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Promoting Sustainable Agriculture: Leveraging Behavioral Insights for Effective Technology Adoption Policies

A *Research* Report prepared for CAPI by
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Research
Report

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To ensure the validity and quality of its work, CAPI requires all *Research* Reports to go through a peer review process. CAPI thanks the Doctoral Fellows Mentors who provided expertise, guidance, and feedback on these reports throughout the first year of this fellowship: Aaron Cosbey, Cam Dahl, Dr. Karen Hand, and Dr. Lenore Newman. The views and opinions expressed in this paper are solely those of the authors and do not necessarily reflect those of CAPI.

Note from CAPI

CAPI recognizes the importance of fostering and mentoring the next generation of thought leaders emerging from Doctoral programs across Canada, who are working in multi-disciplinary fields. Through this program, CAPI offers a small, innovative group of young students the opportunity to apply their newfound knowledge and expertise to some of agriculture's most critical policy issues.

The third cohort of CAPI Doctoral Fellows (2022-2024) was tasked with focusing their research on the intersection of agricultural trade, the environment and food security and this paper is one of the results. In light of recent trade disruptions, food security concerns and climate change commitments, CAPI is interested in how they are impacting Canadian agriculture and agri-food and the policy implications. This paper is the first deliverable in the first year of the two year program, showcasing the interdisciplinary nature of the fellows' research as it relates to leveraging behavioural insights for effective technology adoption by Canadian farmers.

This Fellowship is supported in part by the RBC Foundation through RBC Tech for Nature as part of CAPI's larger environmental initiative, Spearheading Sustainable Solutions.

Key Takeaways

- This paper draws on the behavioural economics literature to identify effective strategies for agri-environmental policies that will be well received by producers and lead to meaningful change. The behavioral aspects of agriculture technology adoption may be only one side of the issue, but they provide a comprehensive understanding of the decision-making process, providing insight that is useful for identifying opportunities for intervention around barriers to adoption in Canadian agriculture.
- To effectively implement voluntary agri-environmental programs that promote sustainability, it is crucial to effectively communicate and engage with those who will be impacted by the changes so as to promote understanding and cooperation. Engaging early with stakeholders in the early stages of program development can create a sense of ownership, responsibility and increased participation in programs instead of a top-down approach.
- Since the determinants of adoption vary between different technologies, regions and individuals, further research should be directed to investigating issues and results that are meaningful to local areas and context rather than generalizing studies to universal application.
- Developing and implementing farmer knowledge exchange programs that provide platforms for farmers to share their experiences, knowledge, and best practices related to innovative farming technologies is important as farmers are more receptive and more likely to act on information obtained from peers.
- Providing flexibility in program and policy design through active-adaptive management systems is needed to leverage the full benefit of insights from behavioral studies. In such a system, decisions are made based on ongoing monitoring and evaluation of the dynamics in the program and adjusting management strategies and actions in response to changing conditions and new information, to improve outcomes and achieve desired objectives.

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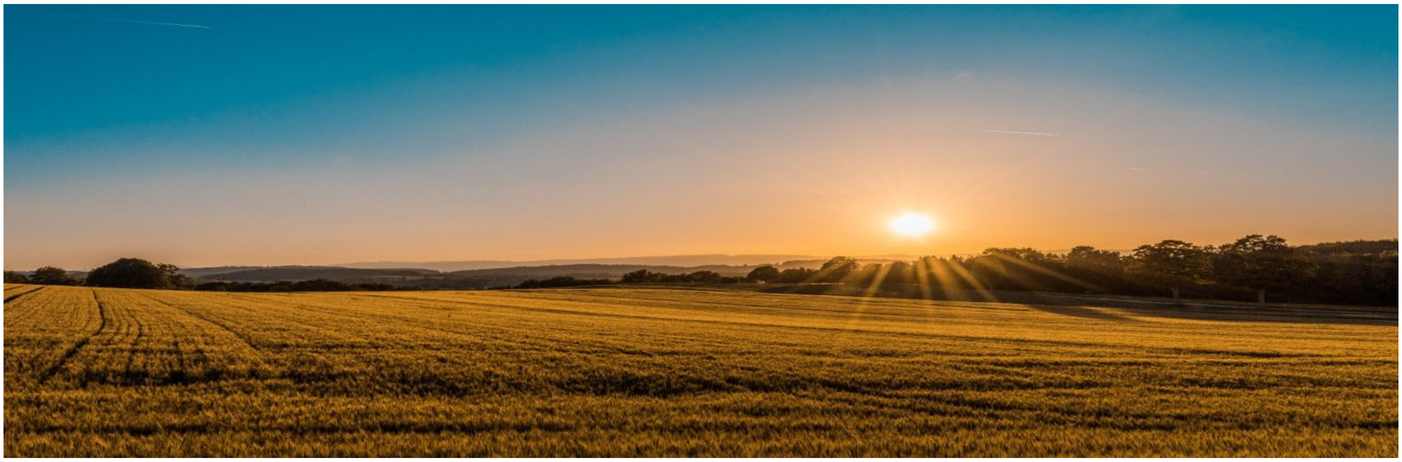

