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Research Article

Optimizing stewardship of the land? Digital agriculture and the ideology of optimization in Canadian policy and media discourse

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Abstract

This research considers the ways in which digital agriculture (DA) technologies (like robotic machinery, big data applications, farm management software platforms and drones) fit into discourses of sustainable agriculture in the Canadian political and media landscape. To undertake this research, I conducted a discourse analysis of relevant government and media materials published between 2016 and 2022. What became evident was an *ideology of optimization,* which works to communicate that environmental sustainability needs to and will be optimized using DA technologies. I then consider how these findings are related to the federal fertilizer emissions reduction target, aiming to reduce emissions arising from fertilizer application in agricultural contexts by 30% below 2020 levels by 2030. I argue that discourse regarding this target deploys the ideology of optimization to keep current systems of fertilizer use in place, solidifying further the industrial and productivist paradigm of agriculture in Canada.

Keywords: Digital agriculture; nitrogen fertilizer; optimization; sustainable agriculture

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Résumé

Cette recherche examine la manière dont les technologies de l'agriculture numérique (comme les machines robotisées, l'utilisation des mégadonnées, les logiciels de gestion agricole et les drones) sont intégrées dans les discours sur l'agriculture durable dans le paysage politique et médiatique canadien. Pour entreprendre cette recherche, j'ai procédé à une analyse du discours des documents gouvernementaux et médiatiques pertinents publiés entre 2016 et 2022. Il en ressort une *idéologie de l'optimisation*, qui vise à faire comprendre que la durabilité environnementale doit être et sera optimisée à l'aide des technologies de l'agriculture numérique. J'examine ensuite la manière dont ces résultats sont liés à l'objectif fédéral de réduction des émissions d'engrais, qui vise à réduire les émissions découlant de l'application d'engrais dans les contextes agricoles de 30 % par rapport aux niveaux de 2020 d'ici à 2030. Je soutiens que le discours concernant cet objectif déploie l'idéologie de l'optimisation pour maintenir les systèmes actuels d'utilisation d'engrais, renforçant davantage le paradigme industriel et productiviste de l'agriculture au Canada.

Introduction

The Canadian agricultural system is facing serious problems; it is both a contributor to climate change and other environmental problems, while simultaneously being heavily impacted by the consequences of these crises (Clapp et al. 2018). Globally, it is estimated that between 20-35 percent of anthropogenic greenhouse gas (GHG) emissions are from the agricultural sector (Clapp et al., 2018). In Canada, the National Inventory Report states that the Canadian agricultural sector currently contributes eight to ten percent of Canada's GHG emissions. Emissions of all three major GHGs (carbon dioxide, methane and nitrous oxide) are emitted through agricultural processes—with enteric fermentation from livestock production being a major contributor, and the release of nitrous oxide from synthetic fertilizer use being another (Environment and Climate Change Canada, 2023). Meanwhile, climate change is wreaking havoc on the agricultural sector across the country. The 2023 growing season was affected by severe drought in Alberta, Saskatchewan and Manitoba (Goodwein & Melgar, 2023), and British Columbia suffered severe droughts in 2021, followed by flooding events that affected hundreds of farms provincewide (Schmunk, 2021). With rising emissions, these impacts will likely continue and become worse (Kornhuber et al., 2023).

Many people believe that the adoption of digital technologies in agriculture may help address the sector's sustainability challenges. Digital agriculture (DA) can mean many things, but it ultimately involves the application of digital technologies—from sensors, drones and robotics to farm management software applications—that support farmer decision making. This paper assesses policy and media texts relating DA and sustainability in Canadian agriculture. Methods consist of a discourse analysis of relevant government and media materials published between 2016 and 2022, which refer to agricultural sustainability: the dataset includes relevant government reports, government media releases, and media articles from national and regional newspapers published in Canada. Discourse analysis of these texts revealed an *ideology of optimization,* which does cultural work along three axes: first, the discourse communicates that environmental sustainability needs to be and will be optimized using DA. Second, the discourse forwards an argument that environmental sustainability will indirectly result via the "optimization" of other farm variables, notably profitability. Finally, the discourse embeds an argument that "optimization" will occur through the quantification and datafication of agricultural environments, a process that necessitates digital technologies. After the results of the textual analysis are presented, the findings are related to the fertilizer emissions reduction target announced by the Canadian federal government in 2020, which aims to reduce emissions arising from fertilizer application. This article demonstrates that discourse about the fertilizer emissions reduction target deploys the ideology of optimization to keep current systems of fertilizer use in place, further solidifying the industrial and productivist paradigm of agriculture in Canada. Furthermore, the article contends that the concept of optimization could be useful to critical food studies scholars, who for years have critiqued this productivist agricultural paradigm for its social and environmental consequences (Buttel, 2006). Lastly, the article concludes that data studies scholars who have critically assessed optimization in relation to digital platforms might find agriculture a useful site of study.

Background: The role of digital technology in Canadian climate and agricultural policy

Canada's federal response to climate change began in a serious way when it signed onto the Paris Agreement in 2016, and committed to achieve "net-zero" emissions by 2050 (Vinco et al., 2023). This response has resulted in many different federal strategies, policies and new pieces of legislation. However, for the most part, the focus of legislation has been on the oil and gas sector, transportation, buildings and electricity (Vinco et al., 2023). At the same time, the federal government has established various programs to encourage more sustainable practices in the agricultural sector. For example, the Canadian Agricultural Partnership has recently evolved into the Sustainable Canadian Agricultural Partnership, which signifies Canada's desire to create more agricultural policy that is focussed not only on the economic growth of the sector but also on environmental sustainability (Agriculture and Agri-Food Canada, 2023). A focus within these recent policies is synthetic fertilizer use. While synthetic fertilizer boosts crop production, a global dependence on these inputs has led to contamination of surrounding bodies of water and the emission of a potent GHG, nitrous oxide (Houser & Stuart, 2020; Smil, 2004). In 2021, Canadian crop production was estimated to have been responsible for 19.4MtCO2eq, and 14.8 MtCO2eq was sourced from the application of synthetic fertilizers in crop agriculture (Environment and Climate Change Canada, 2023). Furthermore, the emissions associated with synthetic fertilizers have increased by 60 percent since 2005, as fertilizer use rose by 71 percent in the last two decades alone (Environment and Climate Change Canada, 2020; Robinson, 2023).

