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Urban Bites and Agrarian Bytes: Digital Agriculture and Extended Urbanization

TIMOTHY RAVIS AND BENJAMIN NOTKIN

Abstract

Capitalist agriculture faces a crisis. Plateauing yields and profits are driving up food prices, and the ability to continue the traditional practice of expanding into new, un-commodified territories appears to be waning. This crisis is due in large part to the accelerating biophysical contradictions of industrial agriculture, which systematically undermine the ecological conditions for its own success in pursuit of profit. We investigate how digital technologies are deployed as a potential data fix that does not solve the crisis but merely staves it off. We situate these technologies within the material context of capitalist urbanization, along the way arguing for bringing information back into the neo-Lefebvrian framework of “extended” or “planetary” urbanization. Digital agriculture technologies continue the centralization of economic knowledge and power as they facilitate the transformation of vast territories into “operational landscapes” that provide the material, energy, and labor for a rapidly expanding urban system.

Keywords: Digital Agriculture, Precision Agriculture, Extended Urbanization, Planetary Urbanization, Globalization, Agrarian Studies, Depeasantization, Globalization, Computation

“Eventually, precision agriculture could take humans out of the loop entirely. Once that happens, the world won’t just see huge gains in productivity. It will see a fundamental shift in the history of agriculture: farming without farmers.”

—Foreign Affairs Magazine (Lowenberg-DeBoer 2015)

“99% of all technological disruption is there to merely ensure that nothing of substance gets disrupted at all.”

—Evgeny Morozov (2019)

Introduction: Feeding “the Next Two Billion”

Hundreds of reports and articles begin with a variation on the same apocalyptic exhortation: The combination of population growth, food price volatility, and climate change demands a new agricultural revolution to expand and secure the global food supply. The biotechnologies first deployed in the Green Revolution are still being constantly improved; food prices, however, stay stubbornly high and many fear a yield plateau. The new revolution, they argue, is digital technology. In a recent article about the use

of artificial intelligence in agriculture, for example, Wired gushed about “an explosion in advanced agricultural technology, which Goldman Sachs predicts will raise crop yields 70 percent by 2050” (Janger 2018). Goldman, for their part, estimate that digital agricultural technologies will become a \$240 billion market by 2050 (Revich et al. 2016). X, Google’s “moonshot” venture, recently hailed the arrival of “the era of computational agriculture” (Grant 2019). Traditional agribusinesses have found themselves competing with Silicon Valley giants, venture capitalists, scrappy startups, intergovernmental organizations, non-governmental organizations (NGOs), and research institutions to develop and market a dizzying array of new technologies to feed “the next two billion” and save the world.

“Digital agriculture” is a heterogeneous suite of information-rich, computationally-complex, and often capital-intensive methods for improving the efficiency of agricultural land and the profit margins of sectoral actors. Digital technologies have come to play a role in every stage of the agricultural cycle under capitalism, from input management to marketing produce, pricing commodities futures to pest control. However, while it is true that these technologies increase efficiency, we contest the notion that they will provide a long-term solution to the looming crises of the global food system. For what the narrative of an agricultural techno-revolution elides is how the methods of industrialized food production (e.g. intensive use of fertilizers and fossil fuels, monocropping, huge amounts of livestock) create these challenges in the first place. We interpret the rise of digital technologies in agriculture as the continuation of a process dating back to the Green Revolution, namely, to reconfigure agrarian life in a manner amenable to increased profits, especially for actors further up the value chain. For the proponents of digital agriculture, the transition is between two technologically-paved pathways to profit: innovations in high dimensional computing supersede innovations in breeding. A purely technological perspective is insufficient and depoliticizes analyses of far-reaching changes to agricultural production, changes which have an effect on the rest of the capitalist economy (Patel 2013). Nevertheless, this has not stopped digital agriculture’s boosters from frequently claiming that it heralds a “fourth agricultural revolution.”¹

However, digital agriculture has received limited critical attention from social scientists. The vast majority of critical work on the ascendancy of global technology mega-firms and new information-centric accumulation strategies looks at their effects in non-agrarian industrial and service sectors. However, the generation of profits in these sectors depends in part on keeping inputs for production and reproduction—like food—artificially cheap (Moore 2010). By perpetuating an unsustainable regime of cheap food, digital agriculture technologies support the continued expansion of an equally unsustainable global urban system.

1 Refer to, for example, Trendov et al. 2019

We argue that the rise of digital agriculture is emblematic of an intensifying relationship between zones of agrarian production and extraction on the one hand, and zones of agglomeration, industrial production, and service provision on the other. A body of neo-Lefebvrian scholarship describes these apparently distinct zones as co-constitutive, entangled in a dialectic of extended and concentrated urbanization (Monte-Mor 2004; Soja 2010; Brenner 2013; Brenner and Schmid 2014). In this framework, the growth imperative of capitalism requires the transformation of vast landscapes beyond the ‘city’ to increase extraction and agricultural output, the product of which is drawn back inward to fuel growth. In this reading, the socio-metabolic process of urbanization is increasingly generalized, to the point that some have argued for thinking of contemporary urbanization as a ‘planetary’ process.

