Protocol for a scoping review on agricultural digital technologies in Canada used for crops.

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Authors' contributions

V.M. S: protocol/search strategy development, review of manuscripts and data extraction, manuscript preparation/revision
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H. G: development/conducting search strategy, manuscript editing/feedback
G. L: project supervision, acquisition of funding, project administration, protocol, and search strategy development, third reviewer for resolving conflicts, and manuscript editing/revision.

Registration

This protocol will be archived in PRISM: University of Calgary Digital Repository (https://prism.ucalgary.ca). The protocol will be reported using the recommended PRISMA-ScR (PRISMA extension for Scoping Reviews) (1).

Support

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Amendments

In case any amendments are made to this protocol after its registration, they will be adequately documented in the review as Protocol Deviations.

INTRODUCTION

Rationale

Agriculture is currently undergoing a notable digital transformation, driven by technologies aimed at improving efficiency, productivity, and sustainability, with the potential to achieve food security while mitigating environmental impacts (2–4). The digitalization of agricultural technologies encompasses a

spectrum from precision agriculture (PA) which gather data for farm, crop and livestock management, and data analysis technologies such as analytical tools for crop and farm management. Moreover, advancements in digital technology have heightened the demand for using data to improve and mitigate these challenges faced by the agriculture sector (4).

The demarcation between digital technologies and precision agriculture or smart farming has become increasingly nuanced (5). However, all of these definitions usually comprise multifaceted sequential processes, including a) the generation and collection of on-farm data, which may involve the deployment of UAV airborne devices, sensors, and satellites (6,7), b) the integration of collected data into software platforms, and subsequent analysis utilizing methodologies such as machine learning (8,9), c) the provision of an interface/output for presenting results and facilitating their interpretation (10)*.

Access to real-time data generation is a fundamental tool for enhancing productivity (11,12). It enables timely and informed decision-making by tailoring the specific needs of individual fields, especially for large farms with high field variability. Through their capabilities, digital technologies furnish empirical evidence on critical factors such as soil moisture (7) as well as the content of specific elements, including organic carbon (6,13) and essential minerals such as nitrogen, phosphorus, and potassium (14,15). The in situ, proximal and remotely sensed data generation using various digital technologies not only facilitates informed decision-making processes between agricultural professionals or technicians and farmers but also holds the potential to mitigate issues such as excessive fertilization, thereby safeguarding profitability and aligning with consumer preferences for 'more natural foods' (15–17).

As Canada's agriculture sector continues to evolve, embracing digital technologies offers promising opportunities to enhance productivity, sustainability, and resilience in crop production. In the year 2023, production of field crops in Canada increased by 32.5% over 2022 (18), driven by a worldwide increase in food demand (19,20). Besides increasing demand of consumers for an increased quantity of food, they are also demanding more transparency concerning the processes involved in the food they consume (21). Given this, other alternatives, including new breeding methods and optimizing soil and crop management using digital technologies, are essential to boost productivity while limiting the environmental impact as much as possible to meet the demand for quantity and quality of food (19,22).

In Canada, a limited number of published studies have addressed this topic, including its impact on ecosystem services (5) and the uptake of digital

technologies by farmers (23–25). However, to the best of our knowledge, no other scoping review has summarized the evidence concerning the digital technologies being developed to be used on farms.

This study aims to conduct a scoping review of all studies conducted in Canada from 2013 to the present on developing and validating digital technologies in crop production in order to gain a comprehensive understanding of the current landscape and trends within this field. It will help identify emerging technologies, methodologies, and research gaps, enabling informed decision-making for future research directions and innovation strategies. Additionally, it will facilitate the assessment of progress in adopting digital technologies in crop production, shedding light on successes, challenges, and areas needing further attention. However, along with the benefits, the review will also highlight emerging challenges associated with digital technology adoption in agriculture, including data governance, privacy, and security issues. Understanding and addressing these challenges are essential for fostering responsible and sustainable deployment of digital technologies in Canadian crop production, ensuring their long-term viability and societal benefits.

Objectives

This protocol describes the methodology that will be used for a scoping review that will summarize the evidence on the following:

1. What are the prevailing digital technologies and methods explored in Canadian crop production research, encompassing areas such as Remote sensing, Artificial intelligence, Internet of Things (IoT), robotics, and automation?
2. What are the practical applications of various digital technologies and methods in addressing challenges related to crop monitoring, pest management, irrigation, and soil health?
3. What are the perspectives of Canadian farmers, industry stakeholders, and policymakers on the opportunities, challenges, and ethical considerations associated with the adoption and deployment of digital technologies and methods in crop production?

