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'You can't eat data'?: Moving beyond the misconfigured innovations of smart farming

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ABSTRACT

This paper presents a critical examination of smart farming. I follow other critical analyses in recognizing the centrality of innovation processes in generating smart farming products, services, arrangements, and problematic outcomes. I subsequently use insights from critical human geography scholarship on the significance of understanding topological transformations to move beyond interpretations that identify only a narrow range of smart farming problems, such as a lack of coordination or limited uptake by farmers. Instead, I examine a broader set of challenges produced by smart farming developments. The overriding concern, I argue, is that smart farming unfolds via the production of numerous 'misconfigured innovations.' Using insights from literature on responsible research and innovation I then probe the stakes of looking beyond the misconfigured innovations of smart farming and discuss how new technologies might come to play a role in producing emancipatory smart farming. I pay attention to research on the 'internet of people,' which paints a stark new picture of social life generally, and in particular how rural life might be computed and calculated according to new conceptualizations of sociality and spatiality.

1. Introduction

In data servers rented from 'cloud' providers such as Amazon Web Services, and across fibre optical cables connecting financial centres such as Chicago, New York, and London, algorithms owned and designed by high-frequency trading firms chase after and exploit milliseconds-long opportunities to make (often, substantial) profits (Hayles, 2017). Involving humans but creating "regions of technical autonomy" (p.142) where they are absent, high-frequency trading revolves around "machine-machine ecologies" (p.172) proceeding along "an autonomous trajectory in a temporal regime inaccessible to direct conscious intervention" (p.165). With around 80% of financial markets now run by machines (Amaro, 2018), this expanding scene of autonomous action signposts the power and social significance of technical cognitive assemblages interacting with human cognition to form a "planetary cognitive ecology" (Hayles, 2017 p.3) – an especially helpful concept, I argue, because it highlights the rising significance of widespread but often obscure digital technologies in the production of daily life.

Farming is constitutive of this emerging ecology because a proportion of the billions of transactions taking place each day on these financial markets always pertains to agricultural commodities (e.g. on relations between high-frequency trading and the live cattle futures market, see Couleau and Serra, 2017). At a time when current and future values and prices of food crops fluctuate according to the autonomous actions of machines, new efforts to create so-called 'smart farming' arrangements *amplify* the relationship between agriculture and digital life (e.g. see Bronson and Knezevic, 2016; Schimmelpfennig, 2016; Schrijver et al., 2016; Wolfert et al., 2017; Eastwood et al., 2017; Eastwood et al., 2019a; Higgins and Bryant, 2020). Underpinned, at least in part, on the claim that digital worlds populated by smart technologies will produce new economic efficiencies, smart farming creates opportunities for firms to collect and use data to then develop valuable insights. A 'smart' tractor, for example, is developed by firms such as John Deere or Kubota with one eye on the field it will harvest, and another eye on connecting data it might be able to harvest (e.g. see Bronson and Knezevic, 2016) with other 'reserves' of data (Cheney-Lippold, 2018).

More broadly, smart farming reflects a drive by agricultural technology providers (ATPs) and agricultural transnational corporations (hereafter, agri-TNCs) to establish strategic positions within the broader digital economy. A useful case in point here is the recent transformation of Monsanto (now owned by Bayer) "from an agricultural biotechnology company into a data-science-driven organization" (Thompson et al., 2020 n.p.). Its strategy "entails the mass collection of farm data through

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sensors attached to everything from tractors to water sources. All the data is fed through a digital platform set up by a service provider, whose algorithms display conditions on the farm and make specific recommendations." The firm bought startups such as Precision Farming in 2012 for USD 210 million and Climate Corp in 2013 for USD 930 million, while adapting a software platform from the AI firm Data Robot as it sought to "invest in the technologies to gather and study all the data underlying decision-making on farms." Today, "Hundreds of models (a third of which are machine-learning based) run on the platform to develop innovations for the company's supply chain, its commercial processes, and, of course, farmers." Monsanto has therefore retooled its employees and increased its data science team from 200 in 2017 to 500 people in 2020.