With this in mind, this article interrogates the political economy of digital agriculture and reinterprets the digitalization of the food system through the lens of extended–concentrated urbanization. We begin by introducing digital agriculture and the limited social scientific literature on the topic. Next, we critique the mainstream rhetoric surrounding digital agriculture, which makes a Malthusian argument for the need to feed a burgeoning global population in the face of climate change. Then, beginning from the observation that the crucial role of information is under-analyzed in the extended–concentrated urbanization framework, we build a theoretical argument for how digital agriculture challenges the urban–rural binarism. We locate the framework’s origins as a reaction to earlier threads of globalization theory, which emphasized the supposedly immaterial nature and deterritorializing effects of information and communications technologies (ICTs). The ‘urbanization of hinterland’ (Brenner 2016) requires the ability to observe, interpret, and manage processes of extended urbanization from zones of concentration. We then “bring information back in” by introducing a more materialist analysis of the role of information in global capitalist space, which centers on computation capital: the infrastructure necessary to transport and make legible enormous amounts of data. In this framework, digital agriculture can be reinterpreted as a “data fix” for multiple entangled crisis tendencies of urbanization. These include the well-documented ecological crisis caused by industrialized agriculture—necessary to keep food prices, and therefore wages, low enough to generate profits in the traditionally ‘urban’ secondary and tertiary sectors—as well as a potential crisis of the overaccumulation of computational capital. This crisis response, in turn, reconfigures the concentrated–extended dialectic of urbanization. The digitalization of agriculture further consolidates agrarian knowledge and decision-making away from the fields and among agribusiness and, newly, technology actors. We note how this off-siting transforms agrarian land tenure and deskills agricultural workers. This connects directly to the concept of ‘depeasantization’ (Araghi 1995), which can be understood as the mirror of urban agglomeration. We conclude with some suggestions for future research on digital agriculture’s effects on the urban/rural divide.

A Digital Agriculture Primer

The intensive use of information technologies in agriculture has received limited attention from social scientists. As recently as 2016, Bronson and Knezevic, in taking a critical look at how such tools affect the power dynamics between farmers and corporations, noted that “there has been no attention given to Big Data’s implications in the realm of food and agriculture” (1). In the years since, a steady trickle of publications has begun addressing this gap: on a “data grab” (Fraser 2018); on the unequal ability between farmers and firms to use data (Weersink et al. 2018; Lioutas et al. 2019); on digital agriculture’s transformation of farmers into consumers (Carolan 2018; Eastwood et al. 2019); on the racialized exploitation of labor (Rotz et al. 2019); on the embedded norms of digital agriculture (Bronson 2019); and on alternatives (Van der Burg et al. 2019).

A variety of labels have been used for this emergent industry: precision agriculture, e-agriculture, smart agriculture, and digital agriculture, among others. Despite early critical use of precision agriculture, the term tends to be used in the industry to signify a specific suite of production-oriented technologies.² However, information technologies are also used to open new markets (to producers, traders, and investors) and new territories for production. For example, digital platforms have become increasingly important for individual producers to bring their goods to market. Figure 1 shows how information technologies are intertwined throughout the cycle of agricultural production and sale.

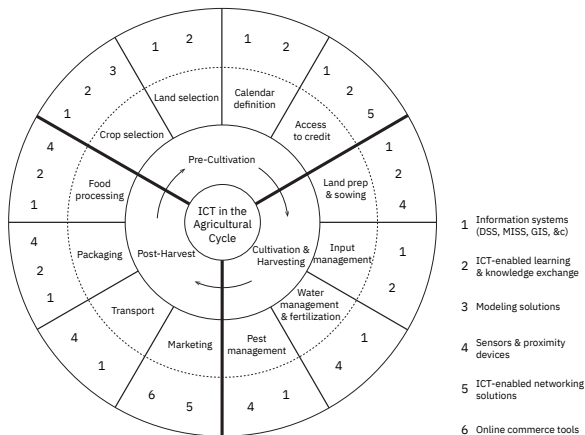


Figure 1 Information technologies in the agricultural cycle.

Source: Deloitte in World Bank 2012.

² While precision agriculture as a term has been used since the 1990s, the International Society for Precision Agriculture only officially defined the term in the summer of 2019 (www.ispag.org/about/newsletters?preview=90).

We use digital agriculture for its semantic breadth and increasing currency. In our taxonomy, precision agriculture is a subset of digital tools which improve efficiency through careful management of inputs. Three other types of tools—marketplace and financial platforms, e-extension, and smallholder management—are typically platform-based systems that mediate the social relation between farmers and the outside world. Marketplace and financial technologies help farmers access new credit lines and optimize their market behavior. E-extension is the digitalization of the practice of implementing technological innovations through farmer education, particularly in the international development context. E-extension, like the analog version that preceded it, is largely reliant on insights produced far from the farm. Finally, smallholder management platforms allow larger agribusinesses to exert control over smallholder farmers through close management of their inputs, products, and so forth. This may allow major actors to divest themselves of the risk inherent in owning land and instead subcontract smallholders in a relationship analogous to other platforms in the gig economy.

Searching for Techno-Revolution

For digital agriculture’s boosters, it has the potential to be the much-needed “fourth agricultural revolution” (refer to, *inter alia*, Lombardo 2014; Lowenberg-DeBoer 2015; De Clercq 2018). In particular, it is framed as a climate-friendly way to feed the world and improve the lot of farmers around the world. By making the application of inputs (seeds, fertilizer, water, fuel, etc.) more efficient, digital agriculture can indeed lessen the environmental impact and yield of agriculture. By increasing input efficiency and improving knowledge of market demand, digital agriculture may indeed improve the fortunes of producers. The rhetoric is not dishonest, but it is incomplete.

Claim 1: Digital Agriculture is about Improved Environmental Outcomes

Optimizing inputs enables the continued use of ecologically-harmful chemicals and practices, which would otherwise be abandoned if their effects were not actively mitigated (Bronson 2019). Digital agriculture’s marketing claims it will improve efficiency, increasing yield and minimizing the use of inputs—many of which are harmful and unsustainable. The externalities produced by using these inputs are the “un- and undervalued costs of industrial capitalist agriculture” (Weis 2010, 316). A team at Cornell, for example, has developed a model that recommends ideal fertilizer application rates for each section of a farmer’s field in order to minimize nitrogen runoff into the Gulf of Mexico, which causes algal blooms, depletes oxygen levels in the water, and kills fish and wildlife.³ While optimization limits the short-term damage of unsustainable practices, it also makes those practices more politically permissible and financially

³ The technology has since been licensed to the global agricultural products conglomerate Yara International.

feasible. Thus, by making unsustainable practices *appear* sustainable, the necessity of adopting more ecologically and socially sustainable and just practices is delayed. By focusing on input management, these technologies advance a limited interpretation of sustainability that still depends on off-farm inputs, rather than a more radical shift to permanently sustainable practices (Barbieri et al. 2019).

