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The Political Impact Of Digital Agricultural Technologies

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ABSTRACT

From farm to fork, digital technologies are being created and embraced throughout the agro-food system. Yet, political considerations brought about by these technological advancements are not given much thought in decision-making settings. This paper examines new technologies and big data systems in agriculture and evaluates some of the major problems that are emerging in the industry by drawing on critical social sciences. After providing an overview and introduction to the so-called "digital revolution," we quickly discuss how political economy might be used to comprehend the main issues facing the regulation of agricultural technologies and data systems. Data ownership and control, technology development and production, and data security are some of these issues. The degree to which the political and economic environment can be changed to promote greater fairness in agriculture is then examined using examples and literature, while also considering the structural obstacles and constraints. In doing so, we highlight that although there are notable systemic conflicts between agroecological practices and digital ag-tech development, we do not view them as mutually exclusive in and of themselves. The goal of this essay is to give decision-makers, practitioners, and academics from a variety of fields a timely evaluation of agro-food digitalization that takes political and economic aspects into account. By doing this, this essay adds to the policy and decision-making debates, which, in our opinion, are still mostly technocentric and give scant consideration to the ways in which digital technologies might specifically benefit agroecological systems

KEYWORDS: Digitalisation, Digital technologies, Agricultural policy.

1. INTRODUCTION

It is anticipated that environmental issues like water scarcity and climate change will make food production more challenging and costly in the future. One of the most important issues of this century, according to farmers, food experts, and policymakers, will be producing enough nutritious food in a sustainable manner (De Schutter 2012; Marsden 2012; Fraser et al. 2016). "Digital agriculture," which is broadly described as the use of big data and precision technology systems in agriculture, is one suggested strategy for tackling this issue. One some claim that agriculture may produce more food on less land and with fewer inputs by implementing digital agriculture through the introduction of a suite of automated, data-intensive "precision" technologies.

In part, the digital agricultural revolution is growing through a combination of technologies that make use of both cloud computing and the Internet of Things (IoT) while relying on the huge quantity of farm data that modern agricultural operations are now creating. For instance, in 2014, an average of 1ç0,000 data points were produced per farm, per day, and by 2050, scientists have anticipated that each farm will produce roughly 4.1 million data points every day (Meola 2016). It is anticipated that farms in the global south will soon be using data-rich technologies, even though these are global averages and the great bulk of the data would be created by farms in the industrialized world (World Economic Forum 2018).

In order to help farmers tailor their practices, emerging technologies like yield monitors and maps, global positioning systems (GPS), remote sensing, variable rate application (VRA), and robotic milking machines each collect their own set of biophysical and production data on the farm (Wolfert et al. 2017). Additionally, farms of all sizes and production methods can now use farm management and decision support software, as well as digital and cloud-based record keeping. Many farmers claim that these technologies enhance their quality of life and save them time and money.

Although there is already a growing body of research examining the moral and societal implications of disruptive innovation in big data across various industries, little research has been done on how new technologies can impact agriculture. Social scientists, for instance, have investigated the ethical issues surrounding big data (Zwitter 2014; Illiadis and Russo 2016), the effects of surveillance through big data (Lyon 2014), and the usage of big data through social media (Schroeder 2014; Brooker, Barnett, and Cribbin 2016; Felt 2016). However, there is still a dearth of research on the use of big data in the food system, and what little research there is has usually concentrated on the scientific and/or economic aspects of big data.

To a lesser extent, there have been emerging discussions concerning how digitalisation will exacerbate power inequities in the food system (Bronson and Knezevic 2016; Carolan 2016a, 2016b, 2018; Chi et al. 2017; Mooney 2018). Currently though, no comprehensive review of the political economy of ag- ricultural digitalisation has been written. In fact, much of the critical literature declares that these technologies are of little help to agriculture, and that, instead, we need to look to agroecological solutions to reform the food system. While we firmly embrace the principles, principals, and practices of agroecology and are concerned about the tendency toward corporate concentration that digitization aids, we – perhaps optimistically – think that agroecology does not need to function outside of digitalisation per se.

Nevertheless, debates over the development and adoption of ag-tech remain overwhelmingly technocentric, stifling chances for digital tools to assist small-scale, agroecological methods. In light of this, this review paper examines if, how much, and under what circumstances big data technology could benefit small-scale and agroecological farmers in addition to large-scale farmers. The authors' wish to investigate the major power dynamics influencing this developing discipline served as the impetus for this article. By doing this, we contend that although there are undoubtedly serious conflicts between agroecological and digital ag-tech methods, they are not inherently antagonistic.

This essay examines new big data and technology systems in farming through the prism of political economics. Making connections between the evolution of various technologies, systems, and components and how evolution reflects their application allows us to integrate political economy. This allows us to investigate which actors are becoming (dis)empowered through the adoption of these technologies (Friedmann 1çç3; Fine, Goodman, and Redclift 1çç4; Clapp, Newell, and Brent 2017). In other words, the aim of this article is to determine who is currently benefiting and who is losing from the development and use of digital agricultural technologies. Considering this political environment, we also examine how much ag-tech can support agroecological efforts.

We first define this political economy lens and describe the trends of digitalization in agriculture that have been observed; then, we go over the political and economic aspects of the three primary issues that are emerging in digital agriculture; and finally, we consider how much more equitable development of digital agricultural technologies is possible given the political and economic circumstances that were evaluated in section two. Data ownership and control, technology development and production, and data (cyber) security are the three primary areas of concern for the field. By doing this, we place conversations about "the digital agricultural revolution" within a broader framework that recognizes the politics of data development (Kitchin 2014; Bronson and Knezevic 2016).

Our analysis of the political economy of big data, agricultural technology, and smart farming offers a distinctive and much-needed contribution to current conversations connecting food and big data studies, as these topics have not received enough attention in academia and decision-making up to this point.