Abstract

The paper discusses the use of behavioral insights to develop policies that promote adoption of sustainable agricultural practices. These insights, provided from the field of behavioural economics, borrow from the fields of psychology, sociology, anthropology and political science make economic choice models more realistic. The major barriers to adoption of fertilizer best management practices (BMPs) are cost, limited perceived benefit of adoption, lack of knowledge and clear communications of program targets and details. The paper explores the use of prospect theory which proposes that farmers' decisions are influenced not only by objective information about potential outcomes but also by the way that information is presented and framed. Incentives can be framed in a way that motivates action and shifts the perceived benefits and costs of adoption. The paper identifies potential areas of messaging/framing opportunities that can support the development of policies that support the wide-spread adoption of sustainable BMPS that achieve the fertilizer targets. Farmers' beliefs and responses to climate change are influenced by their connections to other farmers and sources of information. Creating opportunities where farmers with different norms (desirable and undesirable) can exchange knowledge can encourage adoption among a wider circle. The paper highlights the importance of testing the effectiveness of different policies and programs in different regions through pilot studies as there are regional differences in ecosystems and culture. Making programs flexible to revise strategies based on feedback and learning is vital. Incorporating behavioral insights in standard program development or economic incentives can enhance the effectiveness and efficiency of programs.

Introduction

Sustainable farming practices

Sustainable farming focuses on producing food and other agricultural products in a way that is environmentally responsible, socially equitable, and economically viable (FAO, 2023). The goal of sustainable farming is to meet the needs of the present generation without compromising the ability of future generations to meet their own needs. Sustainable farming practices can include crop rotation, cover cropping, reduced tillage, nutrient management, integrated pest management, precision agriculture, agroforestry, organic farming and other practices that promote soil health, biodiversity, and ecosystem services.

Sustainable agriculture practices have been increasingly used in Canada through the years, with many farmers adopting practices such as conservation tillage, crop rotations, and cover cropping. The adoption of sustainable practices led to an 80 per cent decline in GHG emissions in the crop sector between 1985 and 2016 (Awada, Nagy, & Phillips, 2021). The Census of Agriculture 2021 shows the number of farms and acres where sustainable practices are being used in Canada. These have increased from 1991 to 2021 (Statstics Canada, 2021). In Saskatchewan, conservation tillage is widely used, with approximately 78% of cropland in the province using some form of conservation tillage. Crop rotations are also commonly used, with many farmers rotating crops like wheat, canola, and pulses to manage pests and improve soil health. Ontario leads the provinces in the number of farms equipped with geographic information systems which prevent fertilizer over-application. However, the type of technology used, and the rate of adoption differs across regions based on climate and soil types, among other social, economic and policy factors.

Global population is rising requiring an estimated 60-70 percent increase in food production by 2050 (Hunter, Smith, Schipanski, Atwood, & Mortensen, 2017). While advances in technology and innovations in seed types continue to enhance agricultural productivity, the impact of climate change on agriculture has become a pressing concern. Climate change and agriculture are intertwined in a complex relationship. Climate change is affecting agriculture by disrupting weather patterns, causing droughts and floods, and changing pest and disease ranges, which can lead to reduced crop yields and food insecurity. In addition, climate change has indirect impacts on agriculture by disrupting the natural systems that support farming such as water availability, soil health and nutrient cycles. However, agriculture itself contributes to environmental degradation and climate change through the release of greenhouse gases (GHG) emissions, heavy use of chemical fertilizers and fossil fuel (Foley, et al., 2011 and Tilman, Cassman, Matson, Naylor, & Polasky, 2002). Globally, agriculture is responsible for producing nearly a quarter of the world's GHG emissions when land use change is included. However, Canadian agriculture is characterized by efficiency, contributing a mere 10% to the total emissions of Canada, without considering the removal of greenhouse gas emissions through land use, land use change, and forestry (OECD, 2017; UNEP; ITC; ICTSD, 2012).