In response to broader climate change issues and fertilizer-related environmental impacts, the Government of Canada released an environmental climate plan called "A Healthy Environment and a Healthy Economy" in 2020 which included a national target to reduce GHG emissions arising from fertilizer application in agricultural contexts by 30 percent below 2020 levels by 2030 (Environment and Climate Change Canada, 2020). The government is adamant that the mandate is and will continue to be voluntary, yet it is clear in media articles about the target that farmers are on the defensive, and they worry about the ways that this target could be regulated and/or legislated such that they are affected negatively; novel fertilizer-related regulations could possibly affect their yields, and hence their profit margins (Anderson, 2022). DA is, in this context, promoted by industry, government, and agricultural extension experts as a mechanism to help farmer's reduce emissions. It is assumed by proponents that these technologies will play an ever-increasing role in farming in the Global North (Minority World) (Weersink et al., 2018), and that digitization will facilitate a purported transformation of the food system in which enough food would be produced to feed a growing population, and, simultaneously, environmental impact would be reduced dramatically (Garnett et al., 2013). DA is argued to enable sustainable practices by allowing for precise management and thus more judicious use of inputs like fertilizers and fuel (Balafoutis et al. 2017; Finger et al. 2019; Hebert, 2022).

To some, the precise DA approach represents a paradigm shift in food production (Weersink et al. 2018). Meanwhile, a growing number of social science researchers are pointing out the social and ethical limitations of DA (see Bronson & Knezevic, 2016; Carolan, 2023; Carolan, 2017; Duncan et al. 2021; Klerkx et al. 2019; Montenegro de Wit & Canfield, 2024). Klerkx et al. (2019) conducted a review of this social science literature and identified the need for research that interrogates the link being made (or assumed) between DA and more ecologically sustainable agricultural systems, such as organic farming, agroecology, regenerative agriculture, and urban agriculture. Rotz et al. (2019) found that the available literature identified tensions between the use of DA technologies and sustainable approaches to land use in agriculture. Bronson (2022) found that in their current state, DA technologies contribute to a number of food system challenges, such as corporate concentration and productivist strategies that deepen environmental problems caused by agriculture (see also: Bronson & Knezevic, 2016). Wolfert et al. (2017) carried out a systematic review in the scholarship of DA and made the prediction, informed by the literature, that the future of DA may go in two separate directions—one in which technical systems are closed and benefit only a few entities in the sector, or open, collaborative systems that could enable farmer and stakeholder autonomy (See also: Bronson & Knezevic, 2016; Rotz et al., 2019). This paper adds to this academic debate by investigating how DA is discussed in relation to environmental sustainability within Canadian public and policy discourse.

Theoretical framing and methods

The primary method for this research is critical discourse analysis. Discourse, according to Jørgensen & Phillips refers to the "particular way of talking about and understanding the world (or an aspect of the world)" (2002, p. 2). This "particular way" shifts depending on the source of the language, and the audience consuming it. Discourse analysis is an attempt to interrogate representations of knowledge that are presented as if they are the objective truth. Discourses are systems of thought and demonstrations of power, expressed through different mediums, but often analyzed through text or speech (Van Dijk, 2013). Discourses are underpinned by ideologies, which are, according to Marx, the process "through which dominant ideas within a given society reflect the interests of a ruling class" (1977, as cited in Stoddart, 2007, p. 191). Ideology represents ways of thinking in which certain forms of social organization are represented as inevitable and rational (Stoddart, 2007). The "critical" piece of critical discourse analysis aims to uncover the ways in which certain types of discourse uphold or resist particular social relationships of power that reproduce dominant ideologies.

Other researchers have focussed on ideologies in the agricultural context and revealed how they can mask the tensions and contradictions that are core to the dominant industrial, capitalist agricultural system. Houser et al. (2020) found that this ideology of industrialized agriculture was being maintained by farmers themselves through belief systems around fertilizer pollution—many farmers in their study reproduced ideological positions of market fundamentalism and techno-optimism, ideas that new technologies can and will offer solutions to environmental problems in agriculture, especially having to do with pollution issues surrounding fertilizer use. The authors see this process to be reproducing an ideology that ultimately limits a more widespread emergence of agroecological practices and transitions to address environmental problems in agriculture. Furthermore, Canfield (2022) discusses the ways in which the ideology of innovation has become pervasive in global food discourse; it emphasizes the role of science, research and technology, and has strategically been deployed in international contexts to suppress calls for a transition to agroecology. This paper follows methodologically from these prior studies but takes up a research agenda put forth by Klerkx et al. (2019) who called for scholars to interrogate the role of DA technologies in transitions towards sustainability. Similarly, by focussing on the Canadian context, this paper complements other scholarly conversations about future imaginings of DA in international discourse (Lajoie-O'Malley et al., 2020), and in Sub-Saharan Africa, specifically (Abdulai, 2022). The dataset for this research project was interrogated through the lens of the research question: How is digital agriculture discussed in relation to environmental sustainability? The research question was left intentionally broad and high-level to capture different conceptualizations of environmental sustainability that might emerge inductively from the dataset itself.