2. REVIEW METHODOLOGY

The findings of an interdisciplinary scholars' workshop and a thorough analysis of the academic literature in big data and agro-food served as the foundation for this review paper. Scholars from a variety of fields, including history, computer science, geography, community and criminal justice, and food studies, participated in the workshop. In order to investigate the gaps in existing analyses, the study team first held a workshop. Next, we used the following agri-culture-related keywords to construct a bibliography of scientific papers: big data, digitalization, precision farming, cybersecurity, technology, and smart farming. Between 2010 and 2018, the great majority of the literature was released. White papers and a few media stories were also included because the review was preliminary.

The research team's senior academics then contributed supplementary readings and offered summaries according to their fields of expertise. Following this preliminary assessment stage, we categorized the readings into three main areas: precision agriculture, data governance, and agriculture 4.0. While the other, more specialized domains separated the literature into addressing the difficulties of data itself or precision agriculture, which refers to the technologies used to acquire data, the field of agriculture 4.0 contributed to the broad definition of digital agriculture. topics that cut across these three domains were chosen after careful

consideration of the main topics that emerged from the workshop and the readings.

The three primary areas of concern outlined in the article—(1) data ownership and control, (2) technology production and data development, and (3) data (cyber) security—were then shared with the team for review and revision. It was discovered during this process that there was a significant knowledge gap in the subject on the political and economic aspects.

DIGITAL AGRICULTURE: WHAT IS IT?

The collection of digital technologies that make up the field of digital agriculture must be briefly described before explaining the foundation for this review. In order to enable farmers to be more accurate in their input application and more informed about agroecological conditions, sensors that gather on-farm data in almost real-time should ideally be integrated with "intelligent" farm equipment, such as smart tractors and automatic milkers that use complex algorithms (Wolfert et al. 2017).

To reduce pollution from over-fertilizer application and crop loss from under-fertilizer application, the "smart tractor" could actually be a networked "swarm" of autonomous mini-tractors that use GPS and sensor technology to determine their location in the field. They then "learn" to plant the best seed for that specific agroecological context and provide it with the most efficient amount of fertilizer (Gebbers and Adamchuk 2010). Similarly, many farms in North America and Europe are starting to use automatic milking facilities (Hansen 2015; Schrijver 2016; Shortall et al. 2016).

This is especially true in Canada, where supply management helps dairy farmers better handle increases in capital expenditures by ensuring they receive a fair price for their product and overall price stability (Hansen 2015; Schewe and Stuart 2015). In general, automatic milkers keep an eye on dairy cows' health and welfare almost constantly. In addition to helping maintain production and herd health while lowering inputs like feed and antibiotics, they proactively detect illnesses and diseases like mastitis (Eastwood et al. 2012). According to a number of academics, the outcome has been better cow health and superior outputs with a lower environmental impact (Eastwood et al. 2012; Shortall et al. 2016).

The use of these precision technologies has grown in other industries as well. For example, in the Netherlands, "65 percent of the nation's arable farmland, up from 15 percent in 2007," was managed using precision techniques in 2015. (Carolan, 2017). Big data is being utilized more and more to track the health of animals, aid in the early identification of animal illnesses, and avoid or lessen negative health effects. At the herd level, sensors and other technologies (such as sound analyzers, image-detection techniques, sweat and salivary sensing, microfluidics, and serodiagnosis) are being used to track risk factors that may reveal abnormal environmental conditions, physiological parameters, and animal behaviors that may result in early disease detection or prevention.

For example, sound analysis is being used to identify respiratory disease in pigs in Europe (Ferrari et al. 2008), detect stress in laying hens in South Korea (Lee et al. 2015), and use biosensors for the early detection of respiratory disease in pigs in the UK (Cowton et al. 2018) and in calves in Japan (Nogami et al. 2014). Big data is also being used at the level of veterinary epidemiology to identify high-risk populations in order to efficiently target surveillance and monitoring (Van der Waal et al. 2017). Animal traceability programs, such the EU's Trade Control and Expert System and the UK's Cattle Tracing System, are now required in a number of countries to track the movements of agricultural animals. (Green *et al.* 2018; Bajardi *et al.* 2012). For example, epidemiological modeling using agent-based models of Foot and Mouth Disease transmission in Australia (Bradhurst et al. 2015) and network analysis of livestock movements in France (Lal Dutta et al. 2014), these systems generate large amounts of data that are increasingly being analyzed and modelled to provide early warning and rapid response in the event of an outbreak. Similar moves are being considered in Ireland (Barrett 2017). In Switzerland, genetic and production data are regularly linked to identity and movement databases to identify clusters of on-farm deaths and stillbirths that may indicate the emergence or re-emergence of disease (Struchen et al. 2015).

Of course, businesses, legislators, and investors are all interested in these capital-intensive technologies because they have the potential to be very profitable. For example, in 2017, a significant study on raising middle-class earnings in Canada was released by the Finance Minister's "Advisory Council for Economic Growth." Investing in innovation in the agro-food sector was one of their main recommendations. Similarly, data and artificial intelligence are two of the four challenge areas in the UK Government's £4.7 billion "Industrial Strategy Challenge Fund," with particular initiatives concentrating on precision farming. Additionally, since 2012, venture market investment in agricultural innovations has grown by 80% yearly (Sparapani 2017). In the EU and the US, comparable investments are being made. According to predictions, the global market for precision agriculture technologies is expected to reach over $10 billion by 2025 (PR Newswire 2017).

Although businesses are actively pushing new technologies, it is frequently unclear how they will assist farmers. Farmers are frequently skeptical of the advantages and reluctant to spend money on a costly set of dubious technologies. The affordability of these technologies has become a serious concern because farmers in almost all agro-food industries have little control over the prices they receive for their products (Schewe and Stuart 2015; Rotz 2017). Regarding the exclusion issue, the widening divide between the technological "haves" and "have nots" might further deepen the economic polarization between small and large farmers that has already caused a sharp drop in medium-sized farms (Kirschenmann et al. 2004).

Meanwhile, even for those who have managed to adopt such technologies, significant barriers remain around data access, management, and analysis.

3. DIGITAL AGRICULTURE: HISTORIC & POLITICAL DIMENSIONS

Since political economy assesses how economics affects social and political systems, it has been a popular conceptual idea to explain developments in agriculture. The shift from "local farming practices to concentrated corporate-capitalist agricultural production" has already been studied using political economy (Friedland et al. 1çç1, p. 3). We can start dissecting the politics and power structures underlying the adoption of digital agriculture technologies by using this perspective. The difficulties in comprehending the power dynamics among farmers, agribusinesses, the government, and non-agricultural institutions are attempted to be addressed by political economic theory (Friedland et al. 1çç1, p. 26).