Claim 2: Digital Agriculture is about Improving Yields and Solving World Hunger

Just as digital agriculture promises to minimize inputs, it also promises to maximize yield—yet yield is not the problem. In the 1970s Amartya Sen noted that while starvation was increasing globally, food per capita was also increasing (1977, 33)—as population grew, food production grew at a greater rate, not only globally but even regionally. While some scholars have taken issue with Sen’s empirical basis, an updated analysis using 2010 statistics found the same results (Scanlan, et al. 2010). The direct relationship between hunger and food per capita, when we would expect an inverted one, betrays the simple thesis that hunger is due to a lack of food availability. Instead, Sen attributes hunger to an inability to *exchange* for food. Davis similarly notes the disconnect between food availability and hunger, finding that famine can occur in areas of grain surplus because it is more attributable to rural food management and exploitation than to production (2001). The “solution” to hunger, then, lies not in yield. Yield has increased; food per capita has increased; hunger persists. Therefore, stretching yield through digital agriculture is insufficient and does not address the political-economic basis of systemic hunger.

Claim 3: Digital Agriculture is about Improving the Welfare of Farmers

The third key claim made by digital agriculture’s boosters is that it will improve farmers’ welfare, in particular their profits. Profits may be found in better decision-making, better yields, and better access to market information (refer to, *inter alia*, World Bank 2019). In the Global North, such increased profits may be plausible. However, a primary mode for digital agriculture, the platform service, means that the data produced typically becomes the property of the platform provider. Weersink et al. (2018) note that a key challenge for digital agriculture is making this data useful; this, in turn, may favor larger companies with the capacity to process the data. Bronson (2018) notes this dynamic and warns that it may reproduce the distributional effects of the Green Revolution—that is, to concentrate wealth and power in the hands of major agribusinesses.

In the Global South, digital agriculture presents a different set of problems for farmers’ welfare. Technological innovation that increases a crop’s yield in turn increases supply and undercuts the socially necessary labor time required to produce it. This dynamic lowers the crop’s exchange value at the expense of those at the bottom of global commodity chains, in particular the growers’ compensation per unit of crop. As this price drop is not accompanied by any increase in production for farmers

without access to this technological innovation, this drop translates to lower overall compensation and to “exchange entitlement decline” (Devereux 2001). If they depend on exchange for subsistence, the decreased compensation translates to hunger as well. Digital agriculture’s strategy of overcoming hunger by increasing yield thereby may even exacerbate it.

In reflecting on these mainstream claims, a different theme emerges. Rather than sustainability, nourishment, or farmer welfare, digital agriculture is fundamentally about securing the conditions to generate profit in the food system. Crucially, however, this is not about profit in food production alone, but in the wider capitalist economy for which food is obviously a fundamental input. Therefore, we submit that digital agriculture must be understood as addressing a specific set of crisis tendencies that have emerged at a particular juncture in the social, ecological, and spatial history of capitalism. This juncture is defined by interlocking moments of ecological disaster; enormous advances in information production, gathering, and processing; and “hyper-trophic” urbanization (Ajl 2014).

Digital Agriculture as Data Fix

In this section we argue that rather than a solution to the climate crisis, hunger, or farmer welfare, the rise of digital agriculture can better be understood as an attempt to overcome crisis tendencies of “the relentless growth imperatives of an accelerating, increasingly planetary formation of capitalist urbanization” (Brenner and Schmid 2015, 153). After briefly excavating the informational dynamics latent within the framework of extended and concentrated urbanization, we describe how digital agriculture functions as a “data fix” by allowing the intensification of agricultural industrialization and the extraction and enclosure, for eventual profit, of the data produced by digital agriculture technologies.

An early theme in globalization literature was a tendency to embrace the rise of information technologies in a way that dematerialized the now planetary systems of extraction, production, and consumption (e.g. Lazzarato 1996; Webster 2002; Castells 2010). Such concepts, however, have largely been absorbed by analyses which show that a deterritorialized “information society” is not displacing traditional modes of production and social relations as much as emerging as a financial-managerial stratum in a “new international division of labor.” Another major theme in globalization studies is the ‘global city network,’ a set of nodes in the global space of flows from which the global economy could be commanded and controlled (Sassen 1991). In describing such cities as “strategic sites where global processes materialize” (Sassen 1998, 392), they appear to be material sites floating in a sea of immaterial processes. In this model, cities are simultaneously the result of, yet alienated from, specific material processes—such as agricultural production—taking place beyond their bounds. In both concepts the informational nature of globalization is over-emphasized at the expense of its material effects. In an era of climate crisis, this shortcoming is glaring.

One response has been to radically reframe globalization as a material process of urbanization, which unfolds as the product of dialectically-entwined moments of extension and concentration (Brenner and Schmid 2013, 2015; Brenner 2013, 2016). Concentrated urbanization signifies the moment of agglomeration where the material flows of global capitalism accumulate into cities, megalopolises, and mega-regions. On the flip side, extended urbanization is the moment where remote territories are enclosed and transformed into operational landscapes that funnel energy, materials, and food into areas of accumulation. Both moments cause and are caused by the other: “The urban unfolds into the countryside just as the countryside folds back into the city” (Merrifield 2011, 474). Global capitalist urbanization is a metabolic process of moving and consuming the material world (Bridge 2009). This involves both fragmentation and homogenization (Arboleda 2016)—for example, the simultaneous expansion of monoculture agriculture and of liberal private property regimes. At the same time, enclosure and technological advances deprive peasants of their livelihoods; ‘depeasantization’ (Araghi 1995) is the mirror of urbanization.

