organic matter. This increase in soil organic matter alongside the presence of cover crop roots can assist in the building of stable soil aggregates, which is the ability of soil aggregates to resist disintegration while improving soil structure and water infiltration (Ontario Cover Crops Strategy, 2017). The most common cover crops grown by producers in Ontario are oats, fall rye, radish, and red clover (Ontario Cover Crop Feedback Report, 2020). The most popular motivations for cover crop use in Ontario is to build soil organic matter, break up compacted soil, and to fix nitrogen from the atmosphere (Ontario Cover Crop Feedback Report, 2020).

2.1 Economic Impacts

Direct costs of cover cropping include seed costs, planting, termination, and occasional fertilization (De Laporte et al., 2021b). To establish a cover crop, no-till drills or planters with row cleaners, extra down-pressure springs, and disk openers may be needed to move and penetrate cover. The seed is a significant cost of establishing a cover crop. De Laporte et al. (2021b) report that ryegrass is roughly CAD $88/ac, oats range from CAD $52/ac to CAD $64/ac, and red clover ranges from CAD $40/ac to CAD $74/ac. The costs are listed as a range because costs are heterogeneous across Canada, where costs are often lower in the Prairies than the rest of Canada. De Laporte et al. (2021b) report the abatement cost ($/tonne CO2 emission reduction) of cover cropping to be approximately CAD $51.09/tonne. The regional variability of costs across Canada is due to factors such as variations in growing season length, rotational practices, regional temperatures, and how soil conditions affect cover crop species suitability (De Laporte et al., 2021b). Indirect costs include effects on cash-crop management and foregone opportunities (Continuous Cover, 2022).

Despite the costs incurred through the adoption of cover crops, there are also economic benefits that can result from their implementation. Leguminous cover crops can reduce the extent of nitrogen fertilizer applications required to meet desired soil nutrient levels for future cash crops (De Laporte et al., 2021b). The capacity for leguminous cover crops to fix nitrogen from the atmosphere allows for soil nitrogen levels to be partially replenished in the absence of fertilizer. Reductions in fertilizer needs ranging from 70 to 140 lbs/ac (depending on the N demands of the crop being grown), leading to lowered costs in the following crop season ranging from CAD $28/ac to CAD $56/ac (pricing N at $0.4/lb) (De Laporte et al., 2021b).[1] Crop yields are also reported to increase long-term when cover crops are incorporated into rotations. Soybean yields have been reported to increase by 2.12% after one year of cover crop use and 4.96% after five (De Laporte et al., 2021b). Corn yields have been reported to increase by 0.5% after one year and 3% after five (De Laporte et al., 2021b). Cover crops provide other benefits that would otherwise require costly inputs such as controlling weeds (valued between CAD $0-25/acre), reducing the effects of soil compaction (CAD ~$20/ac), and repairing the impacts of erosion (CAD $2-$4/ac) (De Laporte et al., 2021b).

2.2 Environmental Impacts

The environmental benefits of cover cropping include GHG mitigation, improved agroecosystem biodiversity, resilience, soil quality, and water quality, with the potential for decreased reliance on off-farm inputs. Cover cropping has considerable potential for GHG mitigation through carbon sequestration because of the capacity for cover crops to contribute to soil organic carbon levels (De Laporte et al., 2021b). Cover crops increase the biomass content of farm fields, allowing for the increased capture of carbon dioxide from the atmosphere. The carbon dioxide that is captured from the atmosphere is then stored, or sequestered, into the soil and within the cover crop. Under normal circumstances cropland soils are depleted of soil organic carbon (SOC) over time, containing 30-40% less SOC than soils managed under natural vegetation (Poeplau & Don, 2015). Cover crops aid in restoring SOC levels, creating an average annual change in soil carbon of approximately +0.32Mg/ha/yr (Poeplau & Don, 2015).

Integrating cover crops also enhances biodiversity by increasing on-farm species richness, resulting in heightened agroecosystem resilience (Ontario Cover Crops Strategy, 2017). Increased biodiversity may also result in the recruitment of beneficial soil fauna that would otherwise be absent from the soil (Ontario Cover Crops Strategy, 2017).

2.3 Challenges, Incentives, and other Factors Influencing Adoption

A 2019-2020 survey found that forty-nine percent of respondents reported additional time, labour, and management as barriers to adoption (National Cover Crop Survey, 2020). Forty-two percent of respondents indicated a lack of economic returns as one of the most significant barriers to using cover crops (National Cover Crop Survey, 2020). Seed costs do not encompass the full cost of adopting the BMP, as some farms require additional machinery, management, and alteration of crop rotations, which incurs labour costs. Cover crop adoption enablers include small-scale learning opportunities that can be adapted to local conditions, easily accessible resources and research, decision frameworks on how to manage cover crops, and informed landlords on rented farmland (Ontario Cover Crops Strategy, 2017). See Table 1 for a more detailed description of the challenges, incentives and other factors that influence the adoption of cover crops.

Table 1. 2022 AAFC Cover Crops Literature Review Summary.

Challenges to Cover Crop Adoption	**Incentives to Cover Crop Adoption**	**Other Factors Influencing Cover Crop Adoption**
• Time & Labour, associated costs. • Seed, fertilization, planting, and termination costs. • Upfront cost of machinery. • Lack of knowledge on effective practices specific to farm type, region, etc. • Significant yield gains are not immediate. • Crop insurance concerns. • Restrictive policy. • Complex paperwork burden. • Lack of available	• Long-term yield increases. • Decreased fertilizer needs. • Increased soil cover provides erosion control, securing soil functionality. • Improved soil & water quality. • Increased biodiversity and agroecosystem resilience. • Cost-share and grants. • Small-scale learning opportunities that enable farmers to "test the waters." • Decision-making	• Renters vs. Owners of farm land. • Farm operation size. • Inaccurate and conflicting sources of information make navigating cover crop implementation appear risky and/or create uncertainty. • Cover crops stray away from the traditional perception of what cropland should look like. • Then need to research and learn new techniques. • Perceived risk of impacting

[1] Ranges used because the study uses national data, and therefore varies depending on the region.

information on programs.	frameworks. • Making information available for landlords on rented land.	crop insurance.

3 Method

This section provides a brief background on the theoretical framework, an explanation of the ADOPT model method and how we have applied it to the Canadian context.

3.1 Theoretical Framework

One of the most influential theories for technology adoption and diffusion is Roger's theory entitled *Diffusion of Innovations*, first published in 1962 (Rogers, 1962). According to this theory, diffusion is a process by which new ideas are communicated over time to members of the social system via five elements: the innovation, the adopters, communication channels, time, and the social system. While Rogers initially developed the theory from studying technology adoption in an agricultural context (for example, Rogers, 1958 and Rogers and Burdge, 1961, among many others), the theory was meant to apply broadly to any technology or practice, from health care practices to consumer goods. The theory sought to explain the diffusion of a technology, and understand the characteristics of adopters at different stages, but was not a tool to estimate adoption. Later research built upon this theory to better understand agriculture-specific factors that influence adoption and diffusion of technologies and practices (for example, Feder and Umali, 1993). However, a tool for predicting the adoption of new agricultural technologies without a historical equivalent remained unavailable (Kuehne et al., 2017).