This type of analysis offers a chance to consider the driving forces behind the various players who have shaped digital agriculture and, in turn, how scholars and decision-makers could move forward. We can better understand the trajectory of digital agriculture and its impact on power relations among a wide range of actors across the agro-food system by examining some of the most urgent—and perhaps most political—issues influencing farmers' adoption of digital agricultural technologies, such as ownership, technology development, and data/cyber security.

In some ways, the biggest shift to the food system since the Green Revolution of the 1950s and 1960s is the digitalization of farming (Friedmann 1çç3; Moseley 2017). On-farm costs have increased due to the expansion of corporate influence in agriculture, as is well known (Qualman 2001; Clapp and Fuchs 200ç). Many farmers in North America (Basok 2002; Smithers et al. 2005; Skogstad 2007) and Europe (Flaten 2017; Neuenfeldt et al. 2018) have been forced to increase production or leave the sector due to the fluctuating and, on average, stagnating commodity pricing.

According to Statistics Canada (2016) and USDA (2016), the average farm size in North America increased by 65% between 1Q40 and 2016, while the total number of farms decreased by 66% during the same time period. Similar patterns were seen in Europe (Eastwood et al. 2010; van der Ploeg et al. 2015). A key issue going forward is how to guarantee that the next generation of farmers can engage in farming in ways that are both economically and environmentally viable, given that the average farmer in North America is now 57 years old, and in Europe, it is roughly 55 (European Commission 2015). A similar worry has emerged for rural communities in general as farm sizes continue to increase. That is: fewer, larger farms have led, in many cases, to a hollowing out of rural com- munities as both rural populations and the tax base needed to support services in rural communities declines (Bock 2016).

In light of this, we inquire as to whether digital agricultural technologies are an extension of past patterns. The most evident trend is that these technologies will increase market integration and corporate concentration, which will worsen the debt and income problems facing farmers and further restrict small, peasant, and agro-ecological farmers from engaging in the production of agro-food. Political economy is crucial for comprehending the continuous process of "elite capture," in which powerful actors more readily seize the advantages of new technologies, since it serves as a lens through which to view the relationship between power and technology (Hornborg 2001).

Although market integration, exclusion, concentration, and elite capture are not new phenomena, it is important to take into account how these dynamics may be affected across many agro-food sectors by the economic features of emerging digital technologies. For example, it is particularly risky for farmers to adopt new technology, especially in economically sustainable ways, when crop prices are low and unsteady and the technologies are costly (e.g., $500,000-1 million for a precision tractor). The Canadian dairy industry, on the other hand, is "supply managed," a system that establishes production quotas and minimum price guarantees in order to help stabilize prices for farmers.

In an extremely volatile industry, this gives farmers a more steady and predictable income. Therefore, farmers are better equipped to control their on-farm expenses in accordance with their yearly farm-gate revenues, even though technology (such automatic milking systems) are still capital intensive in the dairy industry. Additionally, Canadian farmers may maintain smaller herd sizes than those in the USA because to supply management, which makes robot adoption more financially feasible (Rotz et al. 2003). For example,

the average herd size in the USA is 223 cows, whereas the average herd size in Ontario is about 70 cows, which is about what a robot can manage (Statistics Canada 2016; USDA 2016).

Herd sizes vary significantly across Europe (from 15 in Poland and Austria to 160 in the Czech Republic), but generally, the uptake of robotic milk- ers on European dairy farms developed much earlier than in the USA and Canada.

However, there are other political and economic factors that complicate the adoption of digital technologies, even though farmers may be encouraged to embrace new technologies on the grounds that they will increase their profits (in addition to the labor-saving advantages of digital agriculture). Concerns about cost are important, but so is farm debt. While overall profitability is declining, farm debt is still rising in North America and Europe (Gloy and Widmar 2014; Holtslander 2015; van der Ploeg et al. 2015). Additionally, a major obstacle to the adoption of new technologies is perceived and actual applicability, which together are making disparities for smaller-scale farmers worse. For instance, farmers have de- scribed first-hand how asset constraints produce inequities in accessing available infrastructure, equipment, resources, and software, which has impacted their ability to participate in digital agriculture altogether (Rotz 2017). In the following section we explore these issues in more detail, with a focus on three key concerns; data ownership and control, the top-down nature of agricultural technology production, and data security.

4. KEY ISSUES IN DIGITAL AGRICULTURE

Global agriculture has been significantly impacted by the political and economic pressures of industrialization, as demonstrated by a number of food researchers (Lang 2003; Clapp and Fuchs 200ç). For example, the Big Six—Bayer, Monsanto, Dow, Dupont, ChemChina, and Syngenta—have approximately 75 percent of the worldwide agricultural input market at the moment. With the recent completion of the Bayer-Monsanto merger, these companies will unite to become the Big Three (Fraser et al. 2016; Clapp 2017). Large-scale commodity production still dominates food and farming systems, despite the growth of the food sovereignty movement in opposition to these trends (Desmarais and Wittman 2014).

Notably, the growth and development of digital agriculture have been greatly aided by these industrialization pressures (Mooney 2018). Small and mid-sized farmers are impacted both directly and indirectly by the concentration of corporate power, as the great majority of digital technologies created to date are designed to meet the needs of large-scale, capital-rich farmers. Food workers, farm laborers, and farmers of all sizes will be impacted as corporate entities try to reorganize the agro-food environment to suit their interests.

There are three main dimensions through which these political economic dynamics are emerging in the context of digital agriculture; (1) data ownership and control; (2) the production of technology and data development; (3) and data/cyber security. By addressing these dimensions, we can then consider whether a more equitable and sustainable development of these technologies is possible for a more diverse range of farmers and food providers.