However, the desire to develop a more materialist model of globalization leads to the black-boxing of information’s role in facilitating vast networks of production and exchange. To bring information back in requires recognizing that something happens at the moment of concentration which sets the stage for extension. In the present framework, production and the growth imperative drive a search for more raw materials. But extension also depends on informational infrastructure to make a massively decentralized network of global supply chains profitable. Indeed, another way to describe capitalist geography is as “a skein of somewhat longer networks that rather inadequately embrace the world on the basis of points that become centers of calculation” (Latour 1993, 121). Information, along with material, is being drawn inwards in the moment of concentration; the processing of raw information—which is “what remains after one abstracts from the material aspects of physical reality” (Reskinoff 1988, 2)—into actionable knowledge informs extension processes. “Information processing” is computation, and computation at the scale required to make legible the vast amounts of data produced in the contemporary economy involves enormous physical infrastructural investment in data centers, undersea cables, and satellite networks (Fard 2018). Such computational capital consists also of intellectual and human capital in the form of models, algorithms, and the expertise to deploy them.

There is a potential for the overaccumulation of computational capital, however; as a result, there is a constant drive for firms to find productive outlets. This is what leads firms like Amazon, Microsoft, Google, Oracle, and Cisco—as well as funds invested in and consultancies hired by them—into digital agriculture. By locating, extracting, and enclosing data relevant to another materially productive sector (Sadowski 2020), a firm like Amazon—whose cloud computing infrastructure Jeff Bezos has compared to power utilities—can continue to grow. This applies at the worker level, too. Just as a glut of NASA-trained engineers and physicists became quants for hedge funds after

the Space Race (Markovits 2019), a glut of software engineers and data scientists which Silicon Valley cannot absorb find employment outside of the tech sector, including at digital agriculture startups or divisions within larger agribusinesses. Indeed, agribusiness are planning for a future in which they become tech companies themselves: the head of digital agriculture at Bayer Monsanto, for example, has described the future of the conglomerate as a digital platform (Bronson 2019).

The fundamental material crisis that digital agriculture attempts to fix through the manipulation of data is in the socio-metabolic processes of capitalism and capitalist urbanization. To support social reproduction for a growing non-agrarian population, present-day industrial agriculture destroys its own ecological foundations. As Weis (2010) explains, the externalized costs of industrial agriculture

are deeply contradictory in that they mask the deterioration of the very biophysical foundations of agriculture (316). . . In order to simplify, standardize and mechanize agriculture, and increase productivity per worker, plant and animal, a series of biophysical barriers must be overridden. Efficiency gains therefore hinge on many unaccounted, non-renewable and actively destructive fixes, with fossilized biomass having an indispensable role in this process (321).

As the consequences of climate change become ever more apparent and render growing conditions ever more difficult, a new ecological regime is needed to prolong the production of cheap food and ensure future accumulation in the face of known crises (Moore 2010). But not only is fossil fuel-based industrial agricultural production partially responsible for climate change—up to one-fifth of all greenhouse gas emissions—it also exhausts the ecologies within which it is practiced. The search for the fourth agricultural revolution is not a straightforward matter of addressing a Malthusian crisis of natural population growth, but a crisis of capitalism itself.

This crisis tendency arises from capitalism's dependency on the "four cheaps"—labor, food, energy, raw materials—to maintain each cycle of accumulation. Prices for these inputs are kept artificially low by finding hitherto un-commodified spaces, "appropriat[ing] unpaid work in service to commodity production" (Moore 2014, 288). Most work must go unpaid for profit to be possible—work that has been historically done by an unpaid and externalized "nature." However, economic growth leads to increased demands for these "cheaps," which in turn threatens to push prices up, threatening profits. This results in a perpetual search for new frontiers of appropriation. The relationship between such appropriation and the exploitation of labor is central. As Moore explains, "historical capitalism has been able to resolve its recurrent crises because territorialist and capitalist agencies have been able to extend the zone of appropriation faster than the zone of exploitation" (291). That is, new frontiers of "nature" have been found or created quickly enough to keep input values low enough to maintain relatively stable rates of exploitation of labor, and thus profits, over time. The danger to capital is the final exhaustion of all such frontiers.

One way that digital agriculture functions as a data fix is by preventing the foreclosure of existing geographical frontiers. By enabling better decision-making and improved efficiency at the individual, firm, and systems levels, it delays a final collapse of the existing mode of appropriation through industrialized practices. It also enables production in areas that were difficult to cultivate even using the biotechnologies developed in the 20th century—deserts, for example, or urban vertical farms—and by making distant territories legible to centralized firms, it reduces the risk of investment in land (Li 2014). However, maintaining a profit depends on data being artificially cheap, just like food, labor, energy, and raw materials.

Data can be kept cheap because of new frontiers which are not necessarily geographical. They can also be vertical—through “varied combinations of coercion, consent, and rationalization . . . [which] maximize the unpaid ‘work’ of life outside the circuit of capital but within reach of capitalist power” (Moore 2014, 293) within territories and societies already incorporated into capitalism. Slavery, unpaid domestic labor, and the stripping away of workers’ protections are all well-known—albeit differentially monstrous—examples of this tendency to appropriate labor to enable system-level profitability. Information, in the form of data, has frequently been described as a new factor of production. A growing body of literature in critical data studies investigates data as a resource to be enclosed, extracted, and reproduced (Sadowski 2020). Digital agriculture tools allow for the enclosure of agricultural data by tech companies and large agribusinesses. This potentially allows farmers to get higher prices for their products while maintaining equal or higher profit margins elsewhere in the system.