Against this general backdrop, the following paper presents a critical examination of smart farming by culling insights from recent contributions across a wide range of pertinent literatures. I begin by reviewing literature on smart farming with a view to identifying lessons about extant and emerging innovation processes. I follow other critical analyses in recognizing the centrality of innovation processes in generating smart farming products, services, arrangements, and problematic outcomes (e.g. see Bronson and Knezevic, 2016; Eastwood et al., 2017; Bronson, 2019; Eastwood et al., 2019a; Higgins and Bryant, 2020). I then use insights from critical human geography scholarship on the significance of understanding topological transformations (e.g. Allen 2011; 2016; 2020; Hinchliffe et al., 2013; Dixon and Jones, 2015) to move beyond interpretations that identify only a narrow range of smart farming problems, such as a lack of coordination or limited uptake by farmers. Instead, I examine a broader set of challenges produced by smart farming developments. The overriding concern, I argue, is that smart farming unfolds via the production of numerous 'misconfigured innovations.' Next, inspired by insights from literature on responsible research and innovation (Bronson, 2018; Rose and Chilvers, 2018; Eastwood et al., 2019b), I probe the stakes of looking beyond the misconfigured innovations of smart farming. I discuss how new technologies might come to play a role in producing emancipatory smart farming. As I will explain, 'actually existing' smart-farming developments connect with activities on the technological horizon. I pay particular attention to research on the 'internet of people' (e.g. see Miranda et al., 2015; Conti et al., 2017; Conti and Passarella 2018; Lagerspetz et al., 2018), which paints a stark new picture of social life generally, and rural life in particular. The provocative scenarios painted by this line of research should alert rural studies scholars to a new scene computed and calculated according to new conceptualizations of sociality and spatiality. Finally, I refer to some recent efforts to introduce 'smart' technologies and practices to India. I use this case as a springboard toward identifying requirements for alternative, *emancipatory* versions of smart farming.

2. Fragile configurations of smart farming

Discussions of smart farming tend to have specific technical developments in mind (Wolfert et al., 2017). The central consideration is the use of information-intensive digital technologies to enable new practices, such as satellite-guided and even auto-steering farm machinery (Bronson and Knezevic, 2016; Schimmelpfennig, 2016), automatic milking systems (Eastwood et al., 2017; Schrijver et al., 2016), or automated body condition scoring for livestock (Eastwood et al., 2019a). The objective is to use digital technologies to make more efficient use of inputs such as labour, pesticides, or fertilizer and thereby improve the quality or quantity of outputs. Smart farming technologies such as soil water outlook tools (Eastwood et al., 2019a) or new rice varieties (Higgins and Bryant, 2020) conceivably create competitive advantages that justify investment. The vision, then, is that "farming and food will be transformed into smart webs of connected objects that are context-sensitive and can be identified, sensed and controlled remotely […] resulting in new control mechanisms and new business models" (Sundmaeker et al., 2016).

Yet, although the main zone of action for smart farming is the farm itself, these developments in rural space connect activities to wider (socio-natural) ecologies. It is impossible to ignore how new digital actions on the farm overlap with numerous other 'smart' moves along the food value chain. In supermarkets such as the UK's Ocado, for example, investments in robotics yield new data-intensive platforms (Fraser, 2020). In restaurants, McDonald's has established a Tech Lab to integrate startups such as the voice-based Apprente, which it purchased with a view to improving the drive-thru customer experience (Thompson et al., 2020); McDonald's has also invested in Plexure, a New Zealand firm which "creates personalized offers for individuals" when they enter a McDonald's drive-thru (Mander, 2020).[1] Elsewhere, artificial intelligence informs voice recognition services in smartphone apps run by companies such as iFood, the Brazilian food delivery company (Mari, 2018). Soon, these sorts of firms will integrate "unsupervised predictive learning" (Anthes, 2017, p.20) to work on data in unanticipated ways and, if society awards it authority, conceivably manage "ever more complex algorithm-centric economies" (Curioni, 2018 p.10). Indeed, in some scenarios, AI will have the computing power and intelligence to paint pictures of future worlds, and thereafter work on activating socio-technical relations, according to *its* vision of what should work (Tegmark, 2017).

In acknowledging the overlaps and connections between on-farm smart farming developments and more general digital shifts along the food value chain, my aim is to locate smart farming as a crucial zone of action within the 'planetary cognitive ecology' (Hayles, 2017). As such, the developments at issue in this paper warrant examination in the light of critical scholarship on digital life (e.g. on 'critical data studies,' see Dalton et al., 2016). One core point of this scholarship is that 'smart' life generally – and particular developments such as those pertaining to smart farming (e.g. see Bronson and Knezevic, 2016; Fraser, 2019a) – creates new sociotechnical realities that empower 'big tech' to syphon off or dispossess diverse digital subjects of value generated by analysing data about their activities (e.g. see Thatcher et al., 2016; Birch et al., 2020; Sadowski, 2020). Moreover, when "data is the new cash crop" (Tatge, 2016) to be harvested from smart farming arrangements, other effects emerge, such as a tendency to enrol automated infrastructures, often governed by opaque, oppressive (e.g. see Noble, 2018), and inherently biased proprietary algorithms searching for and expecting to find predictable patterns across socio-ecological environments. Food producers today are confronting new pressures from the operation of algorithms controlled by tech firms or integrated into the emerging operations of supplier, processing, and retail firms up- and downstream of the farm (Mooney 2018; also Carolan, 2020). There are new players on the scene, such as the British online supermarket Ocado (Fraser, 2020) using data to glean novel insights about food systems. In the US, moreover, Amazon is pursuing market share along the food chain. As Mooney (2018, p.392) notes, it might soon be "setting the standards and trends for food security and nutrition." Thus, per the analytical direction offered by critical data studies, the emergence of smart technologies in the food system – on farms, of course, but also in supermarkets, restaurants, or other foodscapes – requires a focus on uneven effects, with some stakeholders making clear and significant gains, while others lose out in diverse ways.