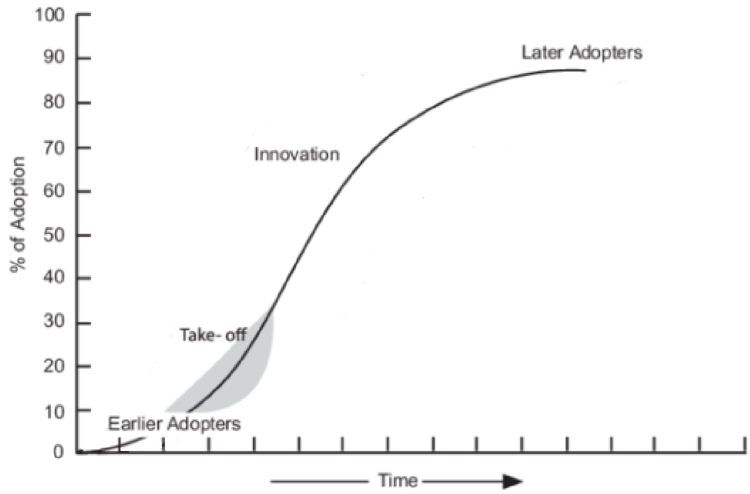

Fig. 2. The Diffusion Process Curve. Figure adapted from Rogers (2003). The diffusion process curve shows how adoption is initially slow as early adopters introduce the practice. Once the practice gains some legitimacy from early adopters, a period of rapid expansion follows (marked as the take-off period). Finally, adoption slows again as the late adopters start to introduce the practice. The ADOPT model output is the estimate of the peak adoption, and an estimate of the time frame for this diffusion process.

The ADOPT model fills this research gap by quantitatively predicting the uptake of new agricultural practices (Kuehne et al., 2017). This model differentiates itself from previous agricultural technology adoption models by including several variables beyond expected profits (such as Caswell et al., 1998), and not basing technology adoption on previous trends (such as Langley et al., 2005). Technology adoption models based on historical trends use previous adoption data of similar technologies to estimate future adoption. Because the intention for the ADOPT model is to be applicable to technologies that do not have a historical comparison, the equation parameters and weights are not calibrated with previous data. Instead, the current model parameters are informed by regional experts who were active during previous diffusion processes , and then validated with real data from technology adoption in Australia (for example, tractor autosteer and no-till cropping systems) (Kuehne et al., 2017). This means that parameters and weights are set to an Australian context. However, as will be discussed below, the model can be re-calibrated for other contexts.

3.2 ADOPT Model Method

The ADOPT model is driven by 22 variables, which are measured using multiple choice questions. The inputs for these questions can be informed by studies, interviews, surveys, consultation with regional experts or census data (although for new practices, census data is not typically available). The researcher determines the level of these variables based on this data. For example:

- Question 1: "What proportion of the target population has maximising profit as a strong motivation?"
    - "Almost none"
    - "A minority"
    - "About half"
    - "A majority"
    - "Almost all."

- Question 15: "To what extent is the adoption of the innovation able to be reversed?"
    - "Not reversible at all"
    - "Difficult to reverse"
    - "Moderately difficult to reverse"
    - "Easily reversed"
    - "Very easily reversed."

The multiple choice questions cover a range of adoption variables informed by previous research (Feder and Umali, 1993; Lindner, 1987; 2006; Rogers, 2008; Vanclay, 2004). For a full list of ADOPT questions, refer to Table 1 of Kuehne et al. (2017). These 22 variables are organized into four broad categories: characteristics of the target population that influence the decision to adopt the innovation, also referred to as "relative advantage for the population" (e.g., short-term financial constraints), the characteristics of the practice that influence learnability (e.g. ease and complexity), characteristics of the population that influence the ability to learn about the practice (e.g., advisory support), and the relative advantage of the practice itself (e.g., relative upfront cost compared to potential benefit) (see Appendix A of this report for a more a detailed description of the four quadrants). These factors are estimated in aggregate, meaning not all inputs (including relative importance of costs and benefits) or outputs (including the factors that most influence adoption) may be true to each individual farm.

The scores for the relative advantage of the practice and the effectiveness of the learning process are the inputs into the two equations that create estimates for peak adoption and time to peak adoption. Each input variable has a parameter set by the ADOPT model creators that adjust the practice's relative advantage and learning scores. Details of the equations, parameters, and weights for each parameter that convert variables into scores and scores into adoption estimators are found in Appendix A of Kuehne et al. (2017).

The ADOPT model parameters and parameter weights are fixed in the online version of the model, so all inputs have the weight they were assigned by the model creators. The researchers chose parameters and weights that provided accurate adoption predictions for the Australian agricultural context. One could use the equations in the appendix of Kuehne et al. (2017) to calibrate the model themselves in a separate statistical software (such as Excel) if there were specific parameters or weights that are known to be different in Canada. For example, the maximum time added due to short term constraints is set to 4 years in the basic model. If a researcher knew that farmers in Canada might take 6 years rather than 4 to recover from a short-term financial constraint, then this parameter could be changed.

3.3 Method 1

Before beginning our analysis, we first established our study's target population. The farms of focus were those that produce field crops with over one thousand acres of land in the Living Lab region in Southwestern Ontario (refer to Figure 1 on page 2). The Ontario Agricultural Soil Health Survey, distributed in 2021 and 2022, was designed to answer ADOPT model input questions for this region. This survey provided most of the data for the ADOPT model inputs. The 42 questions were on topics such as farm and population characteristics, profit and environmental priorities, current BMP adoption, and motivations for adopting or not adopting. Costs and benefits can be directly calculated, and some data was used from the academic literature for cost estimations. However, there is subjectivity because it is the responsibility of the producers to determine whether they consider these costs to be “high” or “low.”

The survey had 52 respondents all located in Southwestern Ontario. Of the 52 respondents, 13 were not recorded due to incomplete responses, for a total sample size of 39 respondents. Two of the respondents were Living Labs participants and the rest were not participants. The Ontario Agricultural and Soil Health Survey did not ask questions about finances, so the 2017 Farm Financial Survey was used to answer questions about farm finances. In addition, cost estimates from the academic literature were used to aid in deciding input questions pertaining to cost estimations. Finally, the Census of Agriculture was used for population-wide statistics. A full explanation of each data source and how they were used to answer each question can be found in Appendix A of this report.