Concentration

Above we have argued digitalization of agriculture is a response to crisis tendencies of urbanization. Digital agriculture, though, is *urban* not only in its origins and motives, but also in its effects. Digital agriculture moves the production of agricultural knowledge, and subsequently agricultural decision-making, away from farms, and indeed, away from agrarian zones entirely. This removal empowers urban actors at the expense, both in wealth and agency, of agrarian actors, upending the quasi-equilibrium of the concentrated–extended dialectic of the past decades. In turn, this shift transforms the motivations and dynamics of agricultural decisions, and thus agricultural practices, land configurations, and actors.

Traditionally, the production of agrarian knowledge has been a process of slow, localized learning. Anthropologists attribute the adoption of agricultural innovations to a mixture of environmental observation and social learning, which often involves imitating peers and people of prestige (Boyd and Richerson 1985; Heinrich 2001 via Stone 2007). The knowledge produced is locally specific, both in regard to local ecology and local values. Farmers learn what to do through their own experience with their immediate ecology, and from listening to neighbors whose experience also derives from the local area. While agronomic innovation is often imported, the learning is still

a local “process of indigenous adaptation or reinvention” (Stone 2010, 13). How and whether to apply this foreign information filters through the same process of environmental and social learning.

The Green Revolution disrupted this process as agribusinesses bussed farmers into demonstration plots on important farmers’ lands to promote bioengineered seeds (Stone 2007). The firms thus eliminated the role of observational learning and co-opted the mechanisms of social learning to sell their products. Farmers continued to imitate one another’s seed selection, but the base learning never occurred. Furthermore, the pace of new seed development was too rapid for communities to truly produce the necessary knowledge to know how a particular seed performed, let alone under various conditions. The Green Revolution deskilled farmers and centralized knowledge with universities and private firms (Patel 2013).

The digitalization of agriculture expands this enclosure into new facets of agricultural practice. In a process common to data capitalism, digital agriculture conducts an “epistemic harvest” (Hunger 2018) in which physical events, actions, and conditions are translated into computationally comprehensible information. This translation into bits not only converts information into material representation, but the ability to move this information renders new spaces legible at a distance. Indeed, given the costs of computational capital, the data are often *only* legible at a distance, in urban control centers with the necessary means of processing. Moreover, the usefulness of these data often depend on their aggregation with other data. Data are relatively uninformative in small quantities, but tremendously generative when aggregated as “big data.” Typically, then, digital agriculture collects agricultural phenomena, whether through sensors or user input, abstracts them into binary form, sends them away for processing into information, and reimports this newly computed information to sites of agricultural production. In this model, knowledge is no longer *learned* by agrarian actors in agrarian zones; instead knowledge is *computed* by off-site processors and farmers are instructed on what to do. As with genetically modified organisms (GMOs), this process alienates farmers from the knowledge they depend on and centralizes it among non-growing actors.

Fraser (2019) labels this contemporary movement of information away from agrarian actors a “data grab” akin to earlier land grabs. The concentration of control shifts from ownership of land to the direction of practices. Agribusiness is already a highly consolidated industry, and its role in digital agriculture means the consolidation of digital agriculture’s information and profits. The ‘Big Four’ seed and chemical agribusinesses have more than 84% global market share in agrochemicals. Two of them—Bayer-Monsanto and Corteva—have more than 43% of the global market in seeds (IPES-Food 2017). Bayer and Monsanto merged in 2018, and Dow and DuPont joined in 2017 (before spinning off their combined agribusinesses as an independent company, Corteva, in June 2019). Further along the value chain, the ‘ABCD’ companies—Archer Daniels Midland (ADM), Bunge, Cargill, and Louis Dreyfus—dominate

agricultural commodities trading. It is estimated that 75–90% of the global grain supply passes through their hands.

All of these actors are investing heavily in digital agriculture. The Big Four's most notable efforts are designed to synergize with their seed and chemical offerings. For example, Corteva owns Granular, which links precision agriculture tools, such as satellite-based field monitoring and machine-learning based fertilizer advice, with a financial management platform. Bayer-Monsanto, BASF, and Syngenta each have prominently-branded digital offerings. Syngenta's not-for-profit arm developed the smallholder management platform FarmForce, which explicitly aims to bring farmers in the Global South into global markets—under Syngenta's aegis. The ABCD companies are also investing in digital platforms. In 2018, for example, ADM and Cargill jointly formed Grainbridge, a platform that provides financial and market decision-making support. All eight of these firms are continuously buying digital startups, and each operates a venture arm that invests in such companies.

Tech companies, startups, and NGOs are also involved in digital agriculture. Google Cloud Platform supports the MIT-run Open Agriculture Foundation, a “global community to accelerate digital agricultural innovation.” Microsoft not only partners with digital agriculture NGOs and startups like the sensor-focused SunCulture and platform-driven Ag-Analytics, but also has an in-house platform built on its Azure cloud computing network. FarmBeats, as it is known, is designed to underlie consumer-facing applications by integrating diverse datasets and feeding them into machine learning models. Amazon Web Services, Oracle, Cisco, and others also seek a place in the agriculture industry.

Globally, investment in agricultural technology grew eight times from 2013 to 2018. This was not just driven by agribusiness and Silicon Valley, however. Sovereign wealth funds have also invested hundreds of millions in digital agriculture and closely related sectors. For example, Temasek, Singapore's fund, has made digital agriculture a key focus of investment. In November 2019 it published “The Asia Food Challenge”—in partnership with PWC and Rabobank—to encourage investment in the sector. Earlier that same year, they launched an impact investment fund specifically targeting agricultural production.