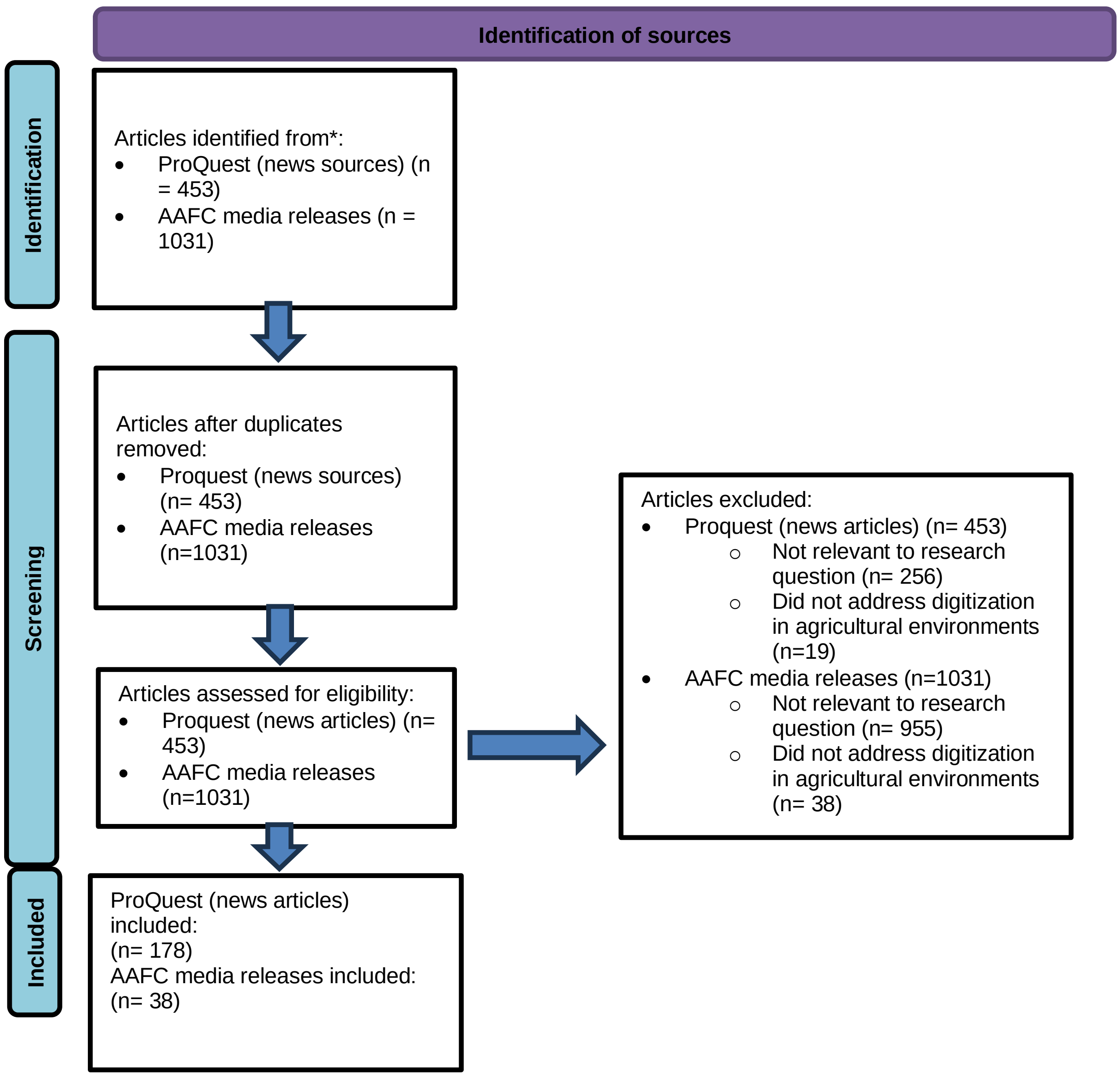
A systematic media analysis of the national and leading regional Canadian newspapers (such as the Globe and Mail, the National Post, the Calgary Herald and the Montreal Gazette) was conducted. Figure 1 shows the sources of all news articles included in this analysis. This was done through a Proquest database called Canadian Major Dailies, which provides current and historical content from more than 35 of Canada's major newspapers. Search terms included were: "digital agriculture", "digital farming", "smart farming", "precision farming", "ag-tech", "big data" and "farming" or "big data" and "agriculture". These terms were searched for in the context of their relationship to: "sustainability", "climate change"/ "climate", "environment", and/or "regenerative agriculture". Articles from 2016-2022 were examined, and 453 media articles were found. Ultimately, 256 were excluded due to irrelevance, and a further 19 were excluded because they did not address digitization in agriculture. Thus 178 articles were included in the analysis. Figure 1 shows the sources of the news articles found. Winnipeg Free Press had the most coverage of these topics during that time period. These articles were mostly written by the same few reporters, who were covering the agriculture technology beat in Manitoba. The time frame was chosen because there has not been a major change in federal governance since Justin Trudeau's election in 2015. Furthermore, the Trudeau government has been more explicit about climate action than any government that has come before it (MacNeil & Paterson, 2017).

Figure 1: News article sources

Newspaper	**Region**	**Number of Articles Analyzed**
Globe and Mail	National	35
National Post	National	18
Toronto Star	Toronto, Ontario	6
Winnipeg Free Press	Winnipeg, Manitoba	49
Regina Leader Post	Regina, Saskatchewan	10
Chronicle Herald	Halifax, Nova Scotia	10
Calgary Herald	Calgary, Alberta	12
Telegraph-Journal	New Brunswick	6
Star Pheonix	Saskatoon, Saskatchewan	9
Times Colonist	Victoria, British Columbia	1
Edmonton Journal	Edmonton, Alberta	5
Vancouver Sun	Vancouver, British Columbia	3
Whig-Standard	Kingston, Ontario	2
Montreal Gazette	Montreal, Quebec	3
Ottawa Citizen	Ottawa, Ontario	3
Sudbury Star	Sudbury, Ontario	1
Windsor Star	Windsor, Ontario	3
The Province	British Columbia	2
TOTAL		**178**

Media releases from Agriculture and Agri-Food Canada (AAFC) were also analyzed. AAFC is the federal department that is most heavily involved with providing funds to both farmers and ag-tech firms through various programs, like the Agricultural Clean Technology Program. These articles were accessed through the AAFC website and all articles that discussed the search terms above were included in the analysis. AAFC released 1031 media releases during the relevant time frame. After screening, 955 articles were excluded due to irrelevance, and a further 38 were excluded as they did not address digitization in agriculture (see Figure 2).

Figure 2: Screening process for news articles and AAFC media releases



Other relevant government documents were gathered as well. These documents included, for example, the 2030 Emissions Reduction Plan, and the National Adaptation Strategy. Documents relating to the Fertilizer Emissions Reduction Target were also gathered. These documents were targeted if they had been mentioned in the media, or mentioned in other relevant documents. Thirty-eight government reports were analyzed in total. Importantly, provinces are also heavily involved in the governance of agriculture.

Provincial policy documents were excluded as their analysis would have been beyond the scope of this particular research project. Research into the ideological positions of the Canadian provinces would be valuable as a *future* site of study—especially as agriculture is such a place-based and context-specific activity in Canada. For this project, choosing federal materials specifically is justified as, together, they effectively demonstrate the ways in which DA is framed on a country-wide scale.

Figure 3: List of Government Documents Analyzed

	Government Document	**Year**	**Publisher**
1	Agri-Environmental Indicator Report Series: Report #4	2016	Agriculture and Agri-Food Canada
2	Agricultural Innovations	2017	Agriculture and Agri-Food Canada
3	The Path to Prosperity: Resetting Canada's Growth Trajectory	2017	Advisory Council on Economic Growth
4	Unlocking Innovation to Drive Scale and Growth	2017	Advisory Council on Economic Growth
5	Investing in a Resilient Canadian Economy	2017	Advisory Council on Economic Growth
6	Learning Nation: Equipping Canada's Workforce with Skills for the Future	2017	Advisory Council on Economic Growth
7	Growing Opportunity through Innovation in Agriculture	2017	Statistics Canada
8	A Portrait of a 21st Century Agricultural Operation	2017	Statistics Canada
9	AgriInnovate Program	2017	Agriculture and Agri-Food Canada
10	Canadian Agriculture: Evolution and Innovation	2017	Statistics Canada
11	Report of Canada's Economic Strategy Tables: Agri-Food	2018	Innovation, Science and Economic Development Canada
12	Federal-Provincial-Territorial Ministers of Agriculture: Progress Report on the Pan-Canadian Framework on Clean Growth and Climate Change	2018	Agriculture and Agri-Food Canada
13	Agriculture Clean Technology (ACT) Program	2018	Agriculture and Agri-Food Canada
14	Living Laboratories: Collaborative Program – Applicant Guide	2018	Agriculture and Agri-Food Canada
15	Clean Growth and Climate Change in Canada: Forestry, Agriculture and Waste	2019	House of Commons
16	Advancements of Technology and Research in the Agriculture and Agri-Food Sector that can Support Canadian Exports	2019	House of Commons
17	Agriculture and Agri-Food Mandate Letter, 2019	2019	Agriculture and Agri-Food
18	Canada's Changing Climate Report	2019	Government of Canada
19	Food Policy for Canada	2019	Agriculture and Agri-Food Canada
20	A Healthy Environment and a Healthy Economy	2020	Environment and Climate Change Canada
21	A Healthy Environment and a Healthy Economy [Annex: Climate-Smart Agriculture]	2020	Environment and Climate Change Canada
22	Agriculture and Agri-Food Mandate Letter, 2021	2021	Agriculture and Agri-Food