Data ownership and control

Utilizing and gathering data to inform management choices is at the heart of the digital agricultural revolution. In this regard, agricultural data is no different from data from other sectors in that it is gathered from various sources (typically involving a range of government agencies and private sector organizations), comes in a number of formats, and may be stored and handled by several parties. There are notable variations in the actors' levels of empowerment within this range of stakeholders, data, and user agreements for data collecting and processing.

The dairy industry is a well-known example of this, as the Lely and De Laval milking systems function nearly identically, but data from these two systems cannot be combined because they are inaccessible. These are generally known as data interoperability challenges. Some of the difficulties with interoperability stem from more general political concerns about data control and management, even if many of them are practical in nature, such as database organization and structure. For instance, the farmer must configure a lot of data while programming a combine harvester, and this data cannot be transferred to the hardware or software of another company.

If the farmer does attempt to adopt technologies – and accept the terms and conditions of using these platforms – by multiple firms, the useful data output required for the next piece of machinery would need to be reproduced from scratch. In this sense, the persistence of multiple, private, competing, and proprietary operating systems and tools are exacerbating interoperability challenges for farmers on the ground. As well, legalistic and technical jargon make it difficult for less resourced stakeholders to remain informed about data frameworks and agreements. In the meantime, how and to what extent interoperability can be

achieved in the interest of consumers, farmers, and less powerful firms and organizations across the food system depends on laws and regulations, national standards, guidelines, and infrastructure, as well as effective lobbying tactics (take, for example, the corporate lobby against right-to-repair legislation by John Deere, Apple, and Verizon, which is based on data access constraints and data security, such as the risk of a data breach during the repair process). New laws and regulatory frameworks that emphasize the rights and abilities of consumers to access and utilize software and data, like the right-to-repair clause, are therefore essential.

Although customers continue to worry about interoperability, problems with data silos and vertical integration—which are ultimately a result of the long-standing propensity for corporate monopolization—are overshadowing it more and more (Lanier 2014). By restricting access to information by a) the same individuals who are producing the raw data and b) the presumed recipients of the proprietary end products, businesses are essentially encouraged to take control of the data and the outcomes of its analysis. Having consumers exchange data ownership for platform access is one way to achieve this (Farmers Edge, Spotify, and Mechanical Turk are compelling examples).

Since many of these platforms are cloud-based, data is stored, managed, and processed online. Furthermore, cloud computing transfers ownership from users to service providers, which worsens corporate data accumulation even as it facilitates access and streamlines data flow (Merritt 2013). Additionally, it may be effective in mitigating some aspects of risk for service users. For example, in certain situations, cybersecurity problems will have a greater impact on the individual users (farmers, for example) of the businesses that develop the platforms than on the business itself, enabling businesses to maintain their financial stability in the face of operational and economic disruptions.

For the benefit of service providers who are using vertical integration to simultaneously hoard data and acquire start-ups that are developing agricultural technologies (AI, sensors, drones, robotics, and biotech) as well as the analytics, software, and platforms that are enabling data control, data can be aggregated and centralized under the framework of cloud computing. Reliability and availability of software are also undermined when control and ownership are taken away from users. Examples of this can be found in many industries, where customers must pay rising leasing costs in order to use the software that houses their data (Merritt 2013). Businesses strive to take control of the data produced across the food system as its value grows, which results in increased corporate concentration.

All things considered, concerns over data ownership and control are not merely a result of technological advancements; rather, they virtually inherently hinder interoperability and strengthen vendor control. Farmers have limited control over their permission rights to personal data, even though they may accept the terms and conditions of utilizing digital agricultural tools. There is a persistent lack of informed consent since digital agriculture enterprises frequently claim that "farmers own their data," but it is unclear what exactly this ownership entails (Custers 2016). According to Mooney (2018), p. 38, democratizing data control is crucial because it would put "the right of society over the interests of shareholders."

These actions would make it possible for agricultural production data to support farmers' and customers' social and environmental interests. Such actions should ideally uphold farmers' rights to transmit on-farm data, such as microclimate, soil health, and seed data, without worrying about companies obtaining it. This is the type of data sharing that many organic and agroecological farmers are requesting. Meanwhile, how and by whom digital agricultural technologies are developed is directly related to data ownership and control issues.

The production of technologies and data development

Farmers are facing the biggest challenges from digital agricultural technology in areas where they have little control over and input into the development process, which is usually driven by corporate interests. In contrast to "bottom-up" or "farmer-driven" development, we refer to this as "top-down" technology development. The former is less likely to be driven by farmer demands since technology is created and data is gathered outside of farmer networks. As a result, many farmers, particularly those who practice agroecology, contend that the technologies being marketed to them are not correctly or successfully resolving the issues they face on the farm. For instance, many farmers report having yield monitors for over ten years without operating them, primarily because they do not have the supports to calibrate the tractor, or they do not have the tools to transform that data into usable decision-making information (Duncan 2018). This is largely the result of how tech- nologies are developed, and for whose interests.

Profit-driven technologies are frequently pricy, unavailable, and practically useless for farmers (Lindblom et al. 2017). Farmers are forced to use a certain brand and system since decision support systems that handle data from multiple sources are increasingly refusing to accept data from multiple sources. Although a recent copyright ruling has declared new freedoms for vehicle software repair and modification in the US (U.S.

Copyright Office 2018), this is a well-documented problem with products sold by John Deere, a company that at least one published study concludes denies farmers access to critical software and to protocols for maintaining and modifying their equipment (Motherboard 2018).

However, since the issue is based on intricate aspects of corporate dominance and concentration, the solution is not simple. Think about open source software: businesses have successfully incorporated open source platforms and software into their business models (to gather data, attract talent, and exert pressure on software developers to produce new, frequently proprietary, advancements). Consider TensorFlow, an internal Google software library that was made available as open source in 2015. Nowadays, the great majority of AI start-ups employ TensorFlow for machine learning applications.

TensorFlow's research and development outputs, which are extremely valuable to Google, are mostly the result of its accessibility and extensive usage. In fact, its open source system is the source of its "learnings" and, hence, its worth. In this sense, without the kinds of structural changes required to control corporate integration, open source technologies just do not provide a significant threat to the current quo. This is why Richard Stallman (2018) was so certain in his claim that open source software does not have a political imperative, in contrast to "free" software. This claim is similar to those made by the data justice community (Dencik et al. 2016; Taylor 2017).