In addition to climate change, geopolitical trade disruptions, gaps in infrastructure and lagging rates of agricultural productivity growth have resulted in global demand for food outstripping the growth in supply (Bilyea, 2023). Therefore, addressing climate change and promoting sustainable agriculture practices that reduce GHG emissions and enhance resilience to the impacts of climate change is essential to ensure current and future global food security in which Canada plays a significant role. In Canada, the increased emphasis on climate change and sustainability is leading most economic and policy discussions and decisions creating a pressing need for innovative sustainable practices (Agricultural Institute of Canada, 2018).

Purpose and Methodology

To effectively implement voluntary agri-environmental programs, it is crucial to effectively communicate and engage with those who will be impacted by the changes so as to promote understanding and cooperation. Crafting policies in a way that minimizes resistance and fosters collaboration is important. As such, this paper will draw on the literature to identify effective strategies for devising policies that are well received by the public and result in meaningful change.

The achieve this purpose the paper focuses on grains, oilseeds and special crop sector in Western Canada with focus on factors impacting the use of nutrient management program as a tool to advance environmental sustainability. The paper is organized in the following way: Section three discusses the fertilizer emissions and reduction targets, and section four briefly discusses the technology adoption process. Section five draws on behavioral economics literature to highlight and discuss behavioral insights that are applicable to agri-environmental practices. Section six concludes by discussing policy implications and recommendations.

Role of Fertilizer Emissions and Reduction Targets

> **“Behavioral agricultural economics has consistently revealed the complexity and diversity of producers and consumers; ignoring this in policymaking is wasteful. Since behavioral tendencies are shared within communities, they should be known and used for policies.”**
> – (Wuepper, Bukchin-Peles, Just, & Zilberman, 2023, p. 8)

The Government of Canada has expressed a strong commitment to sustainability in agriculture and continues to launch initiatives aimed at ensuring sustainable agriculture and climate change resiliency. In December 2020, the federal government set a voluntary national fertilizer emissions reduction target of achieving a 30 per cent reduction in 2020 emissions by the year 2030. While agriculture must do its part in limiting the impacts of climate change, emission reduction strategies must balance the goal of reducing GHGs from fertilizer use against farm profitability, economic growth and global food security. In 2022 the Canadian government released a discussion paper and launched public consultations on the fertilizer reduction target (AAFC, 2022).

In March 2023, the government released the results of their consultations. The common opinion among respondents was that investments in agriculture BMPs must yield economic benefits to incentivize behavior change. A BMP workshop had 59 per cent of respondents highlighting the need for additional support for the upfront costs of adoption and ongoing costs of implementation. Apart from the economic incentives, it has been noted that longer-term commitments to support BMP adoption can provide a sense of investment certainty (Agriculture and Agri-Food Canada, 2023). This observation underscores the existence of uncertainties in the program and highlights the necessity to assure farmers that the program is a stable, consistent initiative that will not be subject to change with changes in government.

In addition, some agriculture groups are concerned that such ambitious emission reductions cannot be achieved without reducing yield and view the target as contrary to the federal government’s goal of increasing agricultural production and exports to 2030. Lack of initial consultation before the announcement of the plan and conceiving the plan as mandatory along with a fertilizer ban has created resistance to the government’s emission reduction goals, which has created a tense environment that hampers an open and meaningful discussion (Scheel, 2022).

The importance and rational for nutrient management

This paper focuses on nutrient management, commonly referred to as the 4R’s of nutrient stewardship (4R). Given the government’s ambitious fertilizer targets and the fact that nitrogen oxide emissions are the key drivers of agricultural emissions in recent years (Environment and Climate Change Canada, 2021), it is crucial that BMPs that improve nitrogen use efficiency are adopted urgently and more broadly. The 4R's stand for right source, right rate, right time, and right place and provides a framework to assist farmers in adopting management practices that effectively retain nutrients on the field. By implementing the 4R's, farmers can minimize environmental concerns related to agriculture while maximizing economic benefits.

Nitrogen fertilizer is crucial for plant growth and increases crop yield, but overuse can harm the environment through GHGs, water pollution, and soil degradation. Two- thirds of emissions from nitrogen fertilizers happen after they are applied on croplands. Increasing the efficiency of nitrogen use is the most effective strategy (combined with decarbonization of fertilizer production) to reduce emissions (Gao & Serrenho, 2023). Studies have shown that current technology can reduce emissions from fertilizer application by up to 14 per cent without reducing productivity and compromising food security through the adoption of aggressive, but reasonable levels of 4R Nutrient Stewardship BMPs (Fertlizer Canada, 2023).