23	A Healthy Environment and a Healthy Economy: Update	2021	Environment and Climate Change Canada
24	Budget 2021	2021	Department of Finance
25	The Guelph Statement	2021	Agriculture and Agri-Food Canada
26	Agricultural Climate Solutions: Grant Application Guide	2021	Agriculture and Agri-Food Canada
27	Sustainable Agriculture Strategy: Discussion Document	2022	Agriculture and Agri-Food Canada
28	Agriculture and Agri-Food Canada's Strategic Plan for Science	2022	Agriculture and Agri-Food Canada
29	Canada's Methane Strategy	2022	Environment and Climate Change Canada
30	Canada's National Adaptation Strategy: Building Resilient Communities and a Strong Economy [for comments]	2022	Environment and Climate Change Canada
31	2023 Emissions Reduction Plan	2022	Environment and Climate Change Canada
32	Budget 2022	2022	Department of Finance Canada
33	Discussion Document: Reducing emissions arising from the application of fertilizer in Canada's agriculture sector	2022	Agriculture and Agri-Food Canada
34	Canada's National Pathways document [consultation draft]	2022	Agriculture and Agri-Food Canada
35	Agricultural Clean Technology Program: Research and Innovation Stream	2022	Agriculture and Agri-Food Canada
36	Agricultural Clean Technology Program: Adoption Stream	2022	Agriculture and Agri-Food Canada
37	2021-22 Consumer Attitudes Towards Innovative Agricultural Technologies Survey and Focus Groups: Final Report	2022	Agriculture and Agri-Food Canada
38	2022 Qualitative Research on Consumer and Producer Views Towards Sustainability in Agriculture: Final Report	2022	Agriculture and Agri-Food Canada

Results: Discourses of optimization

Discourse analyses have been conducted by others in this area of research, and my work builds upon theirs (Duncan et al., 2021; Fleming et al. 2018; Karlsson et al., 2018; McCaig et al., 2023). Analysis for this project was conducted using MaxQDA. A first round of inductive open coding was very helpful in understanding the myriad perspectives of the producers of the texts in the dataset (Cope, 2010). Strauss (1987) describes this process as a close scrutinization of the data: "The aim is to produce concepts that seem to fit the data." (p. 28). A common theme that emerged throughout the dataset was that (implicitly or explicitly) DA is an enabler of environmental sustainability. A less common theme arose as well—that DA would *not* enable environmental sustainability (see Figure 4). Subsequently, a round of selective coding was done, which was more systematic in its approach. DA's role as a solution to environmental problems was the focus of this round. Many sub-themes arose during this round of coding, like "food waste" (DA is presented as a solution to high food waste), "fertilizer emissions" (DA is presented as a solution to high fertilizer emissions). An initial inventory of codes is shown in Figure 4. Through this round of coding, it became clear that a common theme among these codes was *optimization.* A third round of coding was conducted, which was again selective, in which the question posed of the data was "How are DA technologies presented as technologies that optimize?" And a follow-up question included "What variables are assumed to be optimized by DA?" Through this analytic process, 'DA is a suite of optimizing technologies' was a common discursive theme that was deployed in both media and government materials that were analyzed. It was evident that this discourse was ideological when the belief systems, norms, assumptions and values central to the discourse were taken into consideration (Van Dijk, 2013). In the 254 documents analyzed, a predominant ideology of optimization emerged. This overarching ideology of optimization communicates three things: One, that **environmental sustainability needs to be optimized** through the uses of emerging technologies like DA. Two, that **environmental sustainability will inevitably benefit** from the optimization of parameters that aren't necessarily directly linked to environmental sustainability, like productivity. Three, that optimization will happen through the **quantification and datafication** of the agricultural environment—a process that necessitates the uptake of DA.

Figure 4: Initial Inventory of Themes

How does DA relate to environmental sustainability? (positive)	DA will enable environmental sustainability (Explicit)	DA will provide farmers the infrastructure [digital platforms] upon which they can sell carbon credits. A carbon credit market would reduce emissions.
		DA will allow for the optimization of farming inputs like pesticides, herbicides and fertilizers.
		DA will help farmers identify risk areas for greenhouse gas emissions.
		DA will allow for the measurement of soil carbon.
		DA will help the agricultural sector deal with climate change impacts.
		DA would help overcome challenges in data collection which are needed to address sustainability problems.
		DA will help to reduce food loss.
		DA will enable transparency, so consumers will know the sustainability practices of the farms they are buying from.
		DA will enable the identification of diseases, pests and nutrients early, allowing for more directed intervention which will benefit the environment.
		DA will increase farm operators' predictive capacity, making them more resilient to climate change.
		DA will enable 4R fertilizer application. This will optimize fertilizer use, reducing runoff into the environment.
	DA will enable environmental sustainability (Implicit)	DA is a clean technology.
		DA is a climate-smart technology.
		DA is a best management practice.

		DA will allow farmers to make informed decisions, which will benefit environmental sustainability.
		DA will enable a 'digital twin' or a real time information about the farming environment. This will enable better decision making that considers the environment.
		DA will enable productivity growth that is environmentally sustainable.
		DA will improve the resiliency of Canada's agri-food sector.
		DA will optimize the supply chain.
		DA will help to produce more with less.
		DA is required for better yield, quality and sustainability outcomes.
How does DA relate to environmental sustainability? (negative)	DA will *not* enable environmental sustainability	DA would help farmers make better, more environmentally friendly decisions, but they are expensive.
		The decisions enabled by DA are not better than a farmer's intuition.
		DA does not always enable the farmer to access actionable information.
		DA would benefit sustainability, but it is not realistic for farmers without broadband.
		Investments being made into DA are being made with productivity, not sustainability, in mind.
		The outcomes of DA are uncertain.