In this regard, smart farming developments also invite analyses informed by scholarship in critical agrarian studies and its insistence on recognizing power asymmetries within the 'corporate food regime' (McMichael, 2005, 2012; Akram-Lodhi, 2015). At one extreme, a small number of large and powerful agri-TNCs exert influence up- and downstream of the farm; at another, close to three billion people remain (or rely on) smallholders and small family farmers occupying vulnerable

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[1] Plexure also has deals with supermarkets, such as Super-Indo in Indonesia, which is owned by Ahold Delhaize.

positions within global value chains. Whenever arguments about the virtues of smart farming (or similar terms such as 'precision agriculture') emerge in the context of the research and development activities driven by agri-TNCs, scholarship in critical agrarian studies suggests alarm bells should ring. One central concern is the role of smart farming in laying the conditions for 'land grabs' (Fraser, 2019a). Because it is bound up with a broader push to transform and 'modernize' agricultural practices, it emerges with a view (at least implicitly) to widening the 'yield gap' (World Bank, 2007) between capitalist and peasant sub-sectors of the food system (Akram-Lodhi, 2007). Pressures on peasants and other smallholders to leave the land will intensify if smart farming operations in capital-intensive settings increase their yields, potentially while reducing their use of expensive agricultural inputs such as pesticides.

Looking more closely at the emergence of smart farming developments, another crucial consideration pertains to the innovation processes that try to generate and integrate new and striking configurations of firms, farmers, and research institutes. New networks of diverse stakeholders are formed; extant networks are re-made, potentially rendering invisible the role of some actors and their interests. In a sense, then, smart farming can resemble the notion of "innovation by withdrawal" (Goulet and Vinck, 2012), which departs from the view that innovation is "structured around the introduction of a new element, an artefact, a way of operating, a service, and its success is dependent on the number of adopters and the significance of the entities (resources, skills, etc.) which are articulated with it" (p.118). Yet, as demonstrated by the case of no-till farming in France (pp.121-140), withdrawal of one element (tilling) relies on making visible hitherto invisible or overlooked elements (worms), while maintaining problematic practices (using pesticides).

To respond, an alternative to focusing on introduction or withdrawal is to recognize that agricultural innovation, like any other practice, is always a topological affair: it is about overseeing and managing configurations of humans and materials and how they flow through a system or across a specific domain, such as a field (on topological conceptualizations see Allen 2011, 2016, 2020; Hinchliffe et al., 2013; Dixon and Jones, 2015). Where there are blockages, conduits can be installed to increase flows; where there are leaks, plugs are required. Farmers shift and prod to adjust arrangements of materials or relations with a view to addressing problems, such as falling yields, vulnerabilities to climatic variability, or exposure to viruses. A mechanism of implementing innovations such as those associated with smart farming is to reconfigure topological arrangements. As demonstrated by literature on agricultural biosecurity (e.g. see Hinchliffe et al., 2013), farming practice needs to be viewed as occurring against the topological backdrop of an "entangled interplay" (p.540), with numerous "contingent intra-actions" (p.541) occurring across multiple risky "borderlands" (pp.537-540). Proximities, distance, connectivities, and modulations of presence/absence figure in the effort to create desired outcomes, with new insertions or removals pursued in efforts to control or steer activities in defined or experimental ways. Whether the risk is a matter of falling yields or exposure to viruses, it pays to acknowledge the ongoing relationship between farming and innovation through a topological lens; that is, to dwell on farmers as active agents of topological transformation, even if they are rarely acting alone.

One way to combine an analytical concern with digital life, corporate interests in establishing a certain type of smart farming, and topological transformations is highlighted by literature on smart farming innovation processes. Consider, for example, how new configurations come into the picture. As highlighted in research on smart farming in Canada, and as referenced by Relf-Eckstein et al. (2019), the Canadian government has recently established innovation 'superclusters' to examine and exploit technological opportunities. A recent outcome is an industry-led consortia called Protein Industries Canada, which includes a partnership whereby Lucent BioSciences "will use the hulls of pea and lentil seeds which are a co-product from value-added processing completed by AGT Foods and Ingredients [to create] Soileos: a novel carbon-neutral micronutrient fertilizer that uses organic fibre as a carrier to provide micronutrients to plants" (Protein Industries Canada, 2020). As this case suggests, the 'smart' in smart farming can involve astute and imaginative arrangements to make new products and chase after profits in novel ways.