In Canada, expenditures for fertilizers in 2021 were equal to $7.3 billion, increasing by over 29 percent from 2020 (Statstics Canada, 2021). In addition to being one of the largest operational costs on the farm, nitrogen fertilizer application has been increasing over time (Awada, Nagy, & Phillips, 2021). The Canadian agriculture sector currently accounts for 10 percent of Canada's GHG emissions if on-farm energy use is included, and the continuous increase in the application of inorganic nitrogen fertilizer is one of the main drivers of emissions in agriculture (Environment and Climate Change Canada, 2021). It is in an effort to address this issue, that the Government of Canada announced reduction targets for GHG emissions that include a reduction of nitrous oxide from field application of nitrogen fertilizer by 30 percent below 2020 levels by 2030.

Canadian farmers are already among the most sustainable growers in the world, and they have used the 4Rs to reduce fertilizer emissions for the last 15 years resulting in Canada's nitrogen use-efficiency sitting at 78 percent-exceeding the world's average (Fertlizer Canada, 2023). Though, technology in the agriculture sector in Canada is being adopted rapidly and extensively (Phillips & Wixted, 2017), there is a significant opportunity to do even better.

The Technology Adoption Decision - Pathways and Barriers

Agricultural innovations create the opportunity to increase productivity, income, and economic growth. But the improvements in productivity that lead to improved economic welfare are not determined by the rate of new technology development but by the speed and extent of the application of these developments in commercial operations and widespread use (Feder & Umali, 1993). Thus, it is imperative to understand what drives the adoption of innovation and its diffusion as well as the policies that encourage and support widespread uptake and use of these technologies.

The rate of adoption of any agricultural innovation, including sustainable practices, depends on a range of economic, social, cultural and behavioral factors. It also depends on the characteristics of the innovation itself, including the perceived advantages and compatibility relative to existing ones, perceived ease of use, risk, social acceptance and potential adjustment (Rogers, 2003; Feder & Umali, 1993; Veisi , 2012; Marra, Pannell, & Ghadim, 2003).

In the technology adoption decision-making literature, technology adoption decisions were traditionally explained as being mainly an economic, profit maximization decision (Griliches, 1957; Alfons Weersink, 2020). However, the profit maximization model does not explain the whole process and thus is not completely accurate. Weersink and Fulton (2020) argue that the technology adoption decision is more than just an economic and profit maximization one. It is not a binary-to adopt or not to adopt decision either. Rather, the adoption decision is a dynamic process with profit maximization considerations usually appearing in the last stage. The binary decision of adopting or not adopting is also part of the final/last stage of the process. Because adoption is a dynamic process, economic rationale doesn't provide a full picture or a full explanation of the adoption decision. Beyond economic considerations, the adoption decision is influenced by factors such as social, demographic, psychological, political, regulatory, infrastructure, and environmental.

Pannell, (2007) divided the technology adoption process into six stages: awareness, non-trial evaluation, trial evaluation, adoption, review and non-adoption or dis-adoption. The influence of economic, social, and behavioral factors at these different stages can vary. Pannell hypothesized that in general, social factors are the most important factors during the early phases of awareness and non-trial evaluation. After experiencing trial evaluation, the relative advantage of the practice becomes the most important factor. I.e., before experiencing it personally, what other people say is most influential. But after experiencing it personally, the experience itself becomes more influential than outside/external information. The profit maximization model thus fails to accurately predict the early stages of the adoption process because the new technology changes the familiar environment the farmer is used to operating in, and the decision maker needs new or additional knowledge to effectively and efficiently operate in this new environment (Weersink & Fulton, 2020)

A meta-analysis of factors that influence adoption of agricultural BMPs in the United States identified the following variables as having the largest impact on adoption: access to and quality of information, financial capacity, and being connected to agency or local networks of farmers or watershed groups (Baumgart-Getz, Prokopy, & Floress, 2012). Environmental awareness and farmer attitudes are other factors that impact adoption but have been inconsistently used and measured across the literature. Budget constraints, perceptions that the costs outweigh the benefits and a lack of understanding and product support after purchase appear to be the major barriers to adoption of precision agriculture technology across North America (Bannon, Mitchell, & Weersink, 2020).

Fertlizer Canada(2022), in a report covering fertilizer use practices from 2014 to 2021, recognized that awareness of 4Rs is growing but a lack of incentives; lack of information; lack of proven benefits; cost and absence of services provided by growers' Agri-retailer are the top barriers to adopting 4Rs. Fertilizer emissions reduction consultations with stakeholders, farmers and agriculture- related business owners, representing 40 per cent of respondents, revealed similar barriers to the broader adoption of nitrogen management practices, such as high upfront costs and uncertainty about the impact on yields (Agriculture and Agri-Food Canada, 2023). Other concerns include the limited commercial and lab capacity for on-farm soil nitrate measurements, insufficient recognition for progress made, and inadequate data and measurement for future progress. Additionally, concerns about maintaining yield and limited perceived benefits associated with changing some management practices were also mentioned as barriers to adoption.