Section 1: Optimizing Stewardship of the Land

Optimization emerged as the dominant theme during the textual analysis. For example, in a 2022 announcement of an investment into the Agricultural Clean Technology Program (a funding program focussed on three areas: green energy, precision agriculture and bioeconomy solutions), then Agriculture and Agri-Food (AAFC) Minister Marie-Claude Bibeau declared the following:

> Recent droughts and flooding across Canada are another stark reminder that Canadian farmers are on the front lines of climate change. This new wave of innovative green projects announced today under our Agricultural Clean Technology Program demonstrates our intention to help farmers optimize the stewardship of the land, while increasing their productivity and profitability. (Agriculture and Agri-Food Canada, 2022c [AAFC media release])

Bibeau's statements that this program will enable farmer's to "optimize stewardship of the land" is crucial in that it effectively demonstrates the ideological belief that there is an optimal way to achieve environmental sustainability in agriculture, and that "clean technology", of which DA is a key element, will help facilitate it.

The federal Emissions Reduction Plan (ERP) (though it focusses much more directly on sectors like oil and gas or transportation) states:

> Across the country, farmers are already demonstrating innovation and ambition in the adoption of sustainable practices and

> technologies…Moving forward, more ambitious action is needed to further reduce emissions in the agriculture sector, move towards net-zero emissions by 2050, and maximize the potential of agriculture soils to sequester carbon. (Environment and Climate Change Canada, 2022, p. 65 [government document])

Optimization means many things in different contexts, but in mathematical and computing contexts, it refers to the capacity "[to obtain] the best results under given circumstances" (Rao, 2009). The statements in the ERP might seem straightforward enough, but the key discourse being put forth here is that technologies, particularly DA (along with other types of innovation) will allow farmers to *minimize* their negative impact on the environment while *maximizing* environmental benefits of their practices (maximization and minimalization being directly related to ideals of optimization).

More specific environmental indicators are also invoked. For example, a DA platform called Ukko Agro is said to "help farmers optimize pesticide, water and fertilizer usage to operate more sustainably." (Bouw, 2020) In a 2020 media release, a digital food processing system called Onipro was said to reduce food waste (another environmental indicator) by using optimized sorting techniques: "A revolutionary internal and external optical sorting system will reduce food waste by optimizing the sorting of problematic onions." (Agriculture and Agri-Food Canada, 2020b [AAFC media release])

A specific environmental indicator is front-and-center when it comes to the optimization discourse: synthetic fertilizer. Often DA is presented as a mechanism to decrease inputs (like fertilizer), and so DA is used discursively as a proxy for environmental sustainability. For example, a representative of Farmer's Edge, a DA platform, was interviewed in a media article explaining how their technology could enable the optimization of fertilizer use:

> The platform collects and compiles data from a variety of sources—satellite imagery, soil testing, data analytics and computer modelling—to produce a "variable-rate prescription" for how farmers should apply fertilizer to their fields, among other things. That includes not only when to apply it, but also where to apply it, how much to use and even which fertilizer to use. The goal is to optimize the return on their fertilizer costs and minimize damage to the environment, said Dan Heaney, vice-president of research and development and agronomy for Farmers Edge. (McNeill, 2016 [news article])

Furthermore, government documents highlight the principles of 4R Nutrient Stewardship (the approach encourages farmers to select the "right type" of fertilizer, applying it at the "right time" of year, at the "right levels" in the "right place"); DA technologies of different types could seemingly help with all four "Rs", yet it is particularly focussed on for the "Right Rate" approach:

> Right rate matches the amount of fertilizer to crop needs. This entails only applying what can be taken up by the crop over the course of the growing season. This recommendation can include precision application technologies (including those that address in-field variability), and the use of soil tests to make nutrient management decisions accounting for existing soil nutrient levels. (Agriculture and Agri-Food Canada, 2022b [AAFC media release])

The 4R approach is another clear example of the ideology of optimization—it asserts the idea that in every agricultural system there is a perfect way to apply these inputs—if only farmers were applying fertilizer perfectly, then the environment would not be damaged irreparably. The data presented in this section demonstrates that DA is often discursively employed as a mechanism to facilitate the optimization of environmental sustainability, which will, ostensibly, solve the deep environmental problems of the current food system.

Section 2: The Inevitability of Environmental Sustainability through Optimization

Frequently, the documents would imply that multiple factors, namely profitability, productivity and environmental sustainability, are being enhanced, improved and maximized simultaneously through the use of DA:

> By using big data, by using state of the art technology, by using "the Internet of Things," what you can do is develop a brand-new way of looking at climate-smart agriculture that is economically feasible and profitable, but also environmentally sound, Thompson said. At the bottom line of it all is a safe, secure, high quality food system. (Stephenson, 2017 [news article])

In another example, a farmer who was piloting a "digitally customized crop-plan package" developed by Nutrien, a multi-national fertilizer production company, explained: "It's about being smarter in the way we plant," he says. "We see agronomy, economic and environmental performance completely aligned" (Zary, 2020 [news article]).

Often, however, the element(s) or variables of the system that are actively being optimized through DA are synonymous with productivity or crop yields. The assumption that the optimization of these variables will in effect lead to improved environmental sustainability outcomes was common throughout the dataset. For example, in a 2016 report from AAFC, a segment on soil testing is illustrative:

> Soil nutrient testing provides valuable information that producers can use to match crop nutrient requirements with nutrient levels in soil and nutrients applied in the form of manure and commercial fertilizers. This can help to maximize productivity and make the most efficient use of resources while reducing the risk of losses to the environment. The more frequently soil tests are conducted, the more opportunities a producer has to fine-tune nutrient applications in order to optimize crop growth. (AAFC, 2016 [government document])

Now, in 2023, many DA companies have popped up in this market, claiming to provide farmers with, for example, real-time plant tissue analysis, providing them with knowledge about plant growth, nutrient deficiencies, etc. without the farmer having to send soil samples to an off-farm lab, eg. Picketa Systems (Picketa Systems, 2023). In the AAFC excerpt above, environmental sustainability is assumed to be a predestined outcome of the process of optimization. Optimizing "crop growth" is the predominant goal, while reduction of environmental risk is framed as a secondary outcome. In this text, it is indicated that DA (among other solutions) will uphold and sustain the environment, but more importantly, these technologies will sustain the status quo production system at the heart of the Canadian agricultural sector. A parallel example was illustrated in the 2022 Federal Budget: "…farmers' resources, such as time and money will be optimized in a digitally enabled farming system." The document goes on to say that digital technologies can help reduce emissions (Department of Finance, 2022 [government document]).