A similar picture emerges in the Netherlands where a "golden triangle" (Farhangi et al., 2020 p.11) of agricultural research, industry, and government aims to create "new business ecosystems consisting of focal firms, their suppliers, complementor firms, and customers" (p.12). A key feature is the leading role of the Dutch firm Philips, which occupies a prominent position in high-tech urban agriculture (otherwise referred to as 'controlled environment agriculture [Goodman and Minner, 2019]), a growing smart farming sector, by "providing the essential technologies, registration of patents, and creation of new business opportunities" (p.12). Meanwhile, in the larger and more traditional Dutch agricultural sector, the Food Valley Open Innovation Ecosystem includes "the Wageningen Campus and the planned World Food Centre in Ede" (Omta, 2017 p.7) and creates ties between research and development centres run by large firms such as FrieslandCampina and Unilever and wider networks of small-to-medium enterprises and startups. There are 15,000 scientists across Food Valley, with twenty research institutes, 1440 food related, and 70 science related firms (p.7). Such configurations of firms, farmers and research institutes will likely create new smart farming products and services and build on Dutch successes in exporting around €9 billion worth of high-tech agrifood innovations, including "energy-efficient greenhouses, precision agricultural systems and new discoveries that make crops more resistant" (p.9).

Put differently, the topologies of smart farming point toward new forms of "path creation" (MacKinnon et al., 2019) that involve but also often extend beyond farmers. It is instructive that smart farming today is bound up with efforts to use 'open innovation' processes that facilitate co-design or co-innovation between agricultural technology providers, farmers, and others. Such an approach can "blur the boundaries between scientists and agricultural system stakeholders, between agronomists and farmers, and between actors in the agricultural sector and those designing in other sectors" (Berthet et al., 2018 p.112). The virtue of "participatory design processes involving farmers" (p.112) is that it can yield new tools, such as dashboards (Prost et al., 2018), to help farmers understand agro-ecological conditions.

There are, however, no guarantees that smart farming developments will yield effective configurations. Indeed, there is significant evidence that smart farming developments are hamstrung not only by the instrumental logics underpinning technology providers but also by ineffective coordination and inadequate arrangements of materials or skills. Consider here the push to develop automated body condition scoring and a soil water outlook tool (SWO) for Australian dairy farmers (Eastwood et al., 2019a). Noting that these versions of smart farming innovation involve "a unique innovation challenge [not least because of] the new knowledge demands for farmers in a highly dynamic, technology-driven environment" (p.2), one finding is that the new tools and practices confront limitations in the way agricultural relations are configured with respect to the wider institutional milieu. Making the most of the soil water outlook tool, for example, required but did not receive sufficient input from the Australian Bureau of Meteorology "to help farmers to link the SWO with seasonal climate outlooks" (p.5). Then, with regards to automated body condition scoring, the new technology led some farmers to think "maybe we don't need the [farm] advisor as often," (p.6), with the upshot that "some tools were potentially replacing the skills of advisors" (p.6). Yet, because "more remote monitoring of key performance indicator data via online software" (p.7) can enable farm advisors to make fewer farm visits, smart farming in this context conceivably increases the sense of isolation many farmers already experience (Kelly et al., 2019). Elsewhere in Australia, smart farming developments call attention to a different dynamic between farmers and advisors. In some rice farming regions, advisors might be expected to be the “sensemakers” (Eastwood et al., 2019a) who can explain and encourage farmers to adopt new technologies; but in fact one consultant respondent claimed “it’s mainly been the farmers dragging the agronomists along” (Higgins and Bryant, 2020 p.445).

At the same time, “insufficient support structures” (Eastwood et al., 2017 p.2), for example regarding data compatibility or standards, can hold back adoption and frustrate farmers who are “prepared to use evolving and uncertainty-generating technologies” (p.7) but find that their knowledge is not effectively tapped. In Canada, ‘broadacre’ smart farming developments occur amid the “critical constraint” (Relf-Eckstein et al., 2019 p.1) of labour shortages and demographic change, but even here “adoption is lower than anticipated” (p.2), with one explanation focusing on tensions around what happens to data produced on farms. A problem yet to be overcome is industry self-regulation of data usage and a lack of certainty about the legal ramifications of smart farming. Thus, “[u]ntil clarity is brought to the issue of data, the industry is at risk of losing farmer’s trust and potentially hindering innovation opportunities at the farm level” (p.14).