These studies imply that it is important to closely study the non-economic factors. While the demographic, environmental and societal impacts have been widely studied, it is only in recent years that attention has been given to psychological factors. An ability to understand the adoption decision is critical for agricultural policy development as it guides the selection of policy mechanisms, targets and assessment of policy success. Using behavioral insights in the development, communication and implementation of programs can help to address these barriers, improve program success and increase adoption.

Behavioral Insights and Farmer Decision-making

Behavioral economics models emphasize the importance of considering the psychological, cognitive, and social factors that affect technology adoption, complementing traditional economic theories. Behavioral economics draws from the fields of economics, psychology, sociology, anthropology and political sciences to make economic choice models more realistic (Wuepper, Bukchin-Peles, Just, & Zilberman, 2023) .

Behavioral insights refer to the application of behavioral science to gain an understanding of how people make decisions and behave. It gained prominence in public policy with the establishment of the Behavioral Insights Team in the UK in 2010, which aimed to apply behavioral science to inform public policy and improve outcomes. The concept of behavioral insight, however, predates the specific term, as the study of human behavior and decision-making has been a focus in various disciplines for many years. Behavioral economics gained significant attention with the ground-breaking work of psychologists Daniel Kahneman and Amos Tversky, who challenged the assumptions of rationality in economic decision-making and explored cognitive biases, heuristics and decision making under risk (Kahneman & Tversky, 1979; Kahneman & Tversky, 1984). Richard Thaler's work applying behavioral insights to finance and policy design, particularly in areas like nudge theory, mental accounting, and behavioral finance, has significantly influenced the development of behavioral economics (Thaler, 2015).

Agricultural economics has incorporated farmer behavior and risk in decision making analysis early on. Due to the emphasis on applied economic research which is tasked with solving specific, practical problems, to support extension researchers and the interaction with practitioners, behavioral deviations from the traditional economic models have been salient and relevant in agriculture research and policy (Wuepper, Bukchin-Peles, Just, & Zilberman, 2023).

Behavioral research has shown that human decision making is influenced by factors including cognitive biases such as risk aversion or loss aversion, as well as hyperbolic time discounting that place a disproportionately higher value on immediate rewards compared to future rewards making it difficult to prioritize long-term goals over short-term desires (Dolan, et al., 2012). Furthermore, people can become overwhelmed with information and choices, resulting in limited capacity to make informed decisions. These insights can be valuable for policy and program development seeking to influence behavior, as they provide a better understanding of the underlying psychological factors that affect decision-making.

In the last 15 years, there has been a significant increase in behavioral research and interventions in public policy across the world with policy makers around the world incorporating them and using them along with regulations and financial incentives (Straßheim, 2020; Palm-Forster, Griesinger, Butler, Fooks, & Messer, 2022). Behavioral insights teams that translate behavioral insights into public policy have been formed in many public and private organizations, including over 200 dedicated public entities. The Organization for Economic Development and Cooperation has labelled this increased use of behavioral insights in policy design a paradigm shift (OECD, 2015).

Prospect Theory/Loss aversion

Prospect Theory - suggests that people make decisions based on the potential value of gains and losses rather than the final outcome itself (Kahneman & Tversky, 1979).

Loss aversion - when decisions are made under uncertainty, people are generally more sensitive to losses than to gains.

Prospect theory suggests that people make decisions based on the potential value of gains and losses rather than the final outcome itself (Kahneman & Tversky, 1979). The theory proposes that people evaluate outcomes relative to a reference point, such as a current situation or past experiences. The perceived value of an outcome is influenced by how it is framed in relation to this reference point.

Loss aversion, a fundamental part of Prospect theory argues that when decisions are made under uncertainty, people are generally more sensitive to losses than to gains. It indicates individuals dislike losses more than equivalent gains, and they are more willing to take risks to avoid a loss. People are more motivated to avoid losses than to achieve gains of the same magnitude. Therefore, incentives framed as losses may be more effective in motivating behavior than incentives framed as gains. This is in violation of the standard expected utility theory that is widely used in economic decision making which states that people make rational decisions based on the expected value of outcomes, regardless of whether the outcomes are framed as gains or losses. This can mean farmers can be moved to act by framing the technology adoption as a risk and cost reducing measure rather than for environmental or financial gain.