The inevitability of DA and its supposed inherent sustainability factors is a key sub-theme of this discourse. A media article covering companies that were part of a Saskatchewan ag-tech accelerator program interviewed a farmer and asked him about his response to a DA robotics company:

> "What excites me the most is the potential efficiencies long term…the benefits to the environment and sustainability,' [the farmer] said, adding the technology's biggest appeal is its ability to turn reams of raw data into what he calls 'intelligent data' that informs better decisions. 'It's just a matter of time and it will look different, but I do believe we can get there…'" (Rance, 2022 [news article])

This excerpt also speaks to the assumption that DA, through a form of digital calculative reasoning, analyzes a set of varied inputs and reduces them into an "actionable" output that is "better" than prior decision-making strategies, perhaps ones based more on farmer intuition. Furthermore, by saying "it's just a matter of time", the farmer invokes the inevitability of DA as an element of social (and environmental) progress. This perspective was commonplace as early as 2016 as well—a then CEO of a John Deere dealership organization, believed that predictive weather modelling, a common DA technology, would "allow growers to make better business decisions that are going to lead to increased productivity in a more environmentally sustainable manner." (Cash, 2016 [news article]). Through these examples, it is easy to see the ways that DA (and its optimization capabilities) is understood as a necessary tool to make all aspects of farming better, more improved, and closer to some optimal point. In the dataset, optimizing technologies are assumed as capable of facilitating net positive outcomes—in terms of time, profits, crop quality, and productivity indicators. This ideology of optimization is clear throughout the dataset: technological innovation is inevitable and necessary in agriculture; it represents progress. Environmental benefits stemming from the use of these optimizing technologies are a beneficial consequence and a reliable solution to agriculture's environmental problems.

Section 3: Achieving Optimization via Measurement

The process of optimization is enabled through the aggregation, measurement, standardization, and classification of data. According to McKelvey and Neves: "Optimization, firstly, presumes there is data, or should be data, to solve a new problem" (2021, p. 98). In the context of DA, the collection of boundless agricultural data is meant to enable more enhanced resource efficiency and management, as discussed in the previous section. In government documents like the Emissions Reductions Plan, there is a focus on the need to "develop metrics" (Environment and Climate Change Canada, 2022 [government document]), while the Guelph Statement, a government document related to the recently established Sustainable Canadian Agriculture Partnership highlights goals to "enhance data collection" and "performance measures" (Agriculture and Agri-Food Canada, 2021 [government document]). The AAFC's 2022 Strategic Plan for Science, the "application of data" will contribute to multiple facets of sustainability (Agriculture and Agri-

Food Canada, 2022a [government document]). The document stressed the need for agricultural data for the creation of a "sustainable and robust agriculture and agri-food system". In an AAFC media release about an ag-tech start-up from British Columbia, it is highlighted that the measurement of nutrients in the soil is expected to change agricultural practices:

> During a visit to Terramera Inc. in Vancouver, who received $2 million through the ACT Research and Innovation Stream, Minister Bibeau witnessed first-hand the work underway to provide more consistent and precise measurement of soil carbon. Through the adoption of clean technologies, it is expected that this project will help to encourage farmers and ranchers to adopt regenerative management practices and to be incentivized for the carbon they sequester. (Agriculture and Agri-Food Canada, 2022d [AAFC media release])

In this example, the measurement and reporting of soil carbon through a DA technology is delineated as a driver of "regenerative management practices". In many ways, the discourse simplifies the concept of sustainability down into specific variables like, in this case, soil carbon. Another example of this discursive practice is evident from Farmer's Edge; one media article from 2022 highlights the company's plan to continue to develop technology that helps farmers track their sustainability achievements:

> [Wade Barnes, the CEO of Farmer's Edge]… was one of the features speakers at a Tech Manitoba conference where he was extolling the value of the company's ability to track the carbon footprint on the farm, something that will become increasingly important as global food companies try to meet their zero carbon targets in the coming years. (Cash, 2022 [news article])

Implied here is that DA is necessary, and that not only is the measurement of carbon needed in efforts to reduce emissions, but soil carbon measurement is also a sustainability practice in and of itself. So-called "carbon-farming" has become a popular and much-discussed strategy to achieve GHG emissions reductions in agriculture (Sharma et al. 2021). Not only is it exemplary of strategies to perform environmental accountability, but it is also a mechanism through which the private sector is indicating that they do not need top-down interventions from the government in order to meet sustainability goals and avert the worst impacts of the climate crisis (Ghosh & Wolf, 2021).

Media discourse, however, can also highlight farmer skepticism with the idea that quantified agricultural systems are inherently better or more profitable than operations built on decisions informed by farmer intuition:

> The moneyball technique worked for baseball, but if I were to pit the human against the numbers, I wouldn't be able to pick a winner without considering the fact that my family's farm, which has been a successful operation since the late 1800s, has stayed alive and profitable because of the decisions people have made." (Dyck, 2017 [news article])

In this example, this farmer shows skepticism about the application of the "moneyball" technique, referring to the 2003 Michael Lewis book *Moneyball: The Art of Winning an Unfair Game* about the use of statistical techniques like sabermetrics to optimize performance of under-funded American baseball teams (Lewis, 2003). Notably, this farmer doesn't mention sustainability. Sustainability, however, is being deployed as a justification for endless data collection. The desire for datafication, quantification and assessment of sustainability measures on the farm is also driving platformization in this sector. Platformization, according to Poell et al., is understood as the "penetration of digital platforms" economic, infrastructural, and governmental extensions in different economic sectors and spheres of life" (2019, p. 5-6; see also: Srnicek, 2017). McKelvey & Neves (2021) also contend that the turn towards "platforms-as-infrastructure" was a key point in the history of optimization, as they scale up and speed up the process [of optimization], enabling its proliferation into more facets of life. The following excerpt describes a digital platform being supported by the federal government:

> With this support, the CFA will create a single window for data on the sustainability of the Canadian agri-food supply chain. This will provide a forum where producers and processors can share information and connect with new networks interested in sustainability. This initiative will also serve as a hub to benchmark and track the sustainability of the Canadian agri-food industry compared to international standards. (Agriculture and Agri-Food Canada, 2020a [AAFC media release])

In such a way, the platform provides the infrastructure for data aggregation and the proliferation of quantifiable standards, as it works to demonstrate the achievement of certain sustainability "benchmarks". This is a key element of the process of optimization, as farmers can continually improve their practices in the attempt to achieve higher "levels of sustainability". This section has illustrated the ways that quantification of variables in the agricultural system is a key operation of the "optimization of sustainability" in agriculture. Quantification simplifies the complex realities of agricultural ecosystems into sustainability indicators like soil carbon. The analysis also revealed that assumptions are made with regard to the capabilities of DA (and the data it generates) to enable more optimal decision making.

