



MOVING TOWARD AGRICULTURE DIGITALIZATION

By Hanan Ishaque, Sabrina Gulab, Margarita Sanguinetti and Guillaume Lhermie.

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ABSTRACT

This study investigates the conditions shaping the adoption and effective use of Digital Agricultural Technologies (DATs) in Canadian crop production, with a focus on Western Canada. Using a mixed-methods approach, the study integrates findings from a scoping review, a cross-provincial producer survey, and semi-structured stakeholder interviews to explore both technical and socio-behavioural dimensions of digital agriculture. The scoping review, guided by the PRISMA-ScR framework, analyzed 83 peer-reviewed studies published since 2013 to map trends in DAT development, validation, and early-stage adoption across Canada. To assess producer behaviour, a structured online survey was conducted with 587 crop and livestock producers in Alberta, Saskatchewan, and Manitoba, focusing on data use practices, digital literacy, risk perceptions, and trust in data systems. Finally, 11 semi-structured interviews with producers, service providers, and policymakers in Alberta provided deeper insight into the operational, institutional, and attitudinal barriers to adoption. While technical progress in tools such as remote sensing, machine learning, and variable rate technologies is evident, the study finds that widespread and meaningful use is constrained by challenges in agronomic support, usability, data integration, and return on investment. Trust in data governance, particularly around ownership, privacy, and interoperability—is an emerging concern, while behavioural factors such as proactivity, transparency, and perceived risk strongly influence post-adoption data use. The findings highlight the need for a farmer-centered innovation ecosystem and propose policy directions including regionally targeted research investment, expanded advisory services, enforceable data governance frameworks, simplified adoption incentives, and open, interoperable data platforms to support a more inclusive and sustainable digital transition in Canadian agriculture.

INTRODUCTION

The rapid evolution of digital agriculture technologies (DATs) is reshaping agricultural production systems worldwide, offering unprecedented opportunities for increasing efficiency, sustainability, and resilience. In Canada, where crop production contributes to 77% of total primary agricultural output Agriculture and Agri-Food Canada (2023). The integration of digital tools such as remote sensing, artificial intelligence (AI), the Internet of Things (IoT), and automation in primary agriculture is increasingly seen as critical to meeting food, energy, and environmental demands. These technologies enable granular, real-time data collection and decision-making capabilities, transforming everything from field operations to input management and sustainability planning (Agyemang & Kwofie, 2021).

The digital transformation of Canadian agriculture began with early precision agriculture tools—such as yield monitors, autosteer systems, soil sampling, and variable rate technology—which have been in use for decades. However, recent advances have introduced more disruptive innovations that leverage big data, cloud computing, and machine learning to optimize decisions at multiple scales. AI, for example, enables predictive modeling of pest outbreaks or irrigation needs, while IoT-based systems enhance monitoring and control across spatially dispersed operations. Despite this technological progress, adoption patterns remain uneven, and many producers struggle to derive full value from these innovations.

Drawing on a scoping review of recent research, a survey of 587 Western Canadian producers, and 11 semi-structured interviews with producers, service providers, and policymakers in Alberta, the study explores how technical capabilities, behavioural dynamics, and institutional arrangements interact to shape DAT uptake. Findings reveal that while technical innovation is advancing, barriers such as limited agronomic support, trust issues around data governance, fragmented service models, and post-adoption challenges related to digital literacy and risk perception persist. By centering the Canadian context, this research provides a nuanced understanding of digital agriculture’s opportunities and constraints and identifies key leverage points—such as inclusive design, tailored advisory services, and robust policy frameworks—for fostering more meaningful and sustainable technology adoption across the sector.

MAPPING THE CURRENT LANDSCAPE OF DATS IN CANADIAN CROP PRODUCTION

To map the current state of DAT development and adoption in Canada, we conducted a scoping review of recent research focused on the validation and early adoption dynamics of DATs within Canadian crop production systems. Using a systematic search strategy consistent with the PRISMA-ScR framework, we identified and screened studies across major academic databases. The review prioritized intervention studies that statistically evaluated DAT performance in Canadian field crops, alongside qualitative research investigating barriers and enablers of DAT adoption. Eligibility criteria included a focus on field crops, commercially available decision-support technologies, and English-language, peer-reviewed sources.