ADOPT is designed for predicting the adoption of new practices when limited data on their past adoption exists. Since the concept of using cover crops to increase soil health has existed for centuries, it is challenging to assign an objective starting year (i.e. year zero) of cover crop adoption. Therefore, once we had completed our analysis, we examined the ADOPT results for the early adoption years and lined up year 2 with the 2011 Census of Agriculture data on cover cropping. The reason being that the adoption rates for these two years are similar. By working backwards, we determined that year zero for our study was 2009. Because the survey data used for the inputs was collected about 12 years after year zero (with variations depending on the input), we assume that the survey responses would have been similar over the last few years.

The ADOPT results were then compared to observed data on the use of cover crops from the 2016 and 2021 Censuses of Agriculture to determine whether the peak adoption levels predicted by the ADOPT model matched historical levels. The data for cover crop usage included all field crop farms in the Southern Ontario Region (Census Agriculture Region 350100000). To determine if the ADOPT model produces results in line with observed rates of adoption, a 5% error range was used (2.5% above or below the estimated adoption). For example, if the output of the ADOPT model estimates 90% adoption of a practice, we assume the model to be correct if real adoption lies between 87.5% and 92.5%.

3.4 Method 2

AAFC’s Ontario Living Lab partner (OSN) collected data at Canada’s Outdoor Farm Show in Woodstock (Ontario) in September 2022. The purpose of this data collection was to collect information on questions 15, 16, 17, 18, and 20 (see Appendix B). These questions were selected because the Ontario Agricultural Soil Health survey does not provide responses that align exactly with the suggested responses in the model. We relied on academic sources to answer these questions in method 1. Four questions on cover cropping were asked to farmers visiting the OSN booth at the Outdoor Farm Show. A total of 248 farmers agreed to answer one or more of the questions, though not every participant answered every question resulting in between a low of 49 and a high of 248 responses.

4 Results

4.1 Method 1

The ADOPT model estimates a peak adoption level of 46% after six years (Figure 3), all else being equal. In the Southern Ontario Region, 25% of crop farms used cover crops in 2011. Based on our methodology, 2011 is defined as year 2 of adoption. In 2016 and 2021, corresponding with years 7 and 12 respectively, cover crops were used on 48% and 47% of crop farms in the Southern Ontario Region (Census of Agriculture). The results therefore align with cover crop adoption rates reported by the Census of Agriculture for Southern Ontario in 2016 and 2021. Figure 3 is the raw ADOPT model output, while Figure 4 is the comparison of the ADOPT model output with the real adoption data.

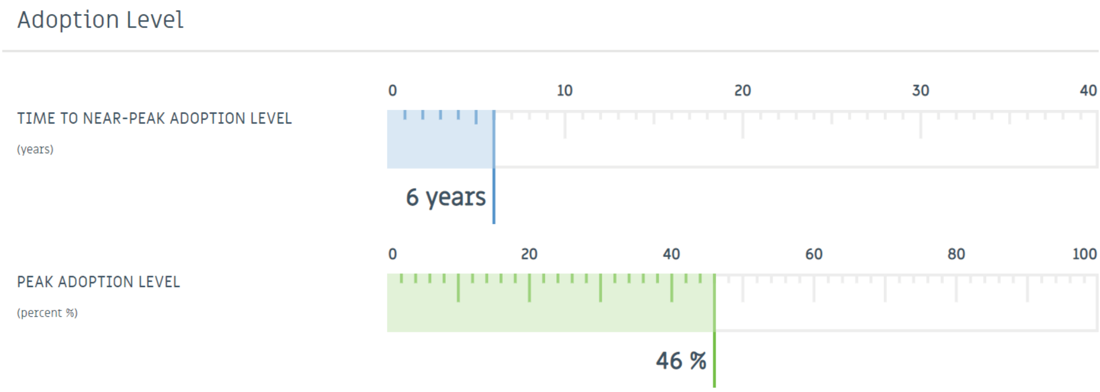

Fig. 3. Peak Adoption - ADOPT Results for Cover Crops in Southern Ontario. Peak Adoption graph produced from CSIRO ADOPT (2022).

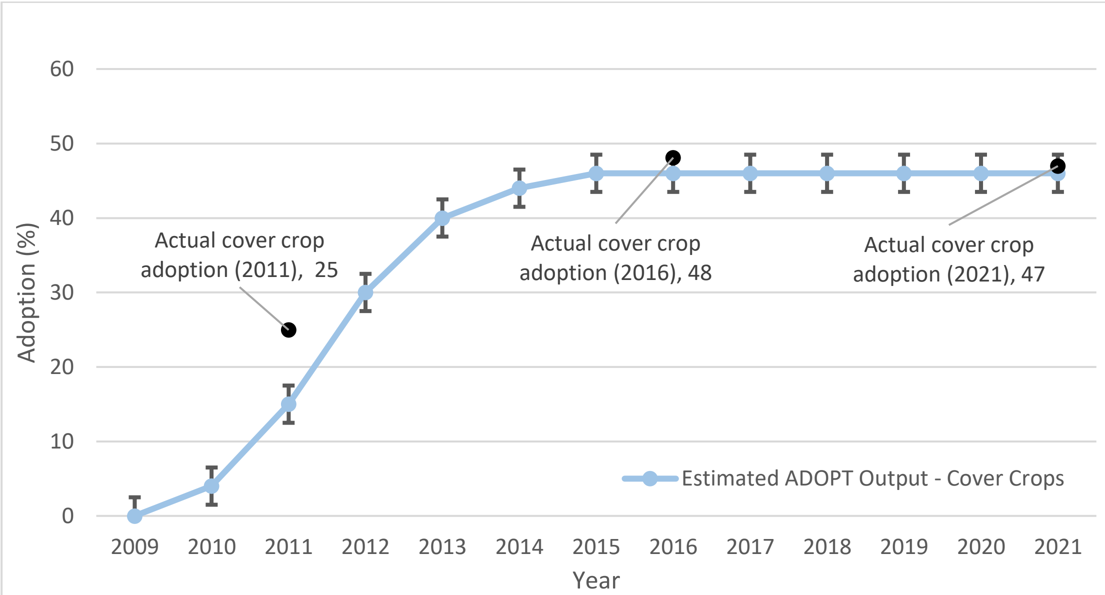

Fig. 4. Estimated vs. Actual Cover Crop Adoption. Actual adoption from crop farmers in Southern Ontario rose from 25% in 2011 to a peak of 48% in 2016 and leveled at 47% in 2021, which falls within the 5% error (bars shown).

In addition to estimates of peak adoption and time to peak adoption, the ADOPT model provides a sensitivity analysis for each question to examine variation in results from the different model factors. In the model this is referred to as a "step up" or a "step down," where a step up generally refers to a positive change that makes adoption easier (such as a lower upfront cost) while a step down is the inverse. The sensitivity analysis shows the percentage point change in peak adoption from a change in each factor, keeping all other factors constant. This is the main method for identifying major incentives and barriers. Figure 5 shows the peak adoption sensitivity analysis and Figure 6 shows the time to peak adoption sensitivity analysis for cover crops.