In the context of promoting the adoption of BMPs, highlighting the potential losses associated with not adopting BMPs, such as decreased soil health, increased fertilizer costs, increased political/social pressure may motivate farmers more than highlighting the potential gains adopting BMPs. This approach can be particularly effective if the losses are framed in a way that makes them seem immediate, concrete, and relevant to the farmers' own experiences and concerns.

The current reference point for farmers may be the costs or risks associated with adopting BMPs, which may make them perceive the adoption of BMPs as a potential loss. By emphasizing BMP adoption as a positive gain, such as improved crop yields, reduced fertilizer costs, and better soil health, the reference point can be shifted towards the benefits of BMP adoption. This shift can make the adoption of BMPs seem like a gain, rather than a potential loss, and may increase farmers' motivation to adopt these practices.

Empirical studies have shown that people are indeed more motivated to avoid losses than gains and framing it as such can impact decision. One study showed monetary incentives did not always improve performance compared to groups offered no compensation. A field experiment offering a small bonus to staff for arriving to work on time was not effective, but imposing a fine for arriving late was effective in increasing punctuality (Gneezy & Rustichini, 2000). Another study found loss-framed incentives improved math achievement while effects for gain-framed incentives were not statistically significant (Fryer, Levitt, List, & Sadoff, 2022). Moser & Mußhoff (2016), find that when farm income is kept constant, penalizing farmers for using fertilizers is a more efficient approach than incentivizing them to reduce their use of fertilizers. Research has also demonstrated that punishment can be more effective than reward in motivating farmers to grow flowering cover crops (Holst, Musshoff, & Doerschner, 2014). Framing the benefits of participating in sustainable farming practices in terms of environment conservation methods and not as compensation for damage already done to the environment have been found to increase participation (Dessart, Barreiro-Hurlé, & Bavel, 2019)

These studies provide evidence that framing incentives or rewards in different ways can have a significant impact on environmental outcomes or performance. Both approaches of framing BMP adoption as a positive gain or as avoiding losses can be effective, depending on the context and the specific concerns and motivations of the target audience. The key is to understand the reference point of the farmers and to frame the adoption of BMPs in a way that resonates with their concerns and priorities. It's also important to test the effectiveness of the framing strategy in different regions by conducting pilot studies or experiments, and to revise the strategy as needed based on the results. By taking a research-based approach to framing BMP adoption, program developers can increase the likelihood of success in promoting sustainable agricultural practices. This paper provides highlights of the behavioral factors that are most relevant and applicable in the context of farmers' response to the fertilizer targets and reduction program, particularly based on incentives, information communication social norms, discounting the future and resistance to change.

The Messenger and who communicates information

Generally, we are heavily influenced by who communicates information to us. How much significance we give to information heavily depends on our automatic responses to the perceived credibility of the source or the messenger (Dolan, et al., 2012). People are more likely to act on information they obtain from an authoritative figure, peers with similar characteristics and a messenger they have positive feeling towards and trust.

An important aspect of technology adoption is awareness and access to a relevant and reliable source of information (Rogers, 2003). Studies have shown that easy access to information and attending extension activities increased farmer's adoption of organic farming and conservation tillage (Dessart, Barreiro-Hurlé, & Bavel, 2019). Adopters were also found to have better skills at obtaining and using information (Läpple & Kelley, 2013). Organic producers in the UK demonstrate that not only information but the source of information is important in innovation (Burton, Rigby, & Young, 1999). These producers were found to find traditional information sources like the media and buyers less relevant for production and marketing information, preferring other farmers.

Farmer's ***social networks*** and their beliefs about climate change impact the decisions they make regarding climate mitigating actions such as conservation (Parks, 2022). Farmers' beliefs and responses to climate change are affected by their connections to other farmers, media, and sources of agricultural and climate information. Individuals and organizations in a network have the potential to help spread critical information on farming practices and climate change. Creating opportunities where farmers can exchange knowledge between each other can build bridges linking distinct groups of farmers and encouraging adoption among a wider circle (Parks, 2022).

According to feedback on the AAFC Fertilizer Targets discussion paper, those who responded emphasized the necessity of involving farmers directly in research endeavors and the crucial role of field demonstrations in developing and adopting technologies. Panelists suggested that universities or research institutes could help engage farmers in the research process. Communicating information through farmer-preferred sources could improve the positive perception of a technology and its subsequent adoption. Trust is an important element in perception of risks and benefits and the processing of information. So public participation and engagement in programs like the Living Laboratories initiative launched by AAFC is an important way of building trust and credibility (Agriculture and Agri-Food Canada, 2023). The Living Laboratories Initiative is an agricultural innovation approach that brings together multiple stakeholders including farmers and scientists to co-develop, test, and monitor new practices and technologies in the farm context. The initiative not only has the potential to increase technology uptake but also helps to develop innovations that are valuable and needed on farms.