However, top-down technologies are frequently very specialized. In contrast to biodynamic and agroecological production systems, many proprietary farm management systems concentrate on highly specialized production systems, such as a vineyard management system, a single row crop, a vegetable truck farming system, or a standard method of soybean cultivation (Cosgrove 2017). Additionally, each technology tends to address certain problems and tasks, making the collection of technologies prohibitively expensive and therefore unaffordable for smaller-scale, less wealthy farmers.

Farmers should think about the extent to which a corporate third party will profit from the process—profits that frequently accrue at the expense of the farmer—when they choose to rely on that party to handle data and provide technologies (such as Farmers Edge, AGDATA, and Climate FieldView, to name a few). People may have access to a tractor's engine control unit (tECN), as Carolan (2017, p. 4) points out. However, because of intellectual property laws, this privilege actually has little effect on farmers' reliance on agro-food companies.

Consequently, farmers express skepticism regarding the relevance and efficacy of a large portion of top-down data and technology compared to their own on-farm expertise. In the case of yield mapping, early research by Tsouvalis, Seymour, and Watkins (2000) shows that farmers who employed this technology did not discover that their yield maps taught them anything new. The farming community is still debating the usefulness and usability of top-down software tools, as well as their ability to efficiently convert raw yield monitor data from on-farm sources into decision-making tools that are pertinent to each individual farm context and the particular informational requirements of that farmer.

In addition, farmers are deeply concerned about the degree of transparency in the software's computations, which makes them doubt the accuracy of the results. For instance, software's algorithmic computations cannot take into account a farmer's firsthand knowledge of the past circumstances and difficulties facing their soil or livestock. Many farmers would find it difficult to accept or respect the results of digital analytical tools if they are unable to incorporate such implicit, contextually specific information (Duncan 2018). Because agroecology necessitates in-depth, microclimate, and frequently intergenerational knowledge of the agroecosystem, farmers that employ agroecological techniques and principles are likely to fall into this category (Francis et al. 2003).

The data requirements of agroecological producers are further at odds with data platforms, which are expected to be created using data gathered from massive, industrial-scale systems. In describing how the platform was launched in Canada, a Climate FieldView representative acknowledged this, saying, "We really did start in a part of Canada that we knew would benefit and work well with the Climate FieldView platform." She goes on to explain that these larger farmers were growing soybeans and grain corn (Real Agriculture 2017).

Farmers are the ones at the most risk and expense of implementing data collection systems throughout the supply chain because a single bad investment may easily cost them their livelihood. Therefore, it seems to reason that they should benefit the most from the data. However, farmers, and agroecological farmers in particular, do not reap the benefits of ag-tech development in the current political and economic environment. Rather, developers and service providers are reaping these benefits not only by directly profiting from the sale of equipment and subscription fees, but also by reinvesting and manipulating the data they have collected from farmers and the equipment.

Instead of working with farmers to generate products and services, these ag-tech businesses—which are sometimes also input companies and offer advice services—are better equipped to produce profitable goods and services because they have access to more agricultural data.

The direct ownership of technology and data by farmers may be ensured by cooperative and open source forms of digital agriculture development, giving them more financial clout and control. Solutions are more likely to be guided by farmers, for farmers, in bottom-up and/or cooperative procedures. Therefore, a group of farmers usually owns and controls the technology and data, perhaps working with a government organization or academic institution. Here, the emphasis is on innovation, which need not be characterized by capital-intensive technologies. In particular, cooperative ag-tech has significant ramifications for small farmers.

A recent report by the Joint Research Centre of the European Commission found that, 'where the field size is small, or when the farmer does not own the technology, specialist contractors, sharing of farming methods and cooperative approaches may be suitable for the use of equipment among different farmers' (2014, p. 22).

Access is another topic covered in this conversation. As Carolan (2017) explains, we need to exercise caution when it comes to access because having the "capabilities to do so in ways that generate material well-being" (p. 17) is not the same as being able to access something. Consequently, merely gaining access does not guarantee that everyone will have equal access to the tools and resources needed to utilize that data. One of the main concerns with open data, for example, is that it has the "potential to exacerbate as much as alleviate injustices" if data sources are merely opened available without the use of checks, balances, and auxiliary resources (Johnson 2014, 263).

Data security

On Friday, May 12, 2017, a significant global news story was unfolding in Europe as North Americans awoke. The National Health Service computer system in the United Kingdom was partially unavailable. FedEx and Deutsche Bank were among the companies that had trouble turning on their computers. When company staff got to their terminals, they saw nothing but a red screen with the words, "Oops, your files have been encrypted!". A bit of ransomware known as WannaCry was what infected computers all around the world. Given the significance of the social and economic services that cyber security systems provide, WannaCry made headlines throughout the world by demonstrating how inadequate these systems were.

As technological innovation rapidly evolves, a growing challenge is arising around data privacy and security (Lesser 2014; Sonka 2014). Although cyber security has garnered a lot of attention and worry in recent years, it has tended to concentrate on risks to industrial control systems, privacy, and proprietary data that are primarily connected to financial services, health care, and other key infrastructures. Digital agriculture and the proper conceptualization of stakeholder participation and risk management in this field have received little attention. Some contend that food systems are becoming more susceptible to unintentional and intentional attacks as a result of the billions of dollars being transacted online using digital currencies like Bitcoin, the scheduling of the numerous food distribution networks, and the growing globalization of our food system while less food is being stored locally. (Rotz and Fraser 2015; Bogaardt *et al.* 2016). In some ways, interoperability and cyber security are in tension with each other. Greater interoperability can mean an expansion of threat or attack surfaces, tied to corresponding decreases in the number of segmented or logically closed areas of networks, and increases in the range and num- bers of endpoints, gateways, networks, and cloud environments (see Macaulay 2016). These worries are reasonable, but it's also important to consider their political and economic value. To maintain control over the repair, recycling, and exchange markets, technology manufacturers and service providers have been fostering concerns about customer safety and cyber security for years. For example, Apple made the unsuccessful claim that "unauthorized repair will turn the state into a'mecca' for hackers" in reaction to the 2017 "right to repair" legislation that was being introduced in Nebraska (Koebler 2017). Because they frequently lack the "right to repair," farmers are forced to hack into their own tractors and equipment in order to practice digital agriculture (Wiens 2015; FarmHack 2018).