While they are increasingly involving themselves in agriculture, these actors are not agrarian. Digital agriculture increases the control of agribusiness and facilitates the entrance of tech and VC firms. Through its capacity to render agriculture legible at a distance, digital agriculture enables firms traditionally outside of agriculture to easily lean into it, and in doing so enables a moment of primitive accumulation of data. Fraser (2019) sees hope in the possibility of ‘data sovereignty,’ a twenty-first century update of Friedmann's agropolitan districts in which growers control the data and knowledge of agricultural production, but that utopia does not yet exist. While digital agriculture could be a set of technologies that empower farmers to learn better, knowledge production via digital agriculture is instead overseen by urban actors, with

differing motives and agendas. In Finistere's 2018 report, a Wells Fargo executive justifies their data grab:

Growers don't really care about data. They care about whatever that will give them either more time or make them more profitable. The companies that really understand that dynamic and how to translate their value into dollars and cents will have the best shot, because they're able to provide links between field productivity and monetary results. Linkage to the financials is so, so important. Not just from a decision standpoint, but from the viewpoint of the bottom line (16).

Many of these firms and organizations involved in digital agriculture are headquartered and process data in sites of urban concentration. The humans of computational capital—the programmers and analysts who develop the digital tools and algorithms—are gathered in cities, and therefore the analytic work of digital agriculture occurs within them. The actors dominating digital agriculture, however, are urban not because of the locations of their offices, but because of their roles in the process of urbanization. As urbanization is a growth-driven process of imploding agglomeration that transforms and appropriates zones of support, the platform-providers of digital agriculture are growth-obedient instances of accumulation and consolidated control. Increasingly the world's countless farms are now partially managed by a countable set of digital agriculture firms.

Extension

The control of knowledge production enables the control of decision-making. The urbanization—the off-site consolidation—of agricultural knowledge through digital agriculture's data grab and the urban bias of computational capital subsequently urbanizes agricultural practices, and affords urban firms more remote influence over agricultural production. This instance of the transformation of the 'hinterlands' is achieved through instruction, nudges, contracts, and conforming. Through these direct and indirect processes digital agriculture has the potential to reconfigure cultivation, land, and labor in the interest of accumulation in non-agrarian urban sectors.

First, the design decisions embedded in digital agriculture prioritize particular growing practices. Precision agriculture privileges industrial planting practices and export-oriented crops. Satellite imaging that detects yield, disease, and pests, for example, depends on homogenous fields of homogenous seed, thus precluding actually sustainable practices of polyculture growing and intraspecific diversity. In order to benefit from many digital agriculture technologies, farmers need to simplify their production to fit into the strictures of what the new technologies can observe and optimize. This simplification is not only of practices but also of values and objectives, as digital agriculture prioritizes profit and export crops (Bronson 2019). The majority of in-field sensors are for soy, maize, and canola—that is, they are for commodity crops which go to and support sites of concentrated urbanization. These are crops which are

primarily intended for export markets and whose derivatives are commonly traded. Digital agriculture technologies, then, increase the advantage of large commercial farms and perpetuate certain data-legible decisions.

In the Global South, digital agriculture more often takes the form of e-extension. Conventionally, agricultural extension consists of field workers, on behalf of the state or development organizations, visiting farmers to educate them on better practices. With e-extension organizations can contact farmers through their mobile devices. This digitalization enables new actors, who are able to bypass the role of the state. As with traditional extension, these e-extension programs generally advise farmers on when and which crops to plant and on inputs to use. E-extension, however, is able to reach many more farmers much more quickly, communicate with them much more frequently, and make more specific recommendations.

The non-profit Precision Agriculture for Development (PAD) goes one step further by using A/B testing and machine learning, not to improve its advice but to increase the likelihood of farmers' adherence to its advice.⁴ While smallholders are not bound to PAD's recommendations, PAD (a) promises higher yields and profits, (b) holds a monopoly on knowledge, and (c) is using its knowledge to ensure obedience. This external control, a dynamic of urbanized agrarian knowledge, is problematic in its own right: while often very specific about climate and soil conditions, PAD appears to take little heed of local social, cultural, and political context, and determines its users' best interests for them.

The off-site decision-making, though, becomes more questionable when we learn that PAD has recently partnered with Bayer. Bayer funds PAD's work in Bangladesh and provides PAD with contact information for its former customers (Lehe 2019). PAD then advises these and other farmers on how much of which inputs to use, such as Bayer's fertilizer. PAD reported in 2019 that "farmers . . . were 18% more likely to report using a Bayer product, while trust and satisfaction did not change. Farmers also recommended Bayer products to 8 other farmers, on average" (Precision Agriculture for Development 2019, 4). Effectively, PAD is a marketing arm for agribusiness as it enlists smallholders into global commodity production. In pursuit of "long-term financial sustainability," and given the success of the Bayer pilot, PAD has begun to consider if "it is worth exploring whether incorporating brand promotions can help PAD and other partners develop commercial advisory services that can be sold to for-profit agribusinesses and offered free of charge to farmers."

Here PAD shifts from being a service for farmers to being a service for for-profit agribusiness. PAD continues to offer free advice to farmers, but its client has changed. The agribusiness company has replaced the farmer as PAD's primary relationship. E-Sagu represents an earlier example, beginning in 2004, of an e-extension company

⁴ PAD attributes this advice to other institutional sources more expert in agricultural advice, but PAD still ultimately decides which recommendations to make, acting as the curatorial gatekeeper of knowledge.

that connected farmers with urban agricultural experts and that ultimately turned to partnerships with input vendors to stay afloat (Stone 2010). Given the wealth extraction already wrought on agrarian and post-colonial zones and the exacerbation of that extraction via digital agriculture, such an e-extension service is unlikely to soon exist without similar privatization, unless supported by the state. We can expect e-extension to continue to be a means, like digital agriculture more broadly, of corporate and urban influence.