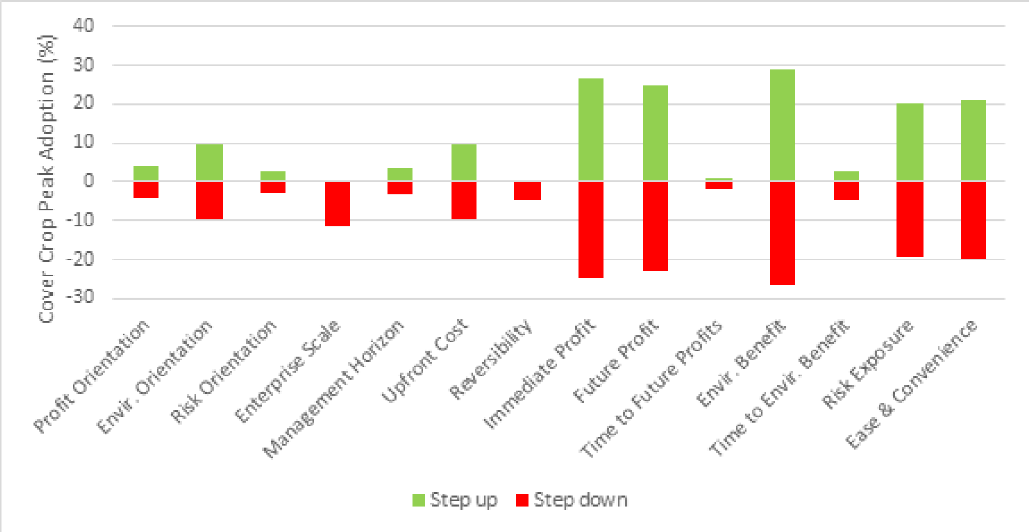

Fig. 5. Cover Crop Peak Adoption Sensitivity Analysis. Peak Adoption sensitivity analysis graph produced from CSIRO ADOPT (2022).

The five most important factors affecting peak adoption according to the sensitivity analysis are immediate profit, future profit, environmental benefit, risk exposure, and ease and convenience. This is intuitive because farmers only have the incentive to adopt if benefits exist. Other factors such as time to future profits and risk orientation may also slightly adjust peak adoption, but if benefits exist, these factors will only encourage or dissuade a few farmers.

For example, the answer selected for the question asking about future profits was "small future profit advantage." If that answer was changed to "no profit advantage," the model predicts a reduction in peak adoption by 23 percentage points (Figure 5). The sensitivity analysis may also provide some insight into the effect of targeted farm financial assistance programs. According to the sensitivity analysis, a reduction in upfront costs is expected to increase peak adoption by approximately 10%.

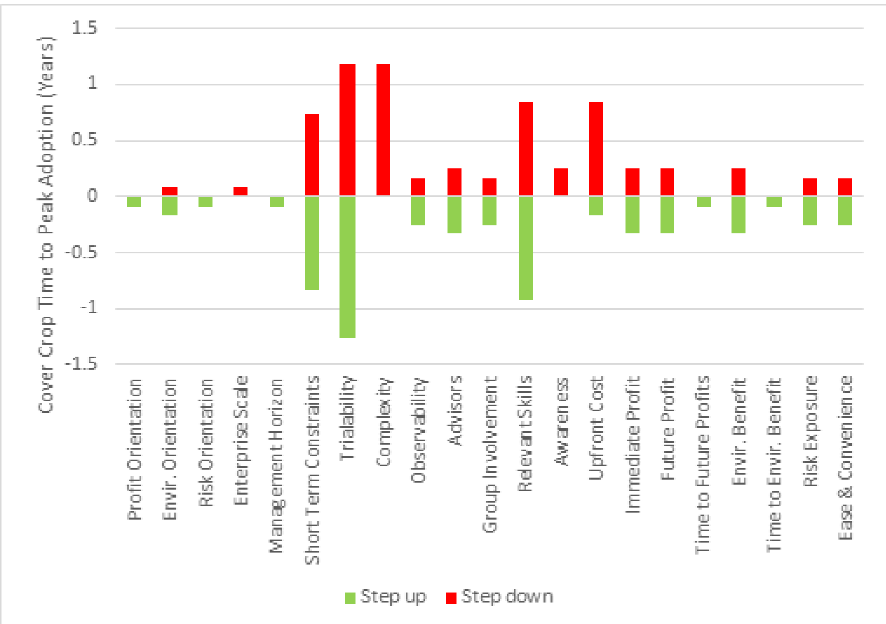

Fig. 6. Cover Crop Time to Peak Adoption Sensitivity Analysis. Time to Peak Adoption sensitivity analysis graph produced from CSIRO ADOPT (2022).

4.2 Method 2

Five inputs were re-evaluated using alternate responses from Canada's Outdoor Farm Show. The five inputs concerned the reversibility of the practice, and the time from implementation of the practice to observable environmental and financial benefits. The reversibility of cover crops was changed from “very easily reversed” to “easily reversed” (i.e. a one unit increase for the multiple-choice question) due to the majority of respondents (57%) answering “slightly concerned” about reversibility. Responses suggested an average of no change in profitability in the year of implementation, which is consistent with the ONLL survey results. However, the time to future profit advantage and environmental benefits may be longer than the original answers inputted in the model. If both answers are changed from 1-2 years to 3-5 years, peak adoption drops to 35%. Time to peak adoption remains at 6 years. However, the lower bound of environmental benefits was 2-4 years, so 1-2 years may still be the best response for time to environmental benefits. If the time to future profits is changed and time to environmental benefits stays the same, peak adoption becomes 39% after 5 years. With a 5% error range, neither the 35% nor the 39% peak adoption estimations include the actual adoption levels.

5 Discussion

5.1 Findings

Our results suggest that the ADOPT model is a potential tool for estimating peak cover crop adoption rates in Canada. Results based on data from the Ontario Agricultural Soil Health survey and official agricultural statistics in addition to academic sources (method 1) are promising. The peak adoption level of cover crops and the approximated portion of the time path to stable adoption in Ontario estimated by the ADOPT model aligned with real adoption rates and growth trends in Southern Ontario. However, when survey data collected at Canada’s Outdoor Farm Show was used instead of academic sources to fill data gaps (method 2), the ADOPT model underestimated the peak adoption rate. This is because farmers estimated it would take longer for the BMP to start becoming profitable and the changes would be more difficult to reverse if needed.

In addition to estimating peak adoption and time to peak adoption, the model indicates five possible high-impact factors affecting the peak adoption of cover cropping. These five factors correspond to the largest impact on peak adoption as per the sensitivity analysis. According to our preliminary analysis, the highest impact factors are profit benefit in years used, the potential for future profit benefit, environmental benefits, risk exposure, and ease and convenience.

5.2 Advantages and Limitations of the ADOPT Model

The primary advantage of the ADOPT model is that it provides estimates of adoption rates for practices with very little historical data. This tool could help Living Laboratories researchers, many of which are in the early stages of testing new BMPs, to better understand the factors that maximize peak adoption. Other ADOPT outputs, such as estimates of peak adoption and time to peak adoption, also provide early insights into novel practices.