Therefore, how is the word "hacker" used in this context? Proprietary barriers and defenses in the agricultural industry make it nearly impossible for farmers or even computer programmers to do small repairs, which could ultimately result in the entire shutdown of high-tech machinery. Furthermore, important on-farm duties could be neglected because it sometimes takes equipment dealers several days to order the item and have it delivered to the farm. As a result, the vast majority of the agtech "hacking" group today consists of farmers themselves, with the goal being to simply gain access to the computer system that enables them to perform simple repairs, adjustments, or gather crucial crop data.

After all, farmers have been fixing their own machinery for as long as there have been farms for a variety of reasons, including time, weather, and financial limitations. Because many farmers are turning to older

equipment that can be repaired without the use of computers and software, the need for high-tech tractors is consequently declining (Wiens 2015).

Therefore, although service providers have voiced concerns about data security during discussions about data control, cyber security in general has not yet emerged as a major issue in the industry. However, as data sets grow, including information on crops, animal health, and even individual farmers' internet profiles, they may allow interested parties to learn about the specifics of farmers' activities, down to the exact square inch of a farm field. Again, how and by whom the data is managed and stored will determine the type and scope of these problems.

The potential ramifications are demonstrated by a recent agreement between the international reinsurer PartnerRe and the agricultural management software platform Farmers Edge. "The insights that we get from our data are helpful for growers to make decisions, but there's a really important opportunity here," says Wade Barnes, CEO of Farmers Edge. Risk management immediately flows into the insurance industry when the farmer increases yield and reduces expenses (Cosgrove 2018). We may see how this data could be used to reject insurance claims and/or increase policy prices, even while it can help farmers obtain insurance. In addition to increasing corporate influence over agricultural production, this could hasten the decline of family-owned agricultural operations.

As a result, farmers should think about the potential value of the data they are gathering on the farm for vendors of digital agricultural equipment and services. They should also think about the unique security and access implications that come with various platforms, whether they are open source or proprietary. For instance, to properly apply VRA technologies, multiple years of historical yield data are needed (Zhang 2016). Farmers would thus be in a vulnerable position if this data were either destroyed as a result of a cyberattack or rendered inaccessible by the supplier, which is particularly worrisome considering the expenditure necessary for data collection equipment.

From a risk management perspective, the core business assets of an independent operator may differ considerably from those of a global vendor. While discussing the contours of digital agriculture offer opportunities for shared understanding be- tween individual producers and technology vendors, no clear discussions of the risks related to data collection, data-driven control systems, and data analysis are evolving between users, vendors and decision-makers. Specifically, the comparative nature of these risks, as they reflect different interests and levels of power, have barely been broached. One notable reason for this divide is likely that the entities selling the technology and services are not simply multinational vendors but are increasingly global owners of the new means of agricultural production – data streams and the mechanisms through which these are created and distributed.

CAN DIGITAL AGRICULTURE PROVIDE POLITICAL AND ECONOMIC SUPPORT FOR MARGINALISED FARMERS AND FOOD PROVIDERS?

For many years, academics have explained how historical and current policies have influenced the political and economic circumstances that give rise to all technologies, and digital agriculture is no different. Land consolidation, the cost-price squeeze, and pressure for export-oriented growth have been both causes and effects of policy in North America (and many other contexts). We recognize that these broader patterns are probably here to stay, which puts substantial structural limitations on the use of digital agriculture as a tool by small-scale, agro-ecological, and other marginalized farmers and food suppliers. The implementation of more localized food policies and policy councils that aim to democratize control and give priority to support for community-based food systems are just two examples of how policy has, in fact, supported access for a wide variety of farmers and encouraged the development of scale-appropriate technologies. These systems are starting to appear in Europe (such as the UK, Germany, and France) and North America (such as Southern Ontario, British Columbia, and California).

However, there is much more to be done. For example, many local food policies do not yet meaningfully address issues of digitalisation and agro-food technology and consider how small and agroecological farmers could be better supported within this context, although they could in the future. In the following discussion, we reflect on the extent to which digital agriculture can provide political and economic support to marginalised farmers and food providers, we then consider some specific limitations.

First, small and medium-sized farmers are being targeted with lower-cost, scale-appropriate technologies and open source platforms that enable them increase their efficiency and create value on the farm "where the farmer is actually owning more of their own supply chain" (Cosgrove 2017). As an illustration, consider the Three Rivers Farmers Alliance, where a group of farmers developed a smartphone app that enables eateries, educational institutions, and retail establishments to place direct orders with nearby farms that utilize the software to manage harvest, processing, and delivery (Three Rivers Farm 2017).

Shorter supply chains and improved communication are made possible by this type of democratized and collaborative software development, which increases the opportunities for agroecologically diverse and politically marginalized farms to gain from digitalization. Once more, open source data and software development by themselves are insufficient to change business focus in the agro-tech sector. In this instance, the political impacts are not inherent, even as these networks promote alternative and/or local supply chains that function independently of corporate agro-food assemblages (Sonnino and Marsden 2006; Knezevic et al. 2013). Open source, collaborative developments such as the Three Rivers Farmers Alliance need to be set within a broader, citizen-led local or regional food policy in order to be sustainable over the long term.

There is a similar trend in specialty crop industries or in fields like viticulture and organics where lower-cost (COG-Pro, AgSquared, or Raspberry Pi automation), co-operative, open source (Farm Hack, FarmOS), and scale-appropriate technologies (Naio Tech's "OZ" or the Wall-Ye V.I.N. robot) is working well, as well as in industries trying to cut labor costs, like horticulture. Notably, according to Cosgrove (2017), these technologies are "creating an alternative for a number of production systems that just simply aren't represented… [T]he goal isn't to necessarily replace but make other systems compatible with one another."