The evidence base is predominantly composed of validation studies, reflecting significant technical advancements across remote sensing, artificial intelligence (AI), Internet of Things (IoT), robotics, and automation applications for crop monitoring, pest management, irrigation optimization, and soil health management. This mapped landscape provides a comprehensive view of where innovation efforts have been concentrated and where critical gaps remain, particularly concerning regional validation and adoption patterns.

From an initial pool of 1,283 records, after duplicate removal and screening, 83 studies were ultimately included in the review. Ontario and Manitoba emerged as key hubs of validation-focused research and innovation.

TECHNICAL INNOVATION FOCUS: ADVANCES IN SENSING, PREDICTION, AND DECISION SUPPORT

We highlighted two broad streams of research: technical validation studies and qualitative research on digital agriculture adoption (Figure 1). To analyze findings across the technology innovation continuum, we applied the

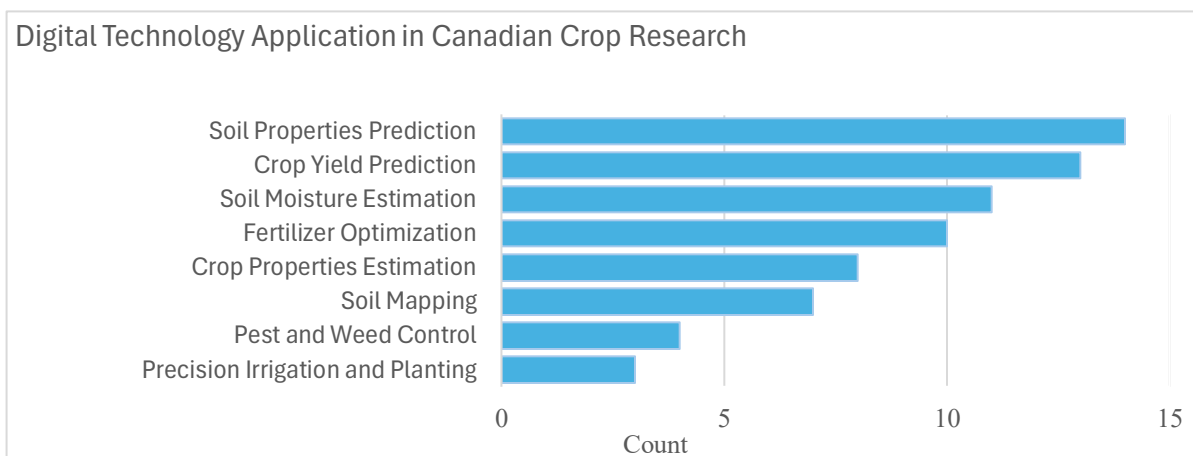


Figure 1: Distribution of Reviewed Studies by Digital Technology Application in Canadian Crop Research.

sectoral innovation system (SIS) framework (Busse et al., 2014a; Bergek et al., 2008; Malerba, 2002), distinguishing between technology validation, production scaling, and adoption phases. Technical studies show significant progress in developing and testing DATs for crop monitoring, yield prediction, fertilizer optimization, and targeted pesticide use, with tools like UAVs, satellite imagery, agroecosystem models, and machine learning playing major roles. This work fits the "validation" phase of the innovation process, creating new knowledge that could later be commercialized.

We found a strong reliance on proximal soil sensing (PSS) and remote sensing technologies for estimating soil properties, soil moisture, crop parameters, and yield prediction in Canadian agriculture (Ishaque et al. 2024). Of the fourteen soil property studies reviewed, twelve used PSS methods like electromagnetic induction (EMI), mid-infrared (mid-IR) spectroscopy, and gamma-ray sensors to predict critical physical soil characteristics. Calibration and prediction approach frequently employed machine learning, regression, and simulation models. Thematic mapping studies similarly combined proximal and remote sensing tools (e.g., UAVs, Landsat, RapidEye) with advanced analytics to create field-specific maps for nitrogen management, crop health, and soil variability. Soil moisture estimation studies leaned heavily on satellite-based radar data from sources like Sentinel-1, UAVSAR, and SMOS, with machine learning commonly applied to enhance prediction accuracy.