Multiple-choice answers neatly fit survey data, even survey answers that are not specifically designed for the ADOPT model questions. On the one hand, this means that answers are based on somewhat subjective interpretations of profitability, risk, and ease of use. For example, if the cost to implement a BMP is cited at $20/acre, it is up to the researcher to decide whether this might be considered a low, moderate or high cost. To reduce uncertainty, previous studies using ADOPT have considered multiple scenarios as inputs. For example, Ludemann (2022) used a “likely” adoption scenario and a more conservative scenario for analysis to ensure that even if adoption rates were lower than the likely scenario, the practice would still provide a substantial benefit to the industry. Some factors such as risk orientation can also be difficult to determine from survey data.

On the other hand, qualitative data on costs and benefits is useful for understanding farmers’ behaviour. The model is simple and results are quickly produced, so advanced mathematical knowledge is not required. However, specialized knowledge is needed to modify the model’s parameters and parameter weights (creating a “black box” phenomenon). With the right data, it is possible to recalibrate the model to align with the specific characteristics of a region.

The ADOPT model does not include changes in technology prices or costs. For example, the increasing cost of fertilizers may increase the adoption of BMPs that reduce fertilizer use. This might skew the ADOPT model results as costs change. The ADOPT model also heavily emphasizes immediate profits, future profits, and environmental benefits as the main factors for adoption. While this is intuitive, it can also create large differences in adoption rates between two close answers, making the model sensitive to small changes in inputs. In addition, in the ADOPT model, every farm is treated the same, regardless of size or income. This means that this tool can be used on different farm sizes and types (e.g., it does not have to be restricted to field crops or large farms). However, this also means that the model cannot predict aggregate changes in profitability, soil conditions, or GHG emissions. Despite the model's drawbacks, it remains one of only a few tools that can quantitatively predict the adoption of agricultural practices (Kuehne et al., 2017).

5.3 Practical Lessons for ADOPT Users

This analysis provides many practical lessons for researchers who want to use the ADOPT model to better understand the potential adoption rate of practices in Canada. Most importantly, we showed that using a well-documented practice like cover cropping is a useful way to test ADOPT in a Canadian context. Doing so requires a tight alignment in definitions between data sources used to populate ADOPT on one hand and real-world adoption data on the other. In a separate analysis comparing estimates of peak adoption for a suite of nutrient management practices to data from the 2020 Fertilizer Use Survey, ADOPT estimates were not closely aligned to real world data.[2] This could be due to a lack of definitional alignment between that data source and the Ontario Agricultural Soil Health survey.

In addition, while the adoption of a specific practice like cover crops can be easily verified through remote sensing and data from the Census of Agriculture, the actual adoption of a suite of practices is difficult to determine. Finally, the Fertilizer Use Survey was largely made up of respondents from the prairies, in contrast with the respondents to the Ontario Agricultural Soil Health Survey. This highlights the fact that different agricultural regions of Canada may experience higher costs or limited benefits for the same technology. For these reasons, the main body of this report focuses solely on cover cropping.

Another consideration is the choice of the initial year of adoption. The ADOPT model is designed to predict the adoption of new innovations starting from year zero. Some BMPs are older technologies that are not currently in widespread use. This is an important distinction. For these BMPs, this might mean that year zero is better defined as the year in which there was a significant shift in the scientific or economic understanding of that BMP, either in terms of its costs, benefits, or environmental impacts.

Overall, it is imperative to be cautious when selecting or creating the data source that will be used to guide the inputs for the ADOPT model. As discussed above, slight changes in how a single ADOPT question is answered can have a significant impact on the results. For example, our analysis showed that using data based on farmer perception can yield different results than academic sources. This is especially true for the high-impact factors that affect the adoption of BMPs, such as future profit benefit, risk exposure, and the convenience of the practice.

5.4 Future Research

The Ontario Agricultural Soil Health survey results cover a relatively small region of Canada, include a limited number of BMPs, and are based on a relatively small sample size. This results in ADOPT model outputs that are specific to the Southern Ontario region and cannot be generalized to the reset of Canada. Future research could aim to look at different geographical contexts and/or different BMPs (including new practices) to ascertain how well the ADOPT model applies to other Canadian contexts. Alternative data sources could also be used to give a range of adoption estimates.

[2] The Ontario Agricultural Soil Health survey was used to collect data on a suite of nutrient management practices in addition to cover cropping.

References

Agricultural Alliance of New Brunswick. (2021). *Adoption Barrier Survey.*

Agriculture and Agri-Food Canada (AAFC). (2021a). *About the Living Labs Initiative.* https://agriculture.canada.ca/en/science/living-laboratories-initiative/about-living-laboratories-initiative

Agriculture and Agri-Food Canada (AAFC). (2021b). *Agricultural Climate Solutions – Living Labs: The power of farms.* https://agriculture.canada.ca/en/environment/agricultural-climate-solutions/agricultural-climate-solutions-power-farms

Agriculture and Agri-Food Canada (AAFC). (2022a). *Agricultural Climate Solutions*. https://www.canada.ca/en/agriculture-agri-food/news/2021/03/backgrounder-agricultural-climate-solutions.html

Agriculture and Agri-Food Canada (AAFC). (2022b). *On-Farm Climate Action Fund (OFCAF).* https://agriculture.canada.ca/en/programs/agricultural-climate-solutions-farm-climate-action-fund

Agriculture and Agri-Food Canada (AAFC). (2022c). *Canadian Agricultural Partnership (CAP)*. https://agriculture.canada.ca/en/department/initiatives/canadian-agricultural-partnership

Agriculture and Agri-Food Canada (AAFC). (2023). *AgriInvest – What this program offers.* https://agriculture.canada.ca/en/programs/agriinvest

Alemu, A. W., Amiro, B. D., Bittman, S., MacDonald, D., & Ominski, K. H. J. C. J. o. A. S. (2016). A typological characterization of Canadian beef cattle farms based on a producer survey. *Canadian Journal of Animal Science. 96*(2), 187-202.

Belfry, K. D., Trueman, C., Vyn, R. J., Loewen, S. A., & Van Eerd, L. L. J. P. o. (2017). Winter cover crops on processing tomato yield, quality, pest pressure, nitrogen availability, and profit margins. *PLoS ONE. 12*(7), e0180500.

Boxall, P. C. (2018). Evaluation of Agri-Environmental Programs: Can We Determine If We Grew Forward in an Environmentally Friendly Way? *Canadian Journal of Agricultural Economics, 66*(2), 171–186. https://doi.org/10.1111/cjag.12170

Bradford, L., Thapa, A., Duffy, A., Hassanzadeh, E., Strickert, G., Noble, B., & Lindenschmidt, K.-E. (2020). Incorporating social dimensions in hydrological and water quality modeling to evaluate the effectiveness of agricultural beneficial management practices in a Prairie River Basin. *Environmental Science and Pollution Research International, 27(*13), 14271–14287.