Second, digital agriculture not only perpetuates certain agricultural practices—namely export-oriented and input-dependent—it also, through partnerships such as with PAD and Bayer, and more straightforwardly through privately-owned PA companies, privileges larger farms and furthers corporate control of independently owned agricultural land.

In the US, the number of farms between ten and 1,999 acres has fallen since 2007, while the percentage of land in farms larger than 2,000 acres has increased from 40% to 47% in 2017 (USDA).⁵ This accompanies a general trend of increasing farm sizes (Deininger 2011), especially in high-income countries (Lowder et al. 2016), and the much discussed global land grab (Borras et al. 2011). While the reasons for this pattern are various, digital agriculture continues the privileging of larger farms. Digital agriculture favors wealthier farms that grow according to methods conducive to data collection and which produce profits sufficient to afford the technology. This privileging begins with the installation of these technologies. Implementation requires capital investment in sensors to acquire data, connectivity infrastructure to connect the data, and advanced machinery to use the data. The cost of this equipment limits much of its application to wealthier or more financialized farms (Bronson 2019).⁶ These significant investments give uneven returns, which further privilege larger-scale commodity-oriented farms.

Digital agriculture, though, also changes *control* of land, even when ownership does not change. McMichael, quoting the peasant coalition Via Campesina, observes of pre-digital agriculture agribusiness that

agribusiness power no longer resided in control over land, rather in the relations that surround agricultural production—those that “control loans, materials supply, the dissemination of new technologies, such as transgenic products, on the one hand, and those that control national and international product warehousing systems, transportation, distribution and retail sales to the consumer, on the other hand, have real power” (McMichael 2012, 684).

Digital agriculture adds to the litany. By dictating decision-making, firms achieve control of farms’ inputs and outputs without the risk of fixed assets or of produc-

5 Authors’ calculations, USDA censuses 2007, 2012, 2019.

6 This machinery becomes a new fixed cost for farmers, often requiring loans, thus further indebting farmers and financializing agriculture.

tion, and without any obligations to labor welfare. This risk minimization parallels the strategy of contract farming, in which firms set prices and conditions with farms at the beginning of the season. Firms, here too, dictate inputs, even providing loans for them. Under this arrangement farmers carry the risk of production—firms instruct what to grow but bear no liability for a bad harvest—all while production is organized into a form that caters to the interest of investment.

Digital agriculture, though, does not just parallel contract farming; it has also become a tool for contract farming. Smallholder farmer management platforms streamline the contracting process by facilitating communication from firm to farm and allowing firms to have more oversight of farms; by making contract farming easier and cheaper, these platforms then spread the model. Farmforce is a particularly notable example of such a platform, and through its Syngenta-provenance indicates contract farming's appeal to agribusiness corporations (Farmforce 2017). Digital agriculture further supports contractors by increasing their ability to forecast prices and thereby minimizing their price risk. Though this risk is minimal for contractors, primarily resting on growers (Sarkar 2014), firms still bear some degree of the price risk. While some platforms have also emerged to better inform farmers of market prices, firms remain better positioned, with greater computational capital, to forecast global production and demand, allowing them to set prices more in their interest.

These digital agriculture models not only minimize economic risk, they also minimize political risk. By allowing family ownership of farms, contract farming and e-extension give the appearances of independence and a distributed means of production and are therefore less provocative of land reform; agribusiness does not need to fear land seizure. In places where land reform has already occurred, such as Zimbabwe, these mechanisms represent a way forward for corporate control.⁷ Rather than a land grab, digital agriculture in the Global South facilitates a data and production grab. The appearance of smallholder ownership makes these new grabs more palatable and may demobilize rural classes.

Finally, digitalization disrupts agricultural *labor*. As an intensification of industrialized and automated agriculture more broadly, digital agriculture is anticipated to eliminate the need for farm labor (Carolan 2020), but its effects on labor are broader. Digital agriculture is likely to deskill workers, further bind their fortunes to the global commodity market and potentially turn them into urban migrants.

Digital agriculture's land consequences described above shape urbanization at its sites of both explosion and implosion. As it reconfigures land ownership in the operational landscapes of extended urbanization by privileging large estates and by making smallholding more amenable to capital's interests, it simultaneously denies the autonomy of the farmers on these smaller plots. Both of these are likely to incorporate

7 For a study of how contract farming has infiltrated and taken advantage of post-land-reform Zimbabwe, refer to Scoones et al. 2018. Agro Axess is one smallholder farmer management platform that has emerged in Zimbabwe to facilitate this contract farming.

more growers into the global commodity market to sustain non-agrarian production. Especially in the Global South, where subsistence farming is more common, digital agriculture's orientation toward larger farms may eventually displace smallholders and convert them into wage workers, as they leave their own plots and work for the commercial outfits.

Meanwhile, farmers that retain ownership are also further incorporated into the global commodity market because of PA and e-extensions recommendations. As such, their food security is undermined (Davis 2001, 289). They lose the means of subsistence, even as they maintain the means of production—they own land but increasingly do not own their time or behavior—and become more vulnerable to the “vagaries of world market prices” (Araghi 1995, 356).⁸ This threatens smallholder farmers' very ability to survive and pushes them toward wage work and cities for imagined greater stability (Sen 1977, 56; Araghi 2000). Contract farming and extension, even more so under their digital exacerbation, could lead to dispossession and displacement, and ultimately de-ruralization, sending peasants to cities to become informal urban surplus labor.

Digital agriculture also contributes to deskilling. As described above, digital agriculture changes how agrarian knowledge is produced and disseminated. As with urbanization at large, this change is important not only for how it concentrates, but also for how this concentration folds back onto the countryside. The disruption of agricultural learning deskills rural workers, ultimately undermining the farmer welfare digital agriculture allegedly pursues. Originally observed in manufacturing contexts, deskilling is the degradation of labor through the separation of mental from manual work; laborers are “more expensive and less controllable” than machines, and thus require replacement (Braverman via Stone 2007, 72). Stone takes this theory and partially applies it to agricultural production in the GMO era. He finds that deskilling appears differently in an agrarian context as, among other differences, farming is “much more dynamic” (73) and the farmer needs to make many more decisions than does a factory worker. He therefore finds that with agriculture, deskilling is primarily useful as a metaphor rather than a theoretical model.