In crop monitoring and yield prediction, remote sensing (especially UAV multispectral imagery and satellite data) played a major role, with vegetation indices such as NDVI, EVI, and WDRVI widely used. Agroecosystem models like DSSAT were also employed to simulate crop responses to inputs and environmental conditions, supporting better decision-making at the farm scale. Studies on fertilizer optimization emphasized digital technologies for improving nitrogen management, combining decision support systems, UAV-based tools, and machine learning models to optimize application rates and reduce environmental impacts. Additionally, targeted pesticide and herbicide application studies utilized IoT sensors, UAVs, and deep learning techniques to improve input efficiency. Overall, the findings point to a growing integration of high-resolution sensing technologies and predictive analytics to enhance precision, productivity, and sustainability in Canadian crop production. Table 1 summarizes the tools and methods used across crop production cycle validated in the select studies.

SOCIO-POLITICAL DYNAMICS SHAPING ADOPTION

While technical validation remains central to digital agriculture research, the adoption of DATs is increasingly understood as a socio-technical process that involves institutions, user values, and the broader innovation ecosystem (Klerkx & Leeuwis, 2009).

This scoping review also mapped qualitative research focused on the 'production' and 'adoption' phases of the innovation process. Although few Canadian studies address the commercialization stage directly, those that do emphasize how early-stage design and market strategies shape long-term adoption outcomes. Research on adoption highlights a dynamic system where institutional structures, farm size, socio-cultural context, technology complexity, and farmers' digital skills all influence technology uptake. Broader political-economic forces, such as corporate consolidation and regulatory frameworks, further mediate access to and benefits from digital technologies.

Table 1: Summary of Studies on Crop Production: Data Collection Techniques and Data Analysis Methods Across Research Categories

Category	Data Collection Methods	Data Analysis Methods
Crop Properties Prediction	UAV multispectral imagery, Satellite imagery, Aerial photography, SAR sensors	Machine Learning, Multiple Linear Regression, Water Cloud Model-Ulaby (WCM-Ulaby), SAR Polarimetric Integration
Crop Yield Prediction	Hand-held imaging, Yield sensors with GNSS, Topographic LiDAR, Satellite imagery (e.g., RapidEye, Sentinel-2), UAVs	Vegetation Indices (NDVI, EVI, etc.), Agroecosystem Simulation Models (e.g., DSSAT, CSM-CROPGRO-Canola, DSSAT-CERES)
Fertilization Optimization	UAV-based tools, Soil moisture sensors, Field sensors	Machine Learning Models, DSSAT Simulation Models, Variable- vs. Uniform-Rate N Application Comparisons
Pest and Weed Control	Cameras on quad/farm equipment, IoT sensors, UAVs with near-IR cameras	Deep Learning, Machine Learning, NDVI-derived Maps, Custom Python Algorithms
Precision Planting & Irrigation	Smart tractor systems with variable rate controls, Soil moisture sensors, UAV imagery	Greenness Excess Index (GEI), Random Forest Machine Learning Algorithm for irrigation forecasting

KEY INSIGHTS: ADVANCES, BARRIERS, AND GAPS

A key insight is that while many DATs have reached technical maturity at the prototype or experimental validation phase, few have transitioned into widespread commercial use. High variability in outcomes, linked to soil type, crop species, data source, and agroclimatic conditions, underscores the necessity of region-specific validation, something current research has largely overlooked. The review finds that most studies are geographically concentrated in Eastern Canada (notably Ontario and Quebec), with relatively few studies conducted in the Prairies, despite this region's critical importance to Canadian crop production (Figure 2).

While technical advancements in DATs—such as UAV-based imagery, SAR satellite sensing, and machine learning-driven models—have expanded the potential for site-specific, data-driven decision-making in Canadian agriculture, adoption patterns remain uneven. Socio-political challenges to adoption, such as farmer concerns over data ownership, transparency, and the concentration of data power among large ag-tech corporations, are also emphasized. Initiatives like Ag Data Transparent, alongside standards like ISOBUS and ADAPT, are emerging to address interoperability and farmer data rights, but the impact has not been studied at length.