Canada-Ontario Lake Erie Action Plan – Ontario Cover Crop Action Plan. (2019). GFO. https://www.gfo.ca/wpcontent/uploads/2019/03/OntarioCoverCropStrategyActionPlan.pdf

Caswell, M. F., Fuglie, K. O., & Klotz, C. A. (1998). *Agricultural Biotechnology: An Economic Perspective.* DIANE Publishing.

Clark, A. (2015). Cover Crops for Sustainable Crop Rotations. *Sustainable Agriculture Research and Education.* https://www.sare.org/wp-content/uploads/Cover-Crops-for-Sustainable-Crop-Rotatio-ns.pdf

Continuous Cover. (2022). CarletonU Student Materials. https://serc.carleton.edu/integrate/teaching_materials/food_supply/student_materials/1164

Cover Crop Economics. (2019). Sustainable Agriculture Research and Education (SARE) Technical Bulletin. https://www.sare.org/wp-content/uploads/Cover-Crop-Economics.pdf

Cover Crops. (2022). Ausable Bayfield Conservation Authority. https://www.abca.ca/ forestry/cover-crops/

CSIRO ADOPT. (2022). https://adopt.csiro.au/

De Laporte, A., Banger, K., Weersink, A., Wagner-Riddle, C., Grant, B., & Smith, W. (2021a). Economic and environmental consequences of nitrogen application rates, timing and methods on corn in Ontario. *Agricultural Systems. 188,* 103018.

De Laporte, A., Schuurman, D., & Weersink, A. (2021b). Costs and Benefits of Effective and Implementable On-Farm Beneficial Management Practices that Reduce Greenhouse Gases. *F. F. C. Solutions*. https://static1.squarespace.com/static/5dc5869672cac01e07a8d14d/t/602fe2b2333 6914026617b11/1613750962334/FCS_BudgetRecommendation2021-EconomicsReport.pdf

Environment and Climate Change Canada (ECCC). (2022). *2030 EMISSIONS REDUCTION PLAN:*

Canada's Next Steps for Clean Air and a Strong Economy. https://www.canada.ca/content/dam/eccc/documents/pdf/climate-change/erp/Canada-2030-Emissions-Reduction-Plan-eng.pdf

Environmental Stewardship through Ecosystem Services. (2022). Alternative Land Use Strategy (ALUS). https://alus.ca/what-we-do/

Farm Succession Planning Guide. (2022). Files Ontario. https://files.ontario.ca/omafra-pub-70-farm-succession-planning-en-2020-07-17.pdf.

Feder, G., & Umali, D. L. (1993). The adoption of agricultural innovations: a review. *Technological forecasting and social change, 43(*3-4), 215-239.

Fertilizer Canada. (2020). *Fertilizer Use Survey, https://fertilizercanada.ca/our-focus/stewardship/fertilizer-use-survey/*

House of Commons Canada. (2017). *Next Agricultural Policy Framework*. https://www.ourcommons.ca/Content/Committee/421/AGRI/Reports/RP8717216/agrirp05/agrirp05-e.pdf

Howe, K. (2017). *France's 'Triple Performance' Agricultural Policy: Insights for Ontario?* [Master's thesis, York University]. https://yorkspace.library.yorku.ca/xmlui/bitstream/handle/10315/34733/MESMP02878.pdf?sequence=2&isAllowed=y

Kuehne, G., Llewellyn, R., Pannell, D. J., Wilkinson, R., Dolling, P., Ouzman, J., & Ewing, M. J. A. s. (2017). Predicting farmer uptake of new agricultural practices: A tool for research, extension and policy. *Agricultural Systems*. 115-125.

Langley, D. J., Pals, N., & Ortt, J. R. (2005). Adoption of behaviour: predicting success for major innovations. *European Journal of Innovation Management, 8*(1), 56–78.

Lapierre, J., Machado, P. V. F., Debruyn, Z., Brown, S. E., Jordan, S., Berg. (2022). Cover crop mixtures: A powerful strategy to reduce post-harvest surplus of soil nitrate and leaching. *Agriculture Ecosystems & Environment. 325*(8), 107750.

Lindner, R. K, (1987). Adoption and diffusion of technology: an overview. In: Champ, B., Highley, E., Remenyi, J. (Eds.), *Technological Change in Postharvest Handling and Transportation of Grains in the Humid Tropics*. ACIAR, Bangkok, Thailand, pp. 144–151.

Living Lab – Ontario. (2021). Agriculture Canada. https://agriculture.canada.ca/en/agricultural-science-and-innovation/living-laboratories-initiative/living-lab-ontario.

Management: Opportunities for Prince Edward Island's and Ontario's Agricultural Sector. S. P. Institute. https://institute.smartprosperity.ca/sites/default/files/NitrogenFertMgmt_Report_final.pdf

McFatridge, S., Moffatt, M., Khalaj, S., Tougas-Cooke, R., & Suppa, R. (2022). *Efficient Nitrogen Fertilizer.* https://institute.smartprosperity.ca/sites/default/files/NitrogenFertMgmt_Report_final.pdf

Natcher, D., Ingram, S., Solotki, R., Burgess, C., Kulshreshtha, S., & Vold, L. (2021). Assessing the Constraints to the Adoption of Containerized Agriculture in Northern Canada. *Frontiers in Sustainable Food Systems*, *5*. https://doi.org/10.3389/fsufs.2021.643366

National Cover Crop Survey. (2020). C. T. I. Center. https://www.ctic.org/files/SARE-CTIC%20Cover%20Crop%20Survey%202013.pdf

Ontario. (2022a). *Canada-Ontario Environmental Farm Plan (EFP).* https://www.ontario.ca/page/canada-ontario-environmental-farm-plan-efp

Ontario. (2022b). *Canadian Agricultural Partnership: Lake Erie Agriculture Demonstrating Sustainability (LEADS).* https://www.ontario.ca/page/canadian-agricultural-partnership-lake-erie-agriculture-demonstrating-sustainability-leads

Ontario Cover Crop Feedback Report. (2020). Ontario Cover Crops Strategy. https://gfo.ca/wp-content/uploads/2021/12/Ontario-Report-V12-Dec-1st-For-PDF-conversion-for-publishing.pdf

Ontario Cover Crops Strategy. (2017). OntarioSoilCrop. https://www.ontariosoilcrop.org/wp-content/uploads/2017/06/Ontario-Cover-Crop-Strategy_May-3_Final-v3compressed.pdf

Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA). (2016). *Cover Crops.* http://omafra.gov.on.ca/english/crops/facts/cover_crops01/covercrops.htm

Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA). (2022). *Best Management Practices Winter Cover Crops.* http://www.omafra.gov.on.ca/english/environment/bmp/AF189.pdf

Ontario On-Farm Climate Action Fund (OFCAF). (2022). OntarioSoilCrop. https://www.ontariosoilcrop.org/ontario-on-farm-climate-action-fund/

Ontario Soil Network (OSN). (2022). Improving Ontario's Soils. https://ontariosoil.net/

Plastina, A., Liu, F., Miguez, F., Carlson, S. (2020). Cover crops use in Midwestern US agriculture: perceived benefits and net returns. Renewable Agriculture. *Food Systems. 35(*1), 38-48.