Although there are examples from the literature which demonstrate that smart farming innovation involves an ongoing process of trying to reconfigure arrangements of sociotechnical relations, I argue a more accurate and urgent conclusion is to emphasize the ‘misconfigured innovations’ of smart farming. One of the main features of smart farming concerns the limited parameters within which innovations operate. In Canada, for example, an element in smart farming arrangements is models and platforms designed for commodity farmers, not those “farmers working outside of the dominant industrial model” (Bronson, 2019 p.3). In effect, “the maps created within those big data platforms developed by industry are made meaningful only if one adheres to a rigid conventional farming strategy of seeding in neat rows separated by areas of soil free of weeds” (p.4). A similar result emerges in Australia where observers note that farmers want autosteer technologies, new imagery services, levelling and GPS guidance because “if they’ve got efficient layouts, laser levelled, they’ll make significant water savings and they’ll have reduced labour inputs as well” (Higgins and Bryant, 2020 p.447). Smart farming therefore means (or, it at least raises the likelihood of demanding) that food producers contemplate, “standardizing the environment” (Bronson, 2019 p.4) in accordance with the commercial imperatives of farmers operating large holdings and using expensive machinery to generate predictable topographies that fit with the new topologies required to make smart farming technologies effective. Built-in biases pervade all algorithmic systems (e.g. regarding search engines see Noble, 2018); the biases in smart farming might only pertain to environments in the first place but they can have broader political-economic effects.

As such, the core problem with the various reconfigurations underpinning smart farming developments is not simply that the absence of one or other action or reform can limit their impact, but rather that smart farming innovation processes begin and proceed without adequately conceptualizing the underlying obstacles and limitations confronting food producers today. Technological innovations that reinforce power asymmetries regarding data ownership, for example, or that fail to challenge implicit biases toward certain types of environments, render some interests invisible while reifying specific types of logics, such as narrow measures of economic efficiency. Like any innovation, insertion, or reconfiguration, smart farming entails topological transformation; but problems emerge when the “quieter registers” (Allen, 2020) of smart farming make it possible for “powerful actors to make their presence felt at one remove, to reach into the everyday life of distant others” (p.5), for example by dispossessing them of valuable data or establishing algorithmic biases toward standardized farm topographies.

This is not to suggest there is nothing to gain from using some smart farming technologies. It can make sense to use devices or services in new arrangements that create efficiencies or give food producers new access to information that can inform decisions. However, because these developments always by necessity involve reconfiguring arrangements of sociotechnical relations, agricultural innovation processes will continue to introduce new misconfigurations when they pursue discrete solutions to specific problems, rather than integrated developments based on incremental adjustments in information-intensive iterative processes that target systemic or structural change. As insisted upon by scholarship on food sovereignty in critical agrarian studies (e.g. Edelman, 2017), the urgent challenge today is to conceptualize a planetary land, agrarian, and food system in which food producers and consumers everywhere are confronted by, but examine ways of overcoming, the same problems of neoliberal capitalism dominated by transnational corporations, authoritarian governance, and climate change. In the shadow of the corporate food regime, producing food in the Netherlands or Canada is bound up with the realities of producing food in India or Kenya. Further, the dynamics of digital life mean smart farming innovations in one place will inform and conceivably move the ‘planetary cognitive ecology’ (Hayles, 2017) generally, with unpredictable but connected results playing out elsewhere. The products of smart farming will only reinforce problems if they yield new patents for agricultural technology providers in a place such as Ireland (Fraser, 2019a), a widening yield gap between capital- and labour-intensive agrarian systems (e.g. as the World Bank [2007] propose), or if they increase the likelihood of ‘smart’ food production in one region leading to food dumping in another (on some of the effects of agricultural dumping, see Murphy and Hansen-Kuhn, 2019). Per the vision of a Common Food Policy in the European Union (De Schutter, 2019), rather than seeing smart farming developments “reinforcing existing production models, leading to trade-offs between different environmental impacts, or between environmental and social sustainability,” the task is to reorient innovation “towards low-input, diversified agroecological systems” (p.52).

In the light of these challenges, a sustainable and successful smart farming innovation process requires what we might imagine as the co-production of ambitious ‘topological repertoires’ that make ongoing assessments of absence, presence, proximity, and reach at the scale of a structure or system and then pursue appropriate technological solutions from the ground up. Although making a success of smart farming is already tricky and adding new complications might appear unhelpful, the task must be to recognize and confront the complexities, rather than sidestep or ignore them. The question is how to construct smart farming innovation processes that yield more effective configurations?

3. Moving beyond ‘responsible research and innovation’ in smart farming

To avoid producing misconfigured innovations, smart farming requires a reimagined innovation process. I argue the challenge is to imagine and realize an innovation process that can yield ‘emancipatory smart farming.’ Some clues of what such an innovation process might entail are provided by research on the possibilities of pursuing ‘responsible research and innovation’ (RRI) in smart farming. With a focus on anticipation, inclusion, reflexivity, and responsiveness (Eastwood et al., 2019b), RRI tries to respond to the new “socio-ethical dilemmas” (p.742) called forth by contemporary technological developments. For example, as stated by Rose and Chilvers (2018), “[i]n the rush to embrace smart agri-tech, we are in danger of forgetting the wider network of other innovations that play an important role, but may also affect societies in different ways” (p.4). One focal point of RRI is therefore “to stage reasoned deliberations on technological needs and concerns between historically marginalized food system actors and prominent decision makers in government” (Bronson, 2018 p.10). An ambition is that RRI might become “a rubric for guiding innovation toward socially and ethically acceptable ends” (p.10). At issue is examining “interrelations between multiple co-existing innovations in sustainable agriculture [to] promote the cultivation of distributed responsibilities across wider innovation ecologies” (Rose and Chilvers, 2018 p.4). In the New Zealand dairy sector, for instance, RRI has recognized that smart farming will yield "adapted advisory structures, potentially leading to displaced farm staff and service providers" (Eastwood et al., 2019b p.742). Moreover, shifts associated with smart farming technologies might have a "major impact on the cultural fabric of what it means to be a farmer," in part because they can entail "detailed monitoring by agricultural equipment makers, input suppliers, processors and retailers" (p.743).