Recognizing these socio-political dimensions is critical for future innovation and policy efforts. The review stresses the need for innovative models that incorporate Responsible Research and Innovation (RRI) principles, advocating for inclusive, multi-stakeholder engagement across the full technology development and diffusion pipeline.

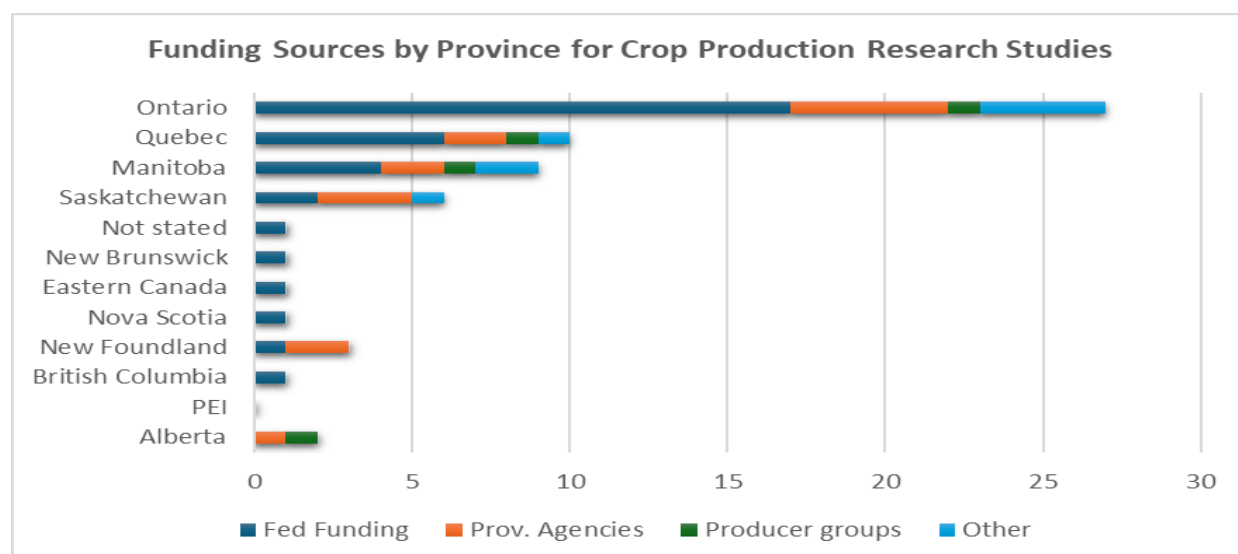


Figure 2: Funding Sources by Province for Crop Production Research Studies

EXPLORING PRODUCER'S DECISION-MAKING DYNAMICS IN AGRICULTURE DIGITAL TECHNOLOGY ADOPTION AND DATA USE

Technical validation and macro-level barriers tell only part of the story. As DAT adoption increases, understanding the behavioural and attitudinal factors that influence how producers use and manage digital data becomes essential. To fill this gap, we conducted a survey across the Prairie provinces focused on crop and cattle producers to explore the psychological determinants of post-adoption data use. We aim to address these challenges by examining why farmers struggle to translate DAT adoption into effective data use. This specific objective of the survey is to:

- Study the post-adoption behaviour, revealing how technical, behavioural, and structural barriers—from low data literacy to mistrust in corporate data handling—hinder integration into farm management
- Identify drivers of data use, demonstrating that practical factors like training, provider support, and transparency matter more to farmers than abstract data governance debates.
- Underscore the need for targeted interventions—such as skill-building programs, on-farm demonstrations, and policies that empower farmers in data ownership—to close the gap between adoption and value realization.

SURVEY OVERVIEW, METHODS AND KEY FINDINGS

Between December 2023 and January 2024, we surveyed 587 producers from Western Canada, in collaboration with Stratus Ag Research. Participants, primarily from Alberta (45%), Saskatchewan (20%), and Manitoba (15%), operated farms larger than 700 acres and represented both crop and livestock sectors. The survey was administered online with digital consent, and participants received modest compensation. Ethics approval was obtained from the University of Calgary Research Ethics Board (REB24-0514).