The objective of this study is to conduct a review of current research conducted on digital technologies being developed or validated in Canada to advance precision agriculture. "Current research" refers to studies published during the last decade, thus limiting the scope to publications from 2013 onwards. The specific objectives are:

- To comprehensively review and document the prevailing digital technologies and methods utilized in Canadian crop production research.

- To evaluate the practical applications of these digital technologies and methods in addressing key challenges encountered in Canadian crop production.
- To analyze the perspectives of Canadian farmers, industry stakeholders, and policymakers regarding the opportunities, challenges, and ethical considerations associated with the adoption and deployment of digital technologies and methods in crop production.

Included studies must at least involve one element of the case definition provided above (a, b or c)* that is commercially available.
Included studies had to include a field trial conducted in principal crops in Canada (26).

METHODS

This review will follow the PRISMA-ScR reporting guidelines for scoping reviews (1). The review team will include four members including experts in agriculture technologies (SG, HI), epidemiological methods (GL, VMS), public policy (FN) and database searching (HG).
The following databases will be searched from 2013 to present (2024): BIOSIS Previews, Web of Science (both on the Clarivate Web of Science platform); CAB Abstracts (Ebsco platform); IEEE Xplore, and ProQuest Dissertations.
Keywords and controlled vocabulary search strings will be developed for the following concepts:

- Agriculture (specifically, crop production)
- Agricultural technologies, as described in the body of this protocol
- Canada

Three types of studies will be identified:

Intervention studies (agricultural digital technology will be used), qualitative and uptake studies (e.g., assessing perceptions and uptake of the technologies) and policy reviews. Not all PICOS elements will be relevant to all three types of studies.

Eligibility criteria

The eligibility criteria will be grounded on the PICOS framework including only studies based in Canada (27):

Population (P) (All three study types)	Intervention or exposure population: crop, productive systems
Intervention (I) (All three study types)	Agriculture digital technologies including: Sensing technologies, decision support systems, GPS and Realtime Kinematic positioning, UAV airborne

	devices, satellite data, advanced data analytics techniques including artificial intelligence, etc.
Comparator (C) (For intervention studies)	For randomized control trials (RCT): placebo, standard therapy, no treatment For observational studies: no exposure, non-cases Conventional technologies/standard practices
Outcome (O) (All three study types)	Identification of intended use of the technologies: equipment- infrastructure Adoption rates Environmental indicators Economic: unit costs, ROI Output and input consumption Productivity and management Interoperability Data ownership and privacy, social considerations Policies
Study designs (S) (All three study types)	Quantitative studies including randomized controlled trials and observational studies. Qualitative studies Public policy reviews
Location (L) (All three study types)	Canada

Information sources and search strategies

CAB Abtracts (Ebsco)

#	Query	Results	Action
S1	DE "livestock farming" OR DE "cattle farming" OR DE "beef cattle" OR DE "beef bulls" OR DE "beef cows" OR DE "dairy cattle" OR DE "dairy bulls" OR DE "dairy cows"	143,883	EditS1
S2	TI (livestock or beef or dairy or cattle) OR AB (livestock or beef or dairy or cattle)	381,279	EditS2
S3	(DE "crop enterprises" OR DE "crop husbandry" OR DE "crop management") OR (DE "crop production")	114,943	EditS3
S4	TI (agricultur* or farm* or crop*) OR AB (agricultur* or farm* or crop*)	1,608,855	EditS4
S5	S1 OR S2 OR S3 OR S4	1,909,635	EditS5
S6	(DE "precision agriculture") OR (DE "computer techniques" OR DE "computer analysis" OR DE "computer simulation")	23,718	EditS6
S7	TI (((digital or smart or precision) w2 (agricultur* or farm* or crop or livestock or cattle or beef or dairy)) or "agriculture 4.0" or agtech or "decision support system*" or drone* or "machine learning" or "big data" or "data analytics" or sensor or sensors or "artificial intelligence" or "internet of things") OR AB (((digital or smart or precision) w2 (agricultur* or farm* or crop or livestock or cattle or beef or dairy)) or "agriculture 4.0" or agtech or "decision support system*" or drone* or "machine learning" or "big data" or "data analytics" or sensor or sensors or "artificial intelligence" or "internet of things")	91,947	EditS7
S8	S6 OR S7	108,391	EditS8
S9	DE "Canada" OR DE "British Columbia" OR DE "Manitoba" OR DE "New Brunswick" OR DE "Newfoundland and Labrador" OR DE "Northwest Territories" OR DE "Nova Scotia" OR DE "Nunavut" OR DE "Ontario" OR DE	146,260	EditS9