Lack of clear communication about the fertilizer reduction targets was another barrier to adoption highlighted in the AAFC discussion paper feedback. It is natural for uncertainty to arise when new technology and practices are introduced. Farmers' perceptions about a new technology or practice have been found to be negatively impacted by insufficient information and ambiguity (Ward & Singh, 2015). A study that measured uncertainty through ambiguity found that an ambiguous environment (i.e., policies, markets) discourages farmers from adopting technology even when they might have insurance that protects against certain risks (Jozwik, 2018) .

Easily accessible and locally available technology along with demonstration plots improves adoption by reducing perceived risk and uncertainty about the innovation's performance because it gives farmers a better understanding and experience of the workings of the new technology in similar growing conditions like their own (Veisi , 2012; Barao, 1992). Policies that provide farmers with greater access to information sources, and that promote education and extension services by leveraging the important role of information in adoption can improve participation and adoption (Veisi , 2012).

Social norms and culture

Social Norms refer to unwritten rules and expectations that are widely accepted, shared, and enforced by members of a community.

Social norms can be a powerful tool for promoting sustainable agricultural practices. A recent study investigated the use of social norms to promote the adoption of conservation tillage practices among farmers in the United States and found that farmers who received information about the prevalence of conservation tillage practices in their area were more likely to adopt these practices themselves (Farrow, Grolleau, & Ibanez, 2017). A laboratory experiment has found that social pressure (disapproval) can be an effective means to increase adoption of a pollution-abatement technology, reducing the need for formal systems of penalties and rewards that can be costly and time consuming (Palm-Forster, Griesinger, Butler, Fooks, & Messer, 2022).

Ferraro and Price, (2013), in a field experiment involving city household, tested the effectiveness of three types of incentives: a social norm, a charitable donation, and feedback on water demand and use. The social norm incentive involved providing households with information on the average energy consumption of their neighbors, along with the message that "your neighbors are reducing their energy use, so should you." The results of the study showed that the social norm incentive was the most effective in promoting energy conservation among households, followed by the charitable donations. The study highlights that social norm can be effective in promoting environmentally friendly behaviors, and that these types of incentives may be particularly useful in situations where financial incentives are not feasible or desirable.

Discounting the future and resistance to change

Present bias refers to the tendency to place more value on immediate gratification than on long-term goals.

The tendency to place more value on immediate gratification than on long-term goals is commonly known as ***present bias***. When farms make adoption decisions, the current cost of adopting a new technology might loom larger than the future benefits that could be obtained.

To address farmers' present bias which gives more importance to current costs in relation to future benefits, payments at the initial stage of adoption when fixed costs are high can incentivize producers to adopt sustainable farming practices. In addition, providing information that encourages individuals to focus on their long-term goals and making the benefits of long-term decisions more salient and tangible can be effective in addressing present bias.

Environmental events including climate change risk occur far away and are less likely to be recalled, they are more likely to be discounted and thus technologies to mitigate such risks might not be adopted (Dessart, Barreiro-Hurlé, & Bavel, 2019; Streletskaya, et al., 2020). In agri-environmental campaigns, messages can influence people's perceptions of risk by presenting vivid and relatable examples of the negative impacts of unsustainable practices. For instance, showing real-life cases of environmental degradation caused by unsustainable farming practices can make the consequences more noticeable and tangible, compared to simply presenting general information or scientific predictions. This type of framing/messaging can affect people's sense of vulnerability, as human judgments are often based on recalling examples from memory or one's surroundings.

Status quo bias refers to when individuals underestimate the advantages of change and overestimate the disadvantages of change leading to the perception that any change is loss (Kahneman & Tversky, 1984).

The ***status quo bias*** is when individuals underestimate the advantages of change and overestimate the disadvantages of change leading to the perception that any change is loss (Kahneman & Tversky, 1984). Due to the preference for stability over change, producers may be biased towards resisting change and maintaining the status quo. Resistance to change has been found to be one of the reasons why farmers may not be adopting sustainable farming practices as much as expected (Burton, Rigby, & Young, 1999).

The high number of viable alternatives in terms of the technologies available can further push producers to prefer the status quo (Barao, 1992). Continuously evolving technology was among the top five barriers to precision agriculture adoption based on a Producer Survey in Western Canada (Steele, 2017). Reducing the number of options and technologies to choose from can reduce confusion and lead to better adoption of technologies as too many choices can lead to confusion and inability to make a decision.