The survey instrument was organized into four sections covering operational characteristics, DAT adoption behaviour, data use practices, and demographics. It assessed a range of factors including producers' digital skills, concerns around data governance, risk perception, attitudes toward data transparency, and perceptions of policies governing digital technologies. The design built on previous surveys conducted in Australia and Canada (Duncan, 2023; Wiseman et al., 2019; Zhang et al., 2017). Special focus was placed on understanding data use behaviour following DAT adoption, including the psychological and support-related determinants influencing producer engagement with digital tools.

Demographically, the average participant was 58 years old, with 91% identifying as male. Producers owned an average of 3,188 acres and rented an additional 1,275 acres. Educational attainment was high, with the majority having at least some college education, and over half of the respondents reported above-average farm income levels.

DATA RELATED CONCERNS

Attitudinal analysis revealed that while perceptions of DATs' contributions to farm profitability and sustainability were generally positive, participants exhibited significant concerns regarding data privacy, ownership, and sharing. The majority expressed a desire for greater transparency from digital service providers, including informed consent before data sharing and clarity regarding data use purposes. However, understanding of terms and conditions in DAT contracts was low to moderate, and many producers reported challenges related to the usability of data analysis platforms and a lack of external support for data management.

FACTORS INFLUENCING FARM DATA USE

Using an ordered probit regression model, we investigated the factors influencing producers' level of data use for farm decision-making. Results indicate that lack of data literacy and support is negatively associated with data use: producers reporting difficulties in interpreting digital outputs or lacking service support were approximately 6.3 percentage points less likely to use data in their decisions. Similarly, risk perception around DATs significantly reduced the likelihood of data use, with a 9.6 percentage point decrease observed among those who perceived higher risks. Figure 3 represents the interaction between risk perception and adopter type. The figure demonstrates that producers who are high adopters with low-risk perception of DATs use more data gathered using DATs for farm decisions than producers who are high adopters but have higher risk perception. These results provide additional