Discussion

The impact of the ideology of optimization

This research has considered how DA is related to environmental sustainability in public and policy discourse in Canada. Through the research process, it became clear that DA is framed as pivotal to the optimization of agricultural practices. The sort of optimization processes that are positioned as being delivered by DA fit with the definition of optimization put forth by McKelvey and Neves (2021) as "a form of calculative decision-making embedded in legitimating institutions and media that seek to actualize optimal social and technical practices in real time" (p. 97). Though this "calculative decision-making" is related to concepts of rationalization (Weber, 1968) scientific management (Taylor, 1911), efficiency, industrial productivism (Montenegro de Wit & Canfield, 2024) or computationalism (Golumbia, 2009), optimization as a unique concept arose from disciplines such as engineering, game theory and computing (Halpern & Mitchell, 2023). The concept, in its disciplines of origin, referred to an "internally referential and relative" measure of performance: "for *this* system, given *these* goals and *these* constraints, the optimal solution is X"

(2023, p. 16 [emphasis in original]). This quest for optimality, however, permeated other disciplines, like economics, since the 1950's and especially since the onset of neoliberalism. This quest is premised on the foundational belief "that everything—every kind of relationship among humans, their technologies, and the environments in which they live—can and should be algorithmically managed" (p. 17). While productivism and logics of efficiency have shaped the agricultural system for a century, optimization is a novel and acutely mathematical approach, made possible by data collection and analytics enabled by digital tools, infrastructures and platforms.

Moreover, throughout the analysis of the discourse about DA technologies and environmental sustainability, a distinct *ideology of optimization* became clear; this ideology asserts that through processes of optimization which centrally depend on the use of DA, an ideal agricultural system will emerge—one that is described as maximizing profitability, productivity, as well as environmental sustainability. A close look at the texts which further this ideology of optimization, however, reveals that this discourse sustains the status quo agricultural system, and with it, the normative assumptions built into what is the "best" or "optimal" way to grow food and organize the whole agri-food sector. Below, it is argued that this ideology of optimization works to keep intact an environmentally destructive food system, along with the inequitable power concentration among a handful of actors that are central to this current system. The ideology of optimization within political and public texts on DA achieves this maintenance of the hegemonic food system in several key ways: it keeps "improvement" towards sustainability incremental, it draws attention away from more radical and transformative policies and pathways, and it rhetorically places solutions to environmental problems in the future. Below, the section demonstrates how political texts related to the fertilizer emissions reduction target in Canada provide an illustration of the deployment of the ideology of optimization via DA by positioning DA as the technical solution to political and environmental problems simultaneously. Finally, the last section explains how the concept of optimization could be useful to critical food studies scholars; and at the same time, how scholars considering the sociological impacts of optimization might benefit from a consideration of agriculture as a site of study.

The Impact of the Ideology of Optimization on the Food System

Optimization embodies incrementality in many contexts; for example, the hill-climbing technique is a mathematical procedure in which an algorithm iteratively improves its solution to a problem until some specific condition is maximized (Norman and Verganti, 2014). In the context of agriculture, the ideology of optimization promises that the food system can systematically and incrementally be improved (using digital technologies) to the point at which environmental impact would be negligible or even positive. Goldstein illustrates how the ideology of optimization operates among "cleantech" entrepreneurs who subscribe to a kind of "planetary improvement imaginary", wherein the technologies they innovate are able to achieve incremental gains, which are then framed as the initial steps towards "major environmental transformation…that will ultimately help save the planet" (p. 2, 2018). He goes on to argue that these innovations result in technical solutions that do little to address environmental problems (p. 10). Fairbairn et al. (2022) have found these narratives to be common in the entrepreneurial world of DA. Likewise, Buttel discusses the ways that agricultural research and development prioritizes "patching up" problems experienced by industrial farmers, while keeping intact the underlying conventional production system (2006, p. 218). Incremental change in agriculture is likely an inadequate solution for the uncertainties presented by catastrophic global climate change and biodiversity loss. Furthermore, the ideology of optimization and its techno-solutionist undertones re-direct attention away from other, more radical policies or changes that could be enacted in the Canadian food system, like for example, a shift towards a less export-oriented agricultural sector (Kanter et al. 2019).

The ideology of optimization also contributes to a problematic futuring of sustainability. As McKelvey and Neves contend: "optimization is never complete" (p. 107). If optimization is never complete—but optimization is a precondition for future sustainability—sustainability will never be achieved. The agricultural system may never be fully quantified and represented through data points, as such datafication becomes a never-ending process continuously in search of an ever more precise optimum (Halpern & Mitchell, 2023). The increasing unpredictability of a warming climate contributes to this phenomenon, as the mapping of agricultural variables will only become more complex in the future. Not only then does the ideology of optimization imply the continuous adoption of increasingly expensive and invasive DA technologies, but it always places the arrival at the optimum at some vague future point in time. Benessia and Funtowicz invoke the idea that we remain *waiting for sustainability* to be achieved in the future instead of making radical and necessary changes now (see also: Booth, 2023). They discuss the "need to shift from predicting and promising what to do (in the future) to a political resolution of how we want to live together (in the present)" (2015, p. 329).

Furthermore, as the food system faces layered crises, quantification (a key operation of optimization) of current conditions creates a sense of techno-optimism and security, re-enforcing the notion that increased data collection will lead to solutions to the agricultural sector's most catastrophic and urgent problems. Relevant here is Visser et al.'s (2021) work that complicates the narrative that the data generated by DA technologies is more precise than analogue data and farmer observation (due to lack of broadband coverage, weak GPS reception and sensor errors). Moreover, Krzywoszynska discusses the "farming by numbers" approach: "a biopolitical regime in which farmers' and advisors' subjectivity is that of calculating managers situated in calculable environments" (2024, p. 1). Scholars who consider the social consequences of the preoccupation with quantification consider the harms it can cause. Porter (1995), for example, elucidates the critique that the practice of quantification and standardization reinforces technocratic governance and devalues alternate forms of knowledge. The turn towards digital quantification in agriculture can leave out, for example, Indigenous ways of knowing that are crucial in sustainable and equitable agricultural systems (Laforge et al., 2021) Furthermore, the digital platforms that enable this scale of quantification have sociological consequences in and of themselves (see: Goldstein & Nost [2022] for their exploration of environmental data infrastructures), and it remains to be seen how the process of platformization shifts the politics and practices of agriculture (see also: Reisman et al., 2024).

An Illustration of the Ideology of Optimization: The Canadian Fertilizer Emissions Reduction Target

Governments worldwide have begun recognizing the danger of high fertilizer-related emissions, and policies, mandates and targets have become a common mechanism for decreasing the negative environmental consequences of high fertilizer use. In the Netherlands, the *stikstofcrisis,* or nitrogen crisis, has "shaken Dutch politics to its foundations" (Tullis, 2023), as the government is planning for the forcible closure of high-polluting farms. Farmer-led protests have become common across Europe in response to environmental regulations of agriculture (Mathiesen, 2023). In Canada, far-right protesters have signalled their solidarity with Dutch farmer-protestors, waving Dutch flags during the Ottawa Freedom convoy protests of 2022 to signal their displeasure with government overreach in Canada and abroad (Montpetit, 2022). In fact, the Canadian government may be keeping the emissions target voluntary to avoid more significant unrest. What the ideology of optimization does in this case is allow the government to demonstrate and perform their desire to reduce fertilizer emissions, seemingly stay within planetary boundaries (Richardson et al. 2023) and give farmers the resources, approaches, and technologies to do so. However, since this ideological paradigm continues to uphold status quo industrial agricultural practices, it will be difficult to meet Canada's 2030 fertilizer emissions reduction target without more drastic policy interventions (Vinco et al. 2023).