To address the status quo bias and resistance to change, a policy recommendation is to propose change when farmers are less resistant to change. Recommending change during major life events like becoming a parent or passing on the farm to the next generation are effective in decreasing resistance to change. It might be difficult to get every farmer when major changes are happening in their personal lives. However, risk aversion and resistance to change can be reduced by promoting small but incremental changes towards technology adoption or to sustainable practices (Öhlmér, Olson, & Brehmer, 1998; Barao, 1992). Exposing people to both the advantages and disadvantages of the current state and providing the platform and opportunity to discuss and articulate the status quo or change might improve adoption rates. Gradual exposure to issues can also make change more acceptable than a rapid, huge change at once. Changing the way options are presented or framed can also help individuals overcome bias towards the status quo. For example, presenting the benefits of a change in a positive light, or emphasizing the potential negative consequences of maintaining the status quo, can help shift the balance towards change.

Policy Implications and Recommendations

The behavioral aspects of agriculture technology adoption are only one side of the issue, but they provide a comprehensive understanding of the decision-making process. These insights can be used to identify opportunities for intervention and the barriers to adoption. There are four main policy implications from this paper: use of incentives, overcoming resistance to change, enabling the messenger and adaptive management of programs.

Most agri-environmental issues are characterized by externalities. Externalities refer to the costs or benefits that are not reflected in the market price of a good or service, and therefore are not taken into account by producers in their decision-making. For example, nitrogen fertilizers use increases crop yields but may also create environmental externalities such as water pollution and GHGs. These externalities are not factored into producer costs and may require intervention (incentives or penalties) to motive more efficient use and account for these negative impacts. Incentives can reward or offer benefits to farmers (i.e., provide a carrot) for engaging in desired behaviors, while penalties can impose costs (i.e., a stick) for engaging in undesired behaviors as means of “internalizing” these externalities.

However, setting regulations and penalizing non-compliance to agri-environmental programs can build resentment and resistance to future change (Dahl, 2023). Having willing partners on the farm in the long run is crucial to ensure continuous involvement of producers in sustainability initiatives. Dahl (2023) argues that the goal of incentives should be to create willing partners in change and providing incentives to early adopters rather than penalties for those who are further behind on the adoption curve is a keyway of overcoming resistance to change.

Pineriro et. Al (2020) undertook a scoping review of nearly 18,000 papers exploring whether incentive-based programs led to adoption of various types of sustainable practices and found that incentive programs that prioritize short-term economic benefits have a greater likelihood of encouraging farmers to adopt sustainable practices compared to those that solely emphasize ecological benefits. Over time, farmers are more likely to adopt sustainable practices when they perceive benefits for their farms, the environment, or both. This highlights the importance of framing incentives in a way that takes into account the characteristics of the target population and that balances trade-offs between economic, environmental, and social outcomes. For instance, regions with stronger environmental culture require lower financial incentives to adopt sustainable farming practices providing crucial information for policymakers who aim to diffuse environmental innovations rapidly and at minimal costs (Wuepper, Bukchin-Peles, Just, & Zilberman, 2023). It is not only about the value of the incentives that are offered, but how they are offered that determine uptake of a program.

Developing and implementing farmer knowledge exchange programs that provide platforms for farmers to share their experiences, knowledge, and best practices related to innovative farming technologies is important as farmers are more receptive and more likely to act on information obtained from peers (Burton, Rigby, & Young, 1999). Enhancing communication strategies to ensure a clear and concise communication of information related to new technologies and practices is paramount. Engaging with stakeholders in the early stages of program development can create a sense of ownership, responsibility and increased participation in programs instead of a top-down approach.

Lack of clarity is one of the main barriers to adoption identified in the literature, therefore, establishing feedback mechanisms to refine programs, address farmer queries, concerns, and uncertainties and providing easily accessible and locally available information to farmers promotes transparency and reduces ambiguity while ensuring programs are relevant and applicable to local farming contexts.

Since the determinants of adoption vary between different technologies, different regions and different individuals further research should be directed to investigating issues and results that are meaningful to local areas and context rather than generalizing studies to universal application (Knowler & Bradshaw, 2007). Providing flexibility in program and policies design through active-adaptive management system is needed to take the full benefit of insights from behavioral studies. In such a system, decisions are made based on ongoing monitoring and evaluation of the dynamics in the program. It involves actively adjusting management strategies and actions in response to changing conditions and new information, aiming to improve outcomes and achieve desired objectives. This iterative process allows for flexibility and learning, enabling utilization of previously acquired knowledge when policies change or are modified (Bahati & Bauer, 2010).

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