There are reasons to applaud RRI. It signals at least an interest in trying to integrate societal concerns in technical developments; and opens avenues for new engagements between groups that might not otherwise interact. It is a close approximation of what an appropriate topological repertoire might look like because it emphasizes the visibility of stakeholders, actors, and material realities that otherwise can be marginalized or ignored. However, RRI in smart farming still fails to produce adequate configurations. It operates via a misplaced insistence that agricultural innovation can successfully reconfigure sociotechnical relations in one domain, without also pursuing systemic or structural change. In short, it is necessary to continue insisting on the need for reimagined smart farming innovation processes that work to sidestep the misconfigured innovations evident in today's smart farming developments.

A pertinent example of what might be possible here is the development of farmOS, which draws on activist engagements and explores how smart technologies can empower communities, through actions of solidarity and co-learning (Bronson, 2018). The software helps farmers record, plan, and manage their operations. It is open-source, produced under a general public license, and is easily hackable, in contrast to proprietary farm management software. Farmers can integrate diverse tools, such as drones for capturing aerial imagery or sensors to record temperatures, and thereby retain latitude to configure their operations in astute ways. In its effort to unsettle established smart farming structures and enable farmers to take back control over the software and data they produce, farmOS resembles other efforts to hack and repair farm technologies (Carolan, 2018). It also reflects a much wider societal shift whereby activists, community groups, or others in civil society embrace contemporary technologies and take advantage of the emergent affordances to pursue "productive resistance" (Ettlinger, 2018). A key dynamic of digital life today is growing realization that 'smart' use of software platforms requires re-platformizing society so urban citizens as much as rural farmers can take advantage of technological affordances without reproducing a platform economy dominated by a few enormous firms (often characterised by troubling corporate cultures) (e.g. see Scholz, 2014). It is therefore illuminating that farmOS is part of a new partnership called OpenTEAM (Open Technology Ecosystem for Agricultural Management) that aims to create a platform to facilitate "soil health management for farms of all scales, geographies and production systems" (OpenTEAM, 2020). There is scope today for farmers and connected others to overcome the problems of 'actually existing' smart farming and the misconfigured innovations it churns out.

4. Smart farming possibilities in the 'internet of people'

Further opportunities to alter smart farming arrangements might arise from new possibilities on the technological horizon. Hitherto, a technical limitation on smart farming developments pertains to the uneven roll-out of high-speed internet access between urban and rural areas (e.g. see Jakku et al., 2019). But there is now evidence that 5G networking technologies using TV White Space (Abozariba et al., 2019) or 'frugal 5G' (Karandikar, 2019) could be a 'game changer' for rural Internet access. If there is to be a 'what next?' of smart farming, it will build on what we find actually existing today to create new possibilities for embedding food production within the wider 'planetary cognitive ecology' (Hayles, 2017), with unpredictable outcomes.

One relevant near-term scenario emerges from research on the 'internet of people' (IoP), a term used by computer science researchers (e.g. see Miranda et al., 2015; Conti et al., 2017; Conti and Passarella 2018; Lagerspetz et al., 2018) with a view to building on and improving the relatively passive 'internet of things.' In the "Next Generation Internet" (Conti et al., 2017 p. 5) they are exploring, the internet of things is not swept away but rather a "new reference architecture" (Miranda et al., 2015 p.40) is carefully-crafted onto it with a view to overcoming problematic features of the "current-Internet data-management paradigm [such as] constant monitoring of users' behavior by global platforms to provide to them 'navigation' and filtering services to find relevant data embedded in the huge amount of available data" (Conti and Passarella, 2018 p.52). The overall design calls for a "human-centric perspective" (p.52) at the scale of implementation and a novel "data-management Internet paradigm" (p.53) in which devices are *proxies* of humans and constantly exist in context and operate in self-organizing networks that create new efficiencies because the need for human decisions is minimized. Significant features include use of new 5G capabilities that enable relatively autonomous 'device-to-device' (or, X-to-X) communications across 'pervasive communities' of connected users. Per an IoP manifesto (Miranda et al., 2015), devices are designed to 'be social,' 'be personalized,' 'be proactive,' and 'be predictable.' The underlying notion is that the IoP will use new arrangements and practices to engender economic efficiencies and positive social impacts.