Poeplau, C., Don, A. J. A. (2015). Carbon sequestration in agricultural soils via cultivation of cover crops–A meta-analysis. *Ecosystems, & Environment. 200,* 33-41.

Poon, K., & Weersink, A. J. A. F. R. (2011). Factors affecting variability in farm and off-farm income. *Agricultural Finance Review.* https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1080.8231&rep=rep1&type=pdf

Portrait of Canadian Farms. (2017). StatCan. https://www150.statcan.gc.ca/n1/pub/11-627-m/11-627-m2017010-eng.htm

Pruitt, J.R., Gillespie, J.M., Nehring, R.F., & Qushim, B. (2012). Adoption of technology, management practices, and production systems by US beef cow-calf producers. *Journal of Agricultural and Applied Economics, 44*(2), 203-222.

Ren, C., Zhang, X., Reis, S., Gu, B. J. A. (2022). Socioeconomic barriers of nitrogen management for agricultural and environmental sustainability. *Ecosystems, & Environment. 333*, 107950.

Rogers, E. M. (1958). Categorizing the Adopters of Agricultural Practices. *Rural Sociology*, 23 (pp. 345-354).

Rogers, E. M., & Burdge, R. J. (1961). Muck vegetable growers: diffusion of innovations among specialized farmers. *Research Circular.* Ohio Agricultural Experiment Station, Wooster, Ohio.

Rogers, E. M. (1962). *Diffusion of innovations.* New York, Free Press of Glencoe.

Rogers, E.M. (2003). *Diffusion of innovations,* 5th ed. New York: Simon & Schuster.

Rogers, E. M., Singhal, A., & Quinlan, M. M. (2008). Diffusion of Innovations. *In An integrated approach to communication theory and research* (pp. 432-448). Routledge.

Schnitkey, G., Coppess, J., & Paulson, N. (2016). Costs and benefits of cover crops: An example with cereal rye. *Department of Agricultural and Consumer Economics. 6*(126).

Shirriff, K., Kc, K. B., & Berg, A. J. A. (2022). Evaluation of Agrobiodiversity and Cover Crop Adoption in Southern Ontario Field Crops. *Agronomy. 12(*2), 415.

Statistics Canada. (2016). *Census of Agriculture*. https://www.statcan.gc.ca/en/census-agriculture

Statistics Canada. (2021). *Census of Agriculture*. https://www150.statcan.gc.ca/t1/tbl1/en/tv.actionpid=3210036901&pickMembers%5pid=3210036901&pickMembers%5B0%5D=1.1049

Teodoro, J. D., Baird, J., & Otung, I. (2022). Longitudinal Network Analysis on a Farmers' Community of Practice and Their Changes in Agricultural Systems Management. *Society & Natural Resources*, 1–18. https://doi.org/10.1080/08941920.2022.2135152

Ugochukwu, A. I., & Phillips, P. W. (2018). Technology adoption by agricultural producers: A review of the literature. *From agriscience to agribusiness: theories, policies and practices in technology transfer and commercialization*, 361-377.

Vanclay, F. (1992). Barriers to Adoption: A General Overview of the Issues, *Rural. Soc*. 47-53.

Weber, M. (2017). *Understanding Farmer Motivation and Attitudes Regarding the Adoption of Specific Soil Best Management Practices. Farm & Food Care Ontario*. https://www.farmfoodcareon.org/wp-content/uploads/2017/10/FCC-Adoption-Behavior-Summary-and-Recommendations.pdf

Appendix A

ADOPT Model Assumptions

Table A1. Quadrant: Relative Advantage for the Population.

Question	Response	Reasoning
1. Profit orientation	Majority	ONLL Survey Question 18_1: 79% answered strong or moderate motivation.
2. Environmental orientation	Majority	ONLL Survey Question 18_2: 85% answered strong or moderate motivation.
3. Risk orientation	About half	ONLL Survey Question 18_5: 71% answered strong or moderate motivation. However, ONLL survey question 21 indicates most LL participants are less risk averse.
4. Enterprise scale	Almost all	2021 Census of Agriculture: out of 17,031 farms in southern Ontario, 15,070 (88.5%) had some land used for crop production.
5. Management horizon	Majority	ONLL Survey Question 14: 85% maintain or expand in 10 years, 71% maintain or expand in 15 years.
6. Short term constraints	Minority	2017 Farm Financial Survey: 24% of all farms surveyed said they were under severe short term financial constraints. 2017 Farm Financial Survey: Approximately 30% of farms have over $100,000 in debt, however, not all debt is unmanageable, so minority is chosen rather than.

Table A2. Quadrant: Learnability Characteristics of the Innovation.

Question	Response	Reasoning
7. Trialability	**Cover Crops:** Easy	**Cover Crops:** Possible to trial on a single field or strip of land (OMAFRA, 2016).
8. Innovation complexity effect on evaluation	**Cover Crops:** Not at all difficult	**Cover Crops:** Seen immediately in first harvest (OMAFRA, 2016).
9. Observability	**Cover Crops:** Easily observed	**Cover Crops:** Some effects may require additional observation, such as environmental effects (OMAFRA, 2016).

Table A3. Quadrant: Learnability of Population.

Question	Response	Reasoning
10. Advisory support	About half	ONLL Survey Question 34: 72% have consulted with advisors. This would have fit into the “majority” category, however this group surveyed is overrepresented by those who are more likely to be

		risk-takers, according to Question 21.
11. Group involvement	Majority	ONLL Survey Question 29: 85% are members of at least one association. This would fit into “almost all” category, but not all groups may be relevant to each BMP.
12. Relevant existing skills & knowledge – need to develop new skills	**Cover Crops:** Minority	**Cover Crops:** ONLL Survey Question 24_8: all non-adopters (23% of total) cite knowledge barriers at least somewhat important in the decision not to use cover crops.
13. Innovation awareness	**Cover Crops:** Almost all	**Cover Crops:** Informative workshops/ programs in Ontario, promoted by Ontario Soil and Crop Improvement Association, Ontario-Living Labs, Ministry of Agriculture, Food and Rural Affairs Improvement Association.

Table A4. Quadrant: Relative Advantage of the Innovation.