A decade later, though, digital agriculture may make agricultural deskilling much more literal, by moving the decision-making off-site. With GMOs, farmers' learning process and ability to make decisions are disrupted by a rapid pace of new technologies they do not understand; they still, however, must make decisions. With digital agriculture, which informs farmers about what to do—whether through sensors or extension—this is no longer the case: farmers no longer need to make decisions as these decisions are made for them, from a distance. More data is needed to understand the effects of deskilling from digital agriculture's various technologies, but the bioen-

8 Araghi here is quoting Sen who, in expanded form, writes, “For those who do not grow food themselves (e.g. artisans or barbers), or those who do grow food but do not possess the food they grow (e.g. cash-wage agricultural labourers), the vagaries of the market can have a decisive influence on their ability (and that of their families) to survive” (Sen 1977, 56)

gineering feats of the late twentieth century give an indication of what is to come. As deskilling is not only the disruption of particular knowledges but the “disruption of the process of experimentation and development of management skill” (Stone 2007, 67), deskilling and the potential obsolescence of on-site decision-making has (concentrated) urban implications, especially should digital agriculture contribute to continued deruralization. This decapacitation of management skills not only disempowers the farmer as farmer, but also potentially renders them less qualified for the urban labor market, and potentially contributes to a less equipped urban reserve of labor. Within agrarian zones, deskilling could also have destructive ecological effects: Vandeman (1995) observed that deskilling alienated farmers’ knowledge of their own land.

Conclusion

The frequently proffered problematic of “feeding the next two billion” is not the fundamental reason a “digital revolution” in agriculture is necessary. The fundamental reason is industrial agriculture’s tendency to deprecate the conditions of its own success in order to keep food prices artificially low, which stabilizes the rate of labor exploitation in non-agricultural ‘urban’ sectors and permits the generation of profit. In other words, it is about using information, computation, and new surpluses of human nature to maintain the status quo of cheap food and subsidized capitalist urbanization.

This analysis is a very early cut at digital agriculture from the perspective of urban/rural relations. A great deal of further research is possible. Open-source platforms for farmer data management are emerging, for example, which allow producers to retain ownership over their data and therefore have the potential to reduce, if only partially, the power imbalance between farmers and transnational agribusinesses. We have also only touched on the role of machine learning and artificial intelligence, a field which is growing at an astonishingly fast rate and may soon have profound effects on digital agriculture. In the near future, “computational agriculture” may offer truly revolutionary developments.

Carefully tracing digital agriculture data usage by tech firms and agribusinesses may also reveal its role in facilitating the financialization of agriculture (c.f. Clapp 2014; Isakson 2014; Vander Stichele 2015; USAID 2016). Financial capitalists must be able to “accurately” assess risk, and price financial instruments and/or speculative purchases accordingly. However, this must be done from their positions in cities—that is, from a distance. Digital agriculture may provide the necessary information they need. The risk profiles of farmers can be more easily determined. Speculation on futures markets can be priced more confidently. The prices offered farmers in contract deals can be set to the advantage of agribusinesses. The knowledge needed to invest in land may be more easily assembled (Li 2014). The agricultural sector can be grasped at larger and larger scales, facilitating financial inflows at all levels, across all actors—producers, input providers, water providers, traders, processors, and so forth. Like all politi-

cal-economic actors at a non-local scale, financial capitalists demand legibility—and computed data, provided by digital agriculture, may provide it.

Finally, digital agriculture demands an analysis of its neocolonial functions in late capitalist globalization. In this paper we have extended the critique of digital agriculture through the perspective of urbanization's concentration and extension. Many scholars have pointed out the relationship between the early modern development of non-agrarian economic sectors, the growth of cities, and colonialism. While generative, the urban lens by itself is incomplete for examining how digital agriculture lays the groundwork for extraction from the periphery and accumulation in the "center." Digital agriculture appears differently in the Global South than in the Global North, and as of yet, most literature on the topic focuses on the northern manifestation, which primarily involves precision agriculture equipment. This paper takes an initial look at the tools, including e-extension and smallholder management, digital agriculture deploys in the Global South, but much more is needed. A specific focus on the Global South is necessary, though, not only because of differences in technologies but also and especially for reasons of colonial legacy. Scholars have identified the colonial and neo-colonial origins of some tools used in digital agriculture and the development organizations that are now promoting digital agriculture in the Global South, but little to none has been written about the neo-colonial functioning of digital agriculture as an industry. Megan Black (2018), for example, writes about Landsat imagery, which is frequently used today to read agricultural field conditions: "American and Interior officials in the 1960s . . . sought to bring the mineral-rich interiors of the Third World into global circulation" (185). Her account, however, focuses on mineral extraction in the pre-digital agriculture era.

Such an analysis should assess not only the extractive effect of external technologies, but also the radical potential of locally-developed and scaled digital agriculture tools. In 1961, Fanon understood the need for re-centering agricultural knowledge within formerly colonized lands, and declared the need for a post-colonial agronomy. Digital agriculture may present an opportunity for this new science to take root.

The soil needs researching as well as the subsoil, the rivers why not the sun. In order to do this, however, something other than human investment is needed. It requires capital, technicians, engineers and mechanics, etc. Let us confess, we believe that the huge effort demanded of the people of the underdeveloped nations by their leaders will not produce the results expected. If working conditions are not modified it will take centuries to humanize this world...(Fanon 1963, 57).

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