Agriculture and farming don't figure much in the IoP literature. But there is every reason to expect the types of behaviours and interactions proposed by this line of research to impact on 'smart farming' practices. Consider a hypothetical example of how the IoP might operate, which, in the absence of available real-world examples to use, I adapt from contributions to the IoP literature (e.g. see Miranda et al., 2015; Lagerspetz et al., 2018):

Maxine is a dairy farmer and cheese producer. Her cheese sales are disappointing. She's confused and worried. She searches online for new recipes. Her phone knows a new recipe or idea is needed ['be personalized']. It shares this info with devices belonging to Maxine's friends ['be social']. At a social event soon thereafter, a phone belonging to a friend of Maxine overhears[2] someone called Sandy say that Maxine's cheese reminds them of another cheese they ate on holiday in Holland. It sends Maxine's device a message along these lines ['be social']; shares the ingredients and recipe of the Dutch cheese ['be predictable']; and suggests a tweaked production process ['be proactive']. Maxine's device also communicates with quasi-autonomous devices in the cheese cellar ['be social'] to produce a new test batch. Some months later, Maxine has produced the new cheese product. Her device then detects that Sandy will be nearby soon ['be social'] and arranges for a sample pack to be delivered to her ['be proactive']. At the same time, Maxine's phone arranges for sample packs to be sent to other people who match Sandy's sociological profile ['be proactive']. Their devices respond to say they like Maxine's new cheese and Maxine's phone sends them discount coupons for their next purchase ['be predictable'].

Today's smart farming developments lay the ground for emerging operations in the IoP: devices such as phones, or sensors to measure soil moisture or temperatures, are now operating on farms all over the world; software platforms are integrating actions, collecting and analysing data, and providing pertinent information to guide decisions; and autonomous machines are already in action. All of these arrangements of devices and sensors share information according to protocols and standards worked out in the context of today's technological limits and

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[2] As I noted with reference to McDonald's purchase of Apprente software, and as evidenced by the popularity of in-home voice assistants such as Amazon's Alexa, advances in voice-recognition software and AI already make it possible for devices to 'overhear' social interactions. In the IoP, if "devices become representatives of their owners and can act on their behalf" (Lagerspetz et al., 2018 p.40) the expectation is that AI will enable more advanced abilities to make sense of human life.

possibilities. The scene is therefore set for new rounds of investment in technologies that adapt architectures and yield realities like those posed above. As such, *tomorrow's* protocols and possibilities will build on the normality of devices and sensors contributing to on-farm intelligence and efficiency but with a view to delivering results impossible hitherto.

As suggested by Maxine's case, then, smart farming in the IoP still relies on human intelligence but the abilities of her farm operation to survive is upgraded and amplified by protocols and standards that grant proxy devices autonomy and intelligence to proactively prompt new connectivities and relations. Maxine's relations with others (known and unknown) are mediated, filtered, and ranked; her digital life draws on new affordances developing dynamically within pervasive communities operating across a proactive internet. Beyond notions of the 'nanny state' infusing debates about communitarian governmental action, the IoP scenario is more akin to people living with numerous devices acting like 'guardian angels,' with autonomous device-to-device decision-making based on assumptions about the needs and possibly the desires of the individuals 'they' oversee. Maxine may be conscious of decisions she makes to engage the internet and might even understand or be sent information about autonomous device-to-device activities pinging messages and moving data according to underlying protocols; but much of her social life in the IoP also unfolds without her active participation. It is a new rural scene; an image of a different society from today's, not least because it suggests the arrival of a new cognitive ecology underpinned and driven by AI, with social relations played out in numerous colliding "regions of technical autonomy" (Hayles, 2017 p.142).

Taking stock of the IoP scenario, there is clearly a strong possibility that smart farming in this forthcoming context will unfold via further rounds of misconfigured innovations. The dynamics of capitalist accumulation will no doubt pervade the design of protocols, devices, and services. Per the orientation of practices within so-called "surveillance capitalism" (Zuboff, 2019), tech firms such as Google or Amazon – as well as agri-TNCs, with their new data science profiles – will explore opportunities in the IoP to construct a more predictable world. Their challenge will be trying to contain the latent capacities and chaos of human and non-human action within tight profitable parameters; to thereby reduce the scope for uncertainty and contingency to interrupt flows of decisions informed by populations of sensors laid out and communicating with each other according to algorithmic models of society.