Question	**Response**	**Reasoning**
14. Relative upfront cost of project	**Cover Crops:** Moderate	**Cover Crops:** Estimated range from USD$20/acre (Schnitkey et al., 2016) to USD$54/acre (Plastina et al., 2020). ONLL survey 24_1: 54% of those farmers that did not introduce cover crops (12% total) cited high upfront cost as a significant or very significant reason for not adopting.
15. Reversibility of the innovation	**Cover Crops:** Very easily reversed	**Cover Crops:** Kill crop, inexpensive, not interrupting cash crop rotation, wait for decomposition (OMAFRA, 2016).
16. Profit benefit in years that innovation is used	**Cover Crops:** No profit	**Cover Crops:** Generally no profit advantage in the year of planting. Some may operate at a loss, while some may be able to sell at a profit (De Laporte, Schuurman, & Weersink, 2021b).
17. Future profit benefit	**Cover Crops:** Small advantage	**Cover Crops:** Belfry et al. (2017) show profit increases from using cover crops in Ontario (radish and oats), but not very well researched. Series (2019) showed a net return of over USD$50/acre after 3 years.
18. Time until any future profit benefits are likely to be realized	**Cover Crops:** 1-2 years	**Cover Crops:** Takes a few years for soil changes to affect profits (De Laporte, Schuurman, & Weersink, 2021b).
19. Environmental costs & benefits	**Cover Crops:** Moderate advantage	**Cover Crops:** ONLL Survey Question 25_5: 83% of adopters cited improving soil health as significant or very significant factor. Environmental improvements contribute to cost

		savings.
20. Time to environmental benefit	**Cover Crops:** 1-2 years	**Cover Crops:** Same time frame as profit advantage (De Laporte, Schuurman, & Weersink, 2021b).
21. Risk exposure	**Cover Crops:** Small reduction in risk	**Cover Crops:** ONLL Survey Question 25_3: 71% of adopters cited reducing risk from severe weather and drought, etc, as significant or very significant.
22. Ease and convenience	**Cover Crops:** Small decrease	**Cover Crops:** More labour and time, maintenance (OMAFRA, 2016).

To answer these questions using survey data, a quantile approach is used as a baseline, where:

Almost none … = 0-20% of respondents answered in the affirmative or strongly agree
A minority … = 21-40% of respondents answered in the affirmative or strongly agree
About half … = 41-60% of respondents answered in the affirmative or strongly agree
A majority … = 61-80% of respondents answered in the affirmative or strongly agree
Almost all … = 81-100% of respondents answered in the affirmative or strongly agree

Appendix B

Canada's Outdoor Farm Show – Survey Results

Q15 (Reversibility): Are you concerned that reversing the BMP would be challenging if the results are not satisfactory?
Q16, 17 (Profit (1st Year)): If you adopted (BMP x), did you see a reduction of costs or increase in revenue within the first year?
Q18 (Profit (After 1st Year)): If you adopted (BMP x), did you see a reduction of costs or increase in revenue in later years?
Q20 (Environmental Benefit (After 1st Year)): If you adopted (BMP x), did you see environmental improvements on your farm in later years?

Table B1. Canada Outdoor Farm Show Survey Results (Q15).

Cover crop		Reversibility (Q15)
2%	4	Very Concerned
31%	78	Somewhat Concerned
57%	142	Slightly Concerned
10%	24	Not at all Concerned

Table B2. Canada Outdoor Farm Show Survey Results (Q16, Q17).

Cover crop		Profit (1st Year) (Q16, Q17)
0%	0	Large Benefit
35%	17	Slight Benefit
43%	21	No Benefit
22%	11	Loss in Profits

Table B3. Canada Outdoor Farm Show Survey Results (Q18).

Cover crop		Profit (After 1st Year) (Q18)
8%	4	10+ years later
55%	27	5-10 years later
37%	18	2-4 years later

Table B4. Canada Outdoor Farm Show Survey Results (Q20).

Cover crop		Environmental Benefit (After 1st Year) (Q20)
4%	2	10+ years later
39%	19	5-10 years later
57%	28	2-4 years later

Appendix C

Table C1. Equations in the ADOPT model from Kuehne et al. (2017).

Peak adoption
Profit advantage = (Profit benefit in years used + Profit benefit in future*(1 + Discount rate)$^{-\text{Years to Future Profit Benefit}}$)/2
Environmental benefit = w_{eb}*Environmental benefit*(1+Discount rate)$^{-\text{Years to environmental benefit}}$
Discount rate = 0.02 if Almost all have a long-term management horizon; 0.04 if A majority have a long term management horizon; 0.06 if About half have a long term management horizon; 0.08 if A Minority have a long-term management horizon; 0.1 if Almost none have a long-term management horizon.
Relative advantage = [(1 + w_p*Profit orientation)*Profit advantage + (1 + w_r*Risk orientation)*Risk + Ease & convenience + (1 + w_e*Environmental orientation)*Environmental advantage]*(1 + w_{es}*Enterprise scale) + w_{ic}*(Investment cost – Max investment cost)
Peak adoption = P_{min} +(P_{max}- P_{min})/(1+EXP(c_c – Relative advantage*c_p))
Time to Peak Adoption
Trialability of Practice = (Trialing ease + Practice complexity)/2
Networks = Min (w_{gi}*Group involvement + Advisory support, 7)
Learning of Relative Advantage = Trialability of practice + Farmer networks skills + w_{RA}*Relative advantage
Awareness Score = A_{min}+ Practice awareness + Observability − A_o*Practice awareness*Observability
Farmer networks and skills = F_a + F_b*Relevant existing skills & knowledge + F_c*Networks + F_d*Relevant existing skills & knowledge*Networks
Time to peak adoption = MAX(T_{max} − Learning of Relative Advantage*L_m + IF(UpfrontCosts ≥ 4, 0, T_{min} − UpfrontCosts) + (C_{max} − ShortTermConstraints)*ShortTermConstraints − AwarenessScore, 3)

Table C2. Parameters in the ADOPT model from Kuehne et al. (2017).

w_p	Profit orientation weight (0.4)	C_{max}	Maximum time added due to short-term constraints (4)
w_r	Risk orientation weight (0.2)	w_{ia}	Practice awareness weight (0.)
w_e	Environmental weight (0.4)	w_o	Observability weight (0.)
w_{ic}	Investment cost weight (0.33)	A_{min}	Minimum level for awareness score (-1.25)
w_{es}	Enterprise scale weight (0.4)	A_o	Weight on interaction between practice awareness and observability (0.15)
w_{re}	Risk effect weight (0.6)	w_{eb}	Environmental benefits weight (0.6)
T_{max}	Maximum time to adoption (50)	w_{RA}	Rescales RA score to have equal influence on learning as do Trialability and Farmer Networks & Skills
T_{min}	Minimum time to adoption (3)	w_{gi}*	Group involvement weight (0.7)
P_{min}	Minimum adoption rate (1)	c_c	Peak adoption curve parameter (3)
P_{max}	Maximum adoption rate (98)	c_p	Peak adoption curve parameter (0.3)
F_a	Intercept term for Farmer networks and skills (-0.63)	F_b	Weight on existing skills and knowledge (1.13)
F_c	Weight on networks (0.63)	F_d	Weight on interaction between networks and skills (−0.13)
L_m	Scalar of Learning of Relative Advantage Score (3.0)		