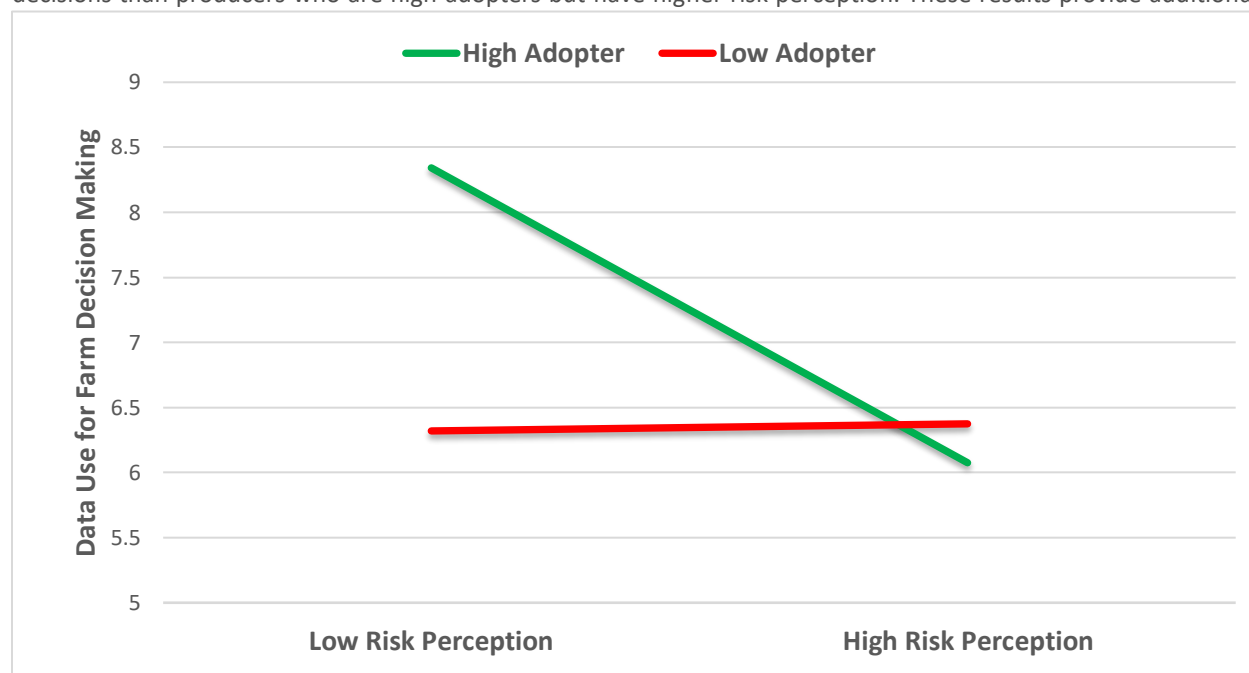


Figure 3: Interaction between Adopter type and Risk perception

insights into what behavioural factors like risk perception play significant role in shaping producers' choices and decisions.

Conversely, proactive behaviours such as actively seeking information, attending workshops, and experimenting with digital tools—was strongly positively associated with data use, increasing the probability by approximately 15 percentage points. Producers who recognized the benefits of DATs for profitability and sustainability were also nearly 10 percentage points more likely to incorporate digital data into farm management practices.

CONCERNS ABOUT DATA GOVERNANCE

Interestingly, while broader concerns about data governance (privacy, ownership, and service provider behaviour) were prevalent among producers, these concerns did not show a statistically significant direct effect on data use behaviour. However, nuanced patterns emerged: a stronger desire for informed data use was negatively associated with data engagement, suggesting that lack of trust or clarity from providers may inhibit adoption. In contrast, a strong desire for informed consent before data sharing was positively associated with data use, implying that when farmers feel agency and control over their data, they are more willing to utilize digital tools.

DEMOGRAPHICS

Among demographic variables, age showed a modest but significant positive association with data use, suggesting that older producers may have more experience integrating new information into decision-making. Education, gender, and income were not significantly associated with data use levels.

Overall, the findings highlight that beyond technical performance, psychological factors—such as trust, risk perception, and proactive engagement—are critical to how producers use DATs after adoption. Despite advances in technical innovation, a significant gap persists between DAT development and practical usability, particularly in Western Canada, where farmer perspectives remain underrepresented. Addressing issues of trust, data literacy, and agency through targeted policies, support programs, and inclusive technology design is essential to ensure that digital agriculture benefits a wider range of producers. Achieving meaningful and equitable adoption will require systemic changes that center farmers' needs and priorities, rather than assuming technical innovation alone can drive transformation.

DIGITAL AGRICULTURE ADOPTION IN ALBERTA: A QUALITATIVE APPROACH USING THE TECHNOLOGY ACCEPTANCE MODEL

Recognizing that technology adoption does not occur in a vacuum, our next line of inquiry turned to the broader socio-technical context shaping DAT integration. Through semi-structured interviews with producers, technology service providers, and policymakers in Alberta, we explored how divergent perspectives across the agri-food ecosystem create misaligned expectations, fragmented support systems, and persistent gaps between data generation and practical decision-making. These insights provide a critical foundation for understanding the organizational and relational barriers that must be addressed to enable more effective, trust-based adoption of digital technologies in Canadian agriculture.

STAKEHOLDER PERSPECTIVES ON DAT INTEGRATION

To deepen our understanding of the socio-technical context shaping the adoption of DATs in Alberta, we conducted a series of semi-structured interviews between July 2024 and February 2025. Participants were recruited through a combination of convenience and snowball sampling, beginning with AgTech service providers expanding to include producers and government stakeholders. In total, 14 interviews were completed, comprising five producers, four technology service providers, one agricultural communication expert, and one government policy representative. Farm sizes among producers ranged from 120 to 17,500 acres, while service providers covered territories ranging from 100,000 to 3 million acres.

Three tailored versions of the interview guide were developed to reflect participants' roles. Interview questions explored themes such as DAT usefulness, data collection practices, decision-making processes, technical support needs, adoption experiences, barriers to technology use, future outlooks, and perspectives on policy and data governance. Interviews lasted between 35 and 50 minutes, with all research procedures approved by the University of Calgary's Research Ethics Board (REB24-0523).