Again however, if public agro-food policy is not developing goals and objectives around how such technologies could be nurtured and supported for local, agroecological farmers, these technologies will remain in the hands of those able to pay, and as these technologies evolve, economic divides will only deepen across the farm-base.

For agroecological and small-scale farmers, open source technology and data sharing appear to be some of the more easily implemented aspects of digitalization, particularly for those operating outside the corporate sphere of precision agriculture and digitalization. This also applies to farmers in general. In order to help farmers, organizations like Farm Hack, FarmOS, ISOBlue, and AgriLedger, as well as publicly financed platforms, are attempting to remove obstacles like corporate competition, data silos, and proprietary ownership in various ways. Farm Hack is 'a worldwide community of farmers that build and modify' their own tools and share hacks online and at meet ups (Farm Hack 2018). This model allows farmers to counter elite capture through collectivisation. For instance, Farm Hack's tool library provides fairly low-cost tech, data software, and innovation solutions for a range of farm sectors, systems and scales. As well, FarmOS software is a free, open source web application open to the whole farm community to support record keeping and farm management. FarmOS is accessible and applicable for farmers of all sizes and sectors (FarmOS 2018).

Once again, collectivization through user-driven and community-driven assemblages may aid in reducing farmer reliance on the corporate food regime, but it won't immediately address the political trajectory of corporate consolidation in the agro-food system as a whole or in ag-tech in particular. Numerous academics and professionals have maintained that in order to address these more general concerns, structural changes in food, environmental, and trade policies at the national and international levels are necessary (Friedland 1çç1; Friedmann 1çç3; Clapp and Fuchs 200ç; Rotz and Fraser 2015).

For example, a national food policy is being developed in Canada that, according to some, could greatly expand resources and support for farming systems, research, markets, and technologies that are currently marginalized (such as organic/biodynamic farming, small-scale and new farmers from non-farming backgrounds, perennials, and non-commodity crops) (Food Secure Canada 2017; Weiler 2017). Others, however, worry that corporate power and commodity interests will control the policy-making process in order to promote the same old policy outcomes that emphasize export output, land consolidation, and commodity specialization (National Farmers Union 2017). How these conflicts manifest themselves in the formulation of a national Canadian food policy remains to be seen. Yet, it is still important for localised, citizen-led food policies to consider how digitalisation might benefit different kinds of farmers and incorporate mechanisms for locally appropriate technological innovation into those policies. A focus on digital innovation at the local level has the potential to influence broader policy shifts at the national and global scale, particularly in gaining support for digi- tal infrastructure improvements (i.e., broadband internet).

In the meantime, others have advocated for open data governance mechanisms like international treaties, social certification programs, national mandates, and inter-organizational data charters (de Beer 2016). They emphasize that open source solutions rely "...in large part on what kind of data is being discussed" (de Beer 2016, p. 17). In fact, "the model for governing qualitative data held by an NGO, and for governing big data collected by a multinational corporation, is likely to be different from the model for governing data pertaining to the traditional and culturally specific knowledge of communities" (de Beer 2016, p. 17).

For governance mechanisms to be effective, they must be linked to larger investments in social infrastructure and resources at the local and regional levels "that are known to be crucial for innovation, including better education, entrepreneurialism, access to markets, other businesses, and already trained employees" (Bock

2016). Furthermore, the development of food policy may be more directly related to governance processes since they should be more closely linked to ideas of justice, rights, and knowledge production. These connections are being established through the frameworks of information and data justice (Johnson 2014; Newman 2015; Taylor 2017).

In relation to agricultural data, let us examine who, outside of agribusiness, now makes up the political space of data generation, access, and interoperability. Universities, different farm bureaus, AgGateway2, the Open Agriculture Data Alliance (OADA), Global Open Data for Agriculture and Nutrition (GODAN), and others are examples of these important stakeholders (Porter et al. 2014; Antle, Jones, and Rosenzweig 2017). Additionally, an open-access agricultural data platform is being developed by CGIAR (the Consultative Group for International Agricultural Research), a global partner conducting food security research to improve human health and alleviate rural poverty (cigar.org 2018).

Additionally, the U.S. Department of Agriculture (USDA) is making significant investments in open data, data governance, and interoperability. What possible political repercussions might these alliances and investments have? Most evidently, digital agriculture will advance through a more universalized perspective even in the public sphere, promoting solutions that are de-contextualized from regional ecological, social, cultural, and economic contexts.

For example, Agrifood Canada and the Office of the Privacy Commissioner in Canada have a great chance to collaborate on public infrastructure investments for open source technologies and data sharing. This could make it possible for a wider variety of farmers to have access to and the ability to utilize emerging technologies in ways that suit their farms. According to Wolfert et al. (2017), these kinds of partnerships are generally referred to as "Agricultural Business Collaboration and Data Exchange Facilities (ABCDEFs)." Whether ABCDEFs "will be closed, proprietary systems like currently Monsanto's FieldScripts or if these will be more open as proposed by e.g., the OpenATK or the FIspace platform?" is undoubtedly a crucial question. (Page 77, Wolfert et al., 2017). Even as public institutions become more involved in data governance, proprietary data systems are likely to remain dominant due to the extent to which agribusiness, trade agreements, and industry associations have an impact on public agro food governance—or rather, the growing trend for government to work for the market (Busch 2010). An equally important question here, again, is a question of scale: to what extent can a federally governed project support locally-appropriate digitalisation that is useful for and accessible to agroecological farmers and the agro-food networks they are a part of?

Political economic limitations to enhancing equity in agricultural digitalisation

The political and economic factors that determine farmers' reliance on agro-food corporations remain largely unchanged, despite the efforts of these important public actors to create open standards and protocols, facilitate data access and transfer across platforms, and create forums for community discussion. In particular, producers are unlikely to be empowered by these procedures alone when confronted with powerful corporate interests (Mooney and ETC Group 2015; Bronson and Knezevic 2016; Carolan 2016b). For example, it is simple to imagine a future in which Apple may possess and control almost all of the techno-data software, platforms, and resources available to food producers given the current state of the North American economy. . This means that, while open source or non-proprietary data and code can help to 'free' some farmers to access and use their data in their interests (e.g., to fix or modify their farm equipment, rather than being forced to rely on John Deere techni- cians), they are not *necessarily* any less dependent on the physical and technological products and services that are embedded in corporate assemblages (Carolan 2016b).