	"Alberta" OR DE "Prince Edward Island" OR DE "Quebec" OR DE "Saskatchewan" OR DE "Yukon Territory"		
S10	TI (Canada or Canadian or "British Columbia" or "Alberta" or Saskatchewan or Manitoba or Ontario or Quebec or Newfoundland or "New Brunswick" or "Nova Scotia" or "Prince Edward Island" or Yukon or "Northwest Territories" or Nunavut) OR AB (Canad* or "British Columbia" or "Alberta" or Saskatchewan or Manitoba or Ontario or Quebec or Newfoundland or "New Brunswick" or "Nova Scotia" or "Prince Edward Island" or Yukon or "Northwest Territories" or Nunavut)	147,255	EditS10
S11	S9 OR S10	176,463	EditS11
S12	S5 AND S8 AND S11	225	EditS12
S13	s12 NOT (salmon or aquaculture or "fish farm*") NOT (blueberr* or strawberr* or apple* or fruit or vegetable* or tomato* or potato*)	179	

Beef and dairy terms will be included as a reference for future reviews on digital technologies that will be conducted by the team.

Study Records

Data management

Database records of the articles recovered will be imported into Covidence (Veritas Health Innovation, Melbourne, Australia) and duplicates will be deleted by the same software. Abstract and full screening will be recorded in Covidence. Data extraction will be documented in Microsoft Excel (Microsoft Corporation, Redmond, WA).

Selection process

The citations will be screened in two independent stages. The first stage of the selection process will consist of titles and abstract screening. Two independent reviewers will carry out this task using Covidence. Conflict will be resolved with a third reviewer. The studies that meet inclusion criteria will pass to the next phase. The concordance among the reviewers will be evaluated by randomly selecting 10% of the citations entering each stage of the process prior to screening all papers. This pilot will enable discussion and solve disagreement before carrying out the full selection process by the two reviewers (28).

First stage

- Does the title/abstract refer to a primary research study published in a peer-reviewed journal, thesis, or a government document after 2013?
- Does the title/abstract refer to a digital technology usable on-farm in crops (26) in Canada?
- Is the title/abstract about review of literature on policy and other social aspects of digital technologies used/to in agriculture?

Exclude:

- Full text not available in English
- Article published prior to 2013.
- Genomic development of crop varieties off-farm
- Intermediate agricultural technologies in the development and validation stage not available for producers yet. (*However, we will make a list of intermediate technologies in this stage)*
- Not based in Canada
- Off-farm used technologies
- Aquaponics
- Fruit and vegetable crops, greenhouse operations
- Not storage digital agricultural technologies or post harvest
- Digital technologies where none of (a, b or c)* are commercially available

The potential answers to the signalling questions shown above are 'yes', 'no' or 'unclear'. By the last, there is insufficient information in the title and abstract to determine whether the study meets the inclusion criteria or not. Articles classified as 'no' by both reviewers will be excluded. Articles with 'unclear' or 'yes' answers by both reviewers will go the next phase. Articles classified differently by the two reviewers will be reviewed by a third reviewer to resolve the conflict; this will be discussed among all three as necessary (29,30).

Second stage
During the second stage of full-text screening, interest will be focused on the methods section. Two independent reviewers will carry out this task using Covidence and a third one will supervise. Studies that meet inclusion criteria will go the next phase. Conflict will be resolved in the same way as described for the previous stage.

For intervention studies:
- Does the title/abstract refer to a primary research study published in a peer-reviewed journal, thesis, or a government document after 2013?
- Does the title/abstract refer to a digital technology usable on-farm in crops (26) in Canada?

For qualitative and uptake studies:
- Does the title/abstract refer to a primary research study published in a peer-reviewed journal, thesis, or a government document after 2013?
- Does the title/abstract refer to a digital technology usable on-farm in crops (26) in Canada?

- Does it report adoption rates, perceptions and barriers associated with the reason or not to adopt the technology as well as social impacts concerning its use?

For policy reviews:

- Does the review describe public policies in Canada concerning agricultural digital technologies used in Canada for the crop sector?

Studies will only be included in case they get a combination of at least 'yes' or 'unclear' answers. All of those which receive a 'no' will be excluded. Studies which receive all 'unclear' answers will be dropped. Conflict will be resolved among the two reviewers and a third if necessary (29,30).

Data extraction

- Type of study (intervention, qualitative/uptake, policy reviews)
- Author, year published, Journal, funding information
- Study design, place of the study, population (crop type), comparator
- Objective of the study, technology used, data analyzed, methodology
- Intended use of the technology, statistical outcome assessed, outcomes

Data synthesis

A narrative review will be done based on the intended use of the technology.

CONCLUSIONS

This scoping review will help map and summarize the evidence concerning which are the agricultural digital technologies being developed in Canada for the crop sector and what is their intended use. Also, it will summarize the evidence from qualitative studies and policy reviews on this subject matter.

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