Data analysis followed a mixed inductive-deductive thematic coding approach, complemented by the Framework Analysis method developed by Ritchie and Liz Spencer (1994) for qualitative analysis, to ensure a structured yet flexible interpretation of findings. The codes were refined iteratively through familiarization, indexing, charting, and interpretation stages. Ultimately, nine core themes were identified. Initial codes were guided by the Technology Acceptance Model (TAM). Originally conceptualized by Davis (1985) and rooted in the Theory of Reasoned Action (Fishbein & Ajzen, 1975), TAM remains a foundational framework for understanding how perceptions of usefulness and ease of use shape users' attitudes and intentions toward adoption technology. To reflect the evolving dynamics of technology adoption, we integrated Perceived Trust (PT) into our analysis, recognizing it as a key factor influencing user acceptance. This aligns with Pavlou's (2003) extension of the Technology Acceptance Model and is supported by Wu et al.'s (2011) meta-analysis demonstrating trust's strong predictive value.

KEY FINDINGS

Perceived Usefulness

Producers recognized the potential of DATs to improve operational efficiency, decision-making, and risk management. However, persistent uncertainty about return on investment, spatial and environmental variability, and lack of interoperability between technologies created skepticism. Profitability remained the primary driver of adoption, but benefits were often highly context-specific and difficult to quantify, especially for smaller operations.

Perceived Ease of Use

Poor interoperability between platforms, cognitive overload from managing multiple systems, and difficulties in translating data into actionable decisions were major barriers. Many producers expressed frustration with technical complexity, limited support, and the burden of self-managing data systems without sufficient training or assistance. Knowledge transfer gaps, particularly for small and mid-sized farms, were highlighted as critical issues inhibiting broader adoption.

Trust and Data Governance

Concerns about data ownership, ethical use, and the consolidation of data by large corporations emerged as complex trust issues. While producers acknowledged that individual farm data has limited standalone value, unease persisted around how aggregated data might be used commercially without farmer benefit. Skepticism toward voluntary industry transparency initiatives such as Ag Data Transparent reflected a broader mistrust of self-regulation without stronger enforcement mechanisms.

Attitudes Toward DATs

Adoption was strongly influenced by risk aversion, attachment to traditional practices, and generational dynamics. Although resistance was common among older farmers, attitudes toward technology varied widely and were more closely tied to learning orientation and willingness to change than to age itself. Peer networks played a critical role in technology diffusion, with farmers relying heavily on trusted peers over corporate or promotional sources for information.

External Factors

Views on government and industry initiatives to promote DAT adoption were mixed. While financial incentives were acknowledged as helpful, administrative complexity and perceived disconnection from on-farm realities reduced program effectiveness. Producers emphasized the need for simpler, more accessible support mechanisms that reflect practical farming contexts rather than top-down regulatory approaches.

Overall, interviews with producers, service providers, and policymakers revealed persistent gaps between innovation supply and farm-level readiness, compounded by concerns over data governance, trust, and fragmented support systems. While AgTech developers emphasized the technical potential of DATs, producers often questioned their day-to-day value, citing a lack of agronomic guidance and practical integration. Building trust through enforceable data governance standards, rethinking service delivery models to prioritize agronomic decision support, and strengthening peer-to-peer learning emerged as critical needs. To address these challenges, the study proposes a multi-dimensional adoption framework grounded in technological fit, transparency, capacity building, and better alignment of policy and market incentives, offering a roadmap for fostering more inclusive and sustainable digital agriculture ecosystems.

CONCLUSION AND POLICY DIRECTIONS

The integration of DATs into Canadian crop production is advancing, but the path toward widespread and meaningful adoption remains uneven and complex. This study—combining a scoping review, a national producer survey, and stakeholder interviews in Alberta—highlights that while technical innovation in remote sensing, machine learning, and precision agriculture is substantial, broader systemic barriers continue to constrain impact. Adoption is shaped not only by technology performance but also by producers' perceptions of value, usability, trust in data governance, and access to meaningful support services.