In other words, while open data platforms may give farmers better access and control over the digital aspects of their farm equipment, to generate that data, they still must invest in the physical technologies being developed by an increasingly consolidated and corporately controlled agricultural industry.

Furthermore, we must take into account the degree to which open source code and data alone will address the reality that the underlying systems, when developed by rival private firms, were never intended for integration in the first place, even though we agree that open and shared data is a crucial way to better ensure that data stays in the hands of the farm community (de Beer 2016) (Wolfert et al. 2017, 77). As previously stated, there are numerous examples of businesses that have a history of implementing new technologies that force customers to use only one vendor and engaging in planned obsolescence with earlier iterations of their own software or products in the critical technology literature (LeBel 2016).

Until corporate integration and concentration are reined in, perhaps through anti-trust legislation, there is a real concern that these technological trends will result in a continued re- striction of farmers' options (as opposed to the expansion of options) by agricultural technologies and the firms behind them. Scale and locally relevant technology development are major concerns, even in the public sphere. Therefore, comprehensive public policy and investment in data ownership and governance may be beneficial, but it must take place in

a locally relevant, citizen-led policy context. Furthermore, the most remote rural areas have the most urgency in technical interoperability concerns. According to Janssen et al. (2017), many rural areas still lack the fundamental infrastructure needed for broadband internet and mobile networks. In other words, it is hard to predict favorable results for the viability of these communities as digitalization advances unless there is a large, dispersed public investment in support of the technical infrastructure required in rural areas.

A wider political discussion about data control and ownership does not appear to be taking place in relation to cyber security, despite the fact that many are trying to better understand data integrity, data security, and cyber threat detection and response (e.g., the human dimensions alongside the operational and sectoral threats and opportunities) (Chi et al. 2017). Politically, farmers, food workers, and consumers should be in charge of working with the government to create regulations that govern how and by whom their data is stored and managed.

Furthermore, for far too long, "innovation" in the food and agricultural industries has been solely associated with "technology." Naturally, on-farm innovation is constantly happening and changing, and it could involve—but is not restricted to—the use of big data and technological systems. Additionally, it could entail adopting naturalistic practices, like integrating trees and naturalized areas to improve biodiversity or adding natural soil amendments, intercropping, and livestock integration to increase soil organic matter and naturally reduce pests (Gliessman 2007; Pretty 2008). Additionally, cutting-edge intensive and ecologically sustainable systems, like agro-ecological vertical farming techniques, are being developed worldwide (Coleman 2014). In this sense, locally-appropriate policy should support ecologically driven agricultural innovation through both programming and resource provision. Focusing on community-level solutions should help nurture innovation that is occurring outside of corporate labs and boardrooms.

Data justice for farmers

Fairness in how persons are made visible, hated, and treated as a result of their output of digital data is known as data justice (Taylor 2017). It is evident from a political-economic study of digital agriculture that many farmers find it difficult to recognize the advantages of the digital data generated by their agricultural systems. Growing corporate concentration has resulted in a situation where farmers lack the authority and permission to access and use data, while corporations hold all the capacity to keep, manage, and manipulate it (Crawford et al. 2014). Although many small and lower-income commodity farmers are systemically motivated to adopt precision and digital technologies, these systems and technologies are frequently in line with the models and production systems of large, incorporated, industrial scale farmers, many of which are simply out of reach for smaller farmers. This raises a similar concern to that which Taylor (2017) raised in the context of farmers. Larger farms can really acquire the newest technology because to economies of scale and capital accumulation, which lowers their input, fuel, and pesticide prices. Economic polarization is exacerbated by these growing technology gaps, which also make it more challenging for small and medium-sized farmers to engage in agriculture at all.

Meanwhile, the data development field of North American agriculture still mostly ignores low-input, agroecological, and niche producers. As agricultural data builds up, this calls into question which farms and farmers are being (mis)represented. Lastly, although there has been an increasing worry about farmers' data rights, we have demonstrated in this paper that bottom-up, locally-appropriate, farmer-driven digitalization—which takes into account farmers' needs—is equally important to data justice in agriculture. This conclusion backs up the ideas put forth by others regarding the broader framings of justice (Taylor 2017).

To better understand how to integrate social justice and fairness into digital agriculture, further research is required that challenges the epistemologies of big data use (Crawford et al. 2014; Kitchin 2014), with a special focus on agriculture. How might digital technology affect the most vulnerable in the sector, such as insecure farm and food workers, for example? The "black box" that surrounds agricultural data after it leaves the farm must also be unraveled by big data scholars. We may begin to imagine how agricultural data can help a varied agricultural system if we have a deeper understanding of these data paths.

5. CONCLUSION

We have a big task for the next generation: how to feed a growing population in a sustainable, safe, and nutrient-dense manner while tackling pressing environmental issues like water scarcity and climate change. Although technology plays a part, many of the so-called technological solutions being created are not empowering independent farmers to make informed decisions about the agroecological system they manage, but rather empowering corporate actors. Inequities for marginalized actors in the food system, particularly between farmers of different sizes and between farmers and agro-food corporations, may be made worse by the current trajectory of agricultural technology.

In this article, we have reviewed the political economy of digital agriculture as it relates to three major challenges in the sector, (1) data owner- ship and control, (2) the production of technologies & data development, and (3) data (cyber) security. Our discussion of these challenges is not meant to be exhaustive but, rather, to profile and clarify some of the most prevalent political economic con- cerns arising across the sector in a way that is useful for a wide range of decision- makers and scholars alike. As initial steps toward promoting solutions that support data justice for farmers, we specifically highlight the importance of open, cooperative, publically supported, and locally relevant technology and data platforms. However, we stress that the degree to which digitalization may advance the interests of underrepresented farmers and food producers is undoubtedly constrained by more significant political and economic obstacles in the agricultural sector. Therefore, if we want to be better equipped to comprehend what data justice means for the agricultural community and how it might be achieved going forward, a lot more academic and practical work needs to be done

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