This section demonstrates how the fertilizer emissions reduction target deploys the ideology of optimization to keep current systems of fertilizer use in place, solidifying further the industrial and productivist paradigm of agriculture in Canada and the industry actors who are served by this paradigm. Many DA technologies have ostensibly been designed and are being promoted by industry and government in the name of, among other things, fertilizer use optimization. One tool that was mentioned numerous times in the dataset is a Canadian company called Farmer's Edge (Farmers Edge, n.d.). DA platforms like Farmer's Edge are critical in the application of the 4R approach to optimize fertilizer use. Again, this approach embodies the incrementality inherent in optimization techniques. Across the dataset analyzed above, the promise was present that evermore precise application will result in the achievement of the fertilizer target. It is important to reiterate here that scholars have found that these technological approaches have not yet proven themselves effective in the loss of synthetic fertilizer into surrounding environments (Blesh & Drinkwater, 2014). However, the ideology of optimization works to lock in the use of DA as the ultimate possibility for salvation. It presents the idea that the deeply rooted problem of high synthetic fertilizer pollution will be solved through expanded capabilities of datafication and quantification. Furthermore, it places the arrival at the target in the future (2030, to be exact), further reinforcing current processes of optimization to reach it.

To achieve fertilizer targets by 2030, there are other possible policy interventions that could be considered. Vinco et al. in their research on farmers' reactions to the 2030 fertilizer target found that monetary incentives could drive fertilizer use reduction in impactful ways (2023). Furthermore, a significant amount of nitrogen fertilizer losses is associated with crop production for livestock feed (Chatzimpiros & Barles, 2013), and so campaigns to reduce meat consumption may have a consequential impact in terms of emissions reductions. Kanter et al. (2019) discuss more policy interventions that could directly and indirectly improve nitrogen management: these policies include everything from more restrictive effluent standards for wastewater management to reduce water pollution to packaging regulation to improve food preservation. Furthermore, organizations from the National Farmers Union to the United Nations argue that policies that support and fund small-scale agroecology and low-input production systems should be considered as well (Qualman & National Farmers Union, 2022; see also Frison & International Panel of Experts on Sustainable Food Systems, 2016). The NFU, in response to the fertilizer crisis, states:

> Rather than telling ourselves and each other that we have a plan, that we are moving toward sustainability, or that efficiency and technology and best-management practices will solve this, we must instead take up our roles as responsible, engaged democratic citizens and shoulder the very real worry that this is in no way solved. (pg. 69)

Their response puts forth the idea that more transformational change might be possible outside the realm of techno-solutionism and optimization (Qualman & National Farmers Union, 2022).

At the Nexus of Optimization and Agriculture

Finally, this article contends that Critical Food Studies scholars and other social scientists critiquing DA can use optimization as a theoretical tool. The scholarly discussion of optimization in agriculture does have a precedent. Fitzgerald (2003) documents the transformation of American agriculture into the industrial project it is today in her book *Every Farm a Factory*, wherein she explains how the logic of efficiency drove the transformation that took place over the first part of the 20th century. She demonstrates the United States Department of Agriculture's role in quantifying agricultural life and production patterns in order to document U.S. farmers' capabilities to be "'efficient", productive, predictable, marketable, and reliable." (p. 34). Blanchette, too, in his book *Porkopolis* (2020), discusses the drive for efficiency in animal agriculture. The industry prides itself on using every part of the pig, and that the total use of the animal is a masterclass in efficiency (Blanchette, 2020). DA is considered by many scholars (Bronson, 2022; Klerkx et al. 2019; Rose et al., 2023; Duncan et al., 2021; Miles, 2019; Montenegro de Wit & Canfield, 2024), yet its role as an *optimizer* of these environments could be more thoroughly explored.

McKelvey and Neves (2021) critique the ways "our bodies, tools, and institutions are now understood as endlessly optimizable" (p. 95). This article has presented ways in which our agricultural environments, too, are understood in this way by powerful federal institutions in Canada. Optimization studies, a still-emerging scholarship, should take agriculture seriously as a site of study. Critique of the concept of optimization in the context of digital technologies is still just emerging, with work done by Halpern & Mitchell (2023), and Halpern (2021). Powell (2021) explores how the ideal of optimization is built into the design of the "smart city", and also, importantly, pervades the citizen efforts to resist these developments. McKelvey and Neves (2021) have introduced a critical perspective on the concept of optimization, and they consider the ways in which this logic is foundational to much of the technological infrastructure that undergirds society today. They engage with the ways that optimization has arranged society and has "deep historical roots in the management of bodies, capital and empire." They invoke Rosenthal's work (2018) on the capitalist organization of slavery in the United States, where plantation owners determined the optimum amounts of productivity that could be gleaned from each slave and pushed them to meet that maximum. McKelvey and Neves (2021) consider the ways that optimization techniques are rooted in white supremacy and colonialism, ideologies that have driven the expansion of industrial agriculture in Canada (Rotz, 2017). In much the same way Critical Data Studies scholars should consider DA seriously (an argument that has been put forth by Bronson (2022) and others), those considering the societal impacts of optimization should consider the ways it's being operationalized in agricultural environments. McKelvey and Neves (2021) ask "optimal for whom, when and where?" to trouble the idea that optimization results in perfect outcomes for everyone—these questions are particularly important in an agricultural system that has already been captured by powerful agribusinesses and ag-tech corporations (Bronson, 2022).

Conclusion

This paper has uncovered an *ideology of optimization* in political and public discourse on DA as it relates to environmentally sustainable agriculture. This ideology positions DA as the *best* method of agriculture in the face of the climate crisis, global food insecurity, and the biodiversity crisis. The ideology of optimization frames deeply rooted social and political problems as technical problems to be solved by the increased adoption of technologies that enable the quantification, datafication and standardization of agricultural environments. Food studies scholars could use the concept of optimization to study power in the food system as it intersects with environment and technology. At the same time, critical data studies scholars who think with the concept of optimization might do well to look beyond urban or online digital contexts to consider the ways that optimization might be used to study rural and agricultural environments. In the context of a catastrophically warming world, the ideology of optimization locks in an arguably narrow and problematic framing of our socio-environmental problems and limits our possible solutions. This ideology is doing a disservice to the imagination of radical new directions—ones that are capable of transformative change.

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