Producers in Western Canada, particularly in Alberta, cited skepticism about return on investment, uncertainty around outcomes, fragmented service delivery models, and interoperability challenges as persistent barriers. Behavioural and attitudinal factors—such as risk aversion, proactive engagement, and the desire for greater transparency—play pivotal roles in shaping whether and how data is used post-adoption. While concerns about data privacy and ownership are growing, they have not yet translated into widespread disengagement. Nevertheless, mistrust in data practices and service provider intentions presents a latent risk to the long-term growth of the digital agriculture sector.

Critically, the research reveals that many DATs have been validated under limited experimental conditions, and adoption has concentrated disproportionately in Eastern Canada, missing opportunities for scaling solutions to the highly productive Prairie provinces. Addressing this regional imbalance, enhancing farmer trust, and focusing on practical, usable solutions rather than purely technological advancements are essential for fostering equitable and sustainable digital innovation in agriculture.

To support a stronger and more inclusive digital agriculture ecosystem, the following policy directions are recommended:

- **Enhance Farmer-Centric Collaboration:** Promote early-stage collaboration among farmers, technology developers, researchers, and policymakers. Regional innovation hubs governed by producer-led boards should guide R&D priorities, ensuring technologies address real farm needs rather than corporate agendas.
- **Expand Practical Support and Data Literacy:** Invest in accessible, on-farm data literacy training tailored to producers' needs. Support peer-to-peer learning networks, independent advisory services ("tech-gronomists"), and practical field-based demonstrations to build confidence and bridge the gap between data collection and decision-making.
- **Strengthening Trust and Data Governance:** Develop a national Ag Data Ethics Charter that moves beyond voluntary transparency toward enforceable accountability in data handling and ownership. Public funding for AgTech innovation should be tied to demonstrable commitments to interoperability, ethical standards, and fair data use.
- **Diversify and Optimize Research Funding:** Strategically allocate federal and provincial research funding to better support regionally relevant studies, especially in crop-dense provinces such as Alberta, Saskatchewan, and Manitoba. Funding should also prioritize inclusion of small- and medium-sized farms to ensure diverse adoption pathways.

- ***Streamline and Incentivize Adoption Programs:*** Simplify the administrative burden associated with programs like OFCAF to make them more accessible. Introduce tiered incentive structures that reward early adopters while encouraging new entrants, fostering a culture of continuous innovation and learning across farm sizes.
- ***Promote Data Interoperability and Usability:*** Invest in platforms and standards that ensure interoperability across equipment brands and data systems. Create an open-access, centralized Alberta-specific soil health database to enable producers, agronomists, and researchers to access actionable, regionally calibrated soil and management information.
- ***Reframe Communication and Extension Strategies:*** Shifts from hardware demonstrations to outcome-oriented messaging that clearly explains the agronomic and financial benefits of DAT adoption. Empower producers with unbiased, easy-to-access information channels to reduce skepticism and promote informed decision-making.
- ***Support Long-Term Capacity Building:*** Integrate digital agriculture, data analytics, and decision-support skills into formal agricultural education curricula and continuous learning programs. Strengthening the human infrastructure necessary for knowledge transfer, ensuring long-term resilience in the agri-tech transition.
- ***Balance Regulation with Flexibility:*** Design regulatory frameworks that promote responsible innovation while minimizing undue compliance burdens. Policies should be sensitive to regional differences in farm size, production systems, and agro-climatic conditions to ensure equitable outcomes across Canada's diverse agricultural landscape.
- ***National Digital Ag Strategy:*** A producer-led national strategy that embeds the aforesaid elements will be essential to maintaining momentum. Such a strategy can provide clear direction and consistency across regions and sectors. It will also help ensure that progress is sustained and measurable over the long term.

In sum, while Canada possesses the technological capabilities to lead in digital agriculture, realizing this potential will require a systemic reorientation: one that centers farmers' needs, builds trust, strengthens capacity, and aligns policy frameworks to support both technological excellence and practical adoption on the ground. Future research should focus on developing regionally tailored interventions, tracking longitudinal behaviour change among producers, and drawing lessons from international best practices to continually strengthen Canada's innovation ecosystem in agriculture.

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