However, the objective reality of space is that no computational architecture can make sufficient calculations to overcome the inherent and pervasive "chance of space" (Massey, 2005 pp.111-117). Maxine operates in a contingency-laden context before any IoP devices arrive on the scene. What happens with digital technologies in general, and the IoP in particular, is simply now that "the chance of space *swells*" (see Fraser, 2019b p.3). In the IoP, Maxine engages a new rural scene that amplifies chaos with unpredictable outcomes. As such, unexpected dynamics might come to the fore. The distinction here is between the architecture of digital life and the actual lived experience of digital subjects, which always entails "intersections and recursive relationships" (Lupton, 2016, p.243) playing out via "iterative interplays" (Fraser, 2019b p.3). As evidence from research on digital worlds demonstrates (e.g. Milan, 2017; Ettlinger, 2018) – and as I have discussed via reference to developments such as farmOS – contemporary and emerging digital devices and services provide affordances for subjects to use technology in unexpected ways, including for the sake of resisting oppressive social formations. In rural space, smart farming seen through the lens of IoP research might place new value on intelligent, efficient, and even to some extent ruthless practices that squeeze as much profit from land and labour. Nevertheless, and emphatically, outcomes of the technological shifts at play here remain unwritten. Like farmOS or other efforts to re-imagine smart farming technologies, the IoP might create scope for users to create new forms of cooperation, reciprocity, and solidarity. There is significant scope for further investigation into this emerging scene.

5. Smart farming perils: 'you can't eat data' – or can you?

A final element to consider in creating smart farming innovation processes that yield more effective configuration comes to light from actions in India. Over the last few years, a team of Berkeley University technologists, economists, and development practitioners has worked with the government in Andhra Pradesh to create 'smart villages' (Darwin et al., 2018). Reflecting the vision that innovation processes can deliver effective results when they are open, as argued by Chesbrough (2003) in particular, the plan was to bring the team together to produce new sociotechnical arrangements in one village, Mori, that would empower villagers, improve their material situations, and yield insights about how to 'scale up' the interventions across the entire state. There is no evidence to suggest that people in Mori wanted their village to be 'smart' prior to the intervention, but from the outset the process was designed to tap the Mori crowd for insights in a form of co-design that identified specific problems that might be addressed by new technical fixes. One such problem involved the condition of textile weavers within value chains, which the 'smart village' initiative tried to address by creating a new 'virtual village mall.' Another problem concerned the structural relationship between farmers and the suppliers of agricultural inputs. To make the village 'smart,' the apparent solution was to create more direct connections between farmers and retailers. A partner on the project was the Indian agricultural e-commerce startup firm BigHaat. So long as farmers could access the Internet – as was facilitated by Google, one of the project partners – they could consider purchasing inputs directly from BigHaat and for a lower price than if they had to rely on various intermediaries. In this smart village, tapping the crowd informed and then guided a tech firm to create a 'win-win' solution: Mori farmers paid less for inputs, while BigHaat made new sales and, crucially, created opportunities to learn from analysing data generated by the new flows of information when farmers tapped screens on their devices and communicated with BigHaat's servers.

Writ large over the entire state – 'scaled up' – this new type of 'smart' engagement would conceivably lay the ground for further innovations based on tapping the crowd for insights. The smart village envisioned by this project would play a new role in expanded open innovation ecosystems designed to upgrade the technical sophistication of rural life and address societal challenges. Yet, the technical dimensions of all this action deserve critical scrutiny. Initiatives such as the smart village *might* empower some or indeed many villagers and they *could* improve their material situations. However, based on what we know about digital life in general, what seems much more likely is that these initiatives will generate significant scope for tech firms to create new assets and value from data flows (Thatcher et al., 2016; Birch et al., 2020; Sadowski, 2020); assets and value, moreover, that they will not share with the users of their technologies. Whether framed as a matter of surveillance capitalism (Zuboff, 2019) or data colonialism (Thatcher et al., 2016), an important dynamic of digital life concerns the maldistribution of opportunity to convert data curation into profits. The asymmetries of digital life mean firms such as BigHaat stand to gain the most from smart village projects.

In this context, then, it is worth remembering some pertinent lessons from the green revolution. Consider that when India embraced green revolution practices in the 1960s, the government redirected scarce resources toward importing fertilizer needed to support the planting and growth of new green revolution wheat varieties (e.g. see Cullather, 2010). Part of the issue was a realization in India that, although the country had "doubled its output of machinery, chemicals, and power [...] 'you can't eat steel'" (p.203). In the contemporary context – when investment in smart cities, villages, and farming is bound up with the notion that "data is the new cash crop" (Tatge, 2016) – the refrain 'you can't eat data' might have some purchase, especially given India's rush toward smart technologies despite malnutrition currently affecting around one-seventh of the population (FAO, 2020a). The stark difference now, though, is that some of the lead actors in the production of smart life in India (and elsewhere) *do* eat data, albeit by virtue of their ability to convert (control over and analysis of) data into profits. In a place such as Mori, it is not so much that villagers *can*'t eat data but rather that the current rush toward using digital technologies is underpinned by approaches and economies that mean Mori's villagers are unlikely to share in the harvest. The Mori smart village project yields a unique but striking type of misconfigured innovation.

Given the growing number of similar digital initiatives rolling out in the shadow of high-level belief that digital technologies can "play an increasingly important role in achieving global food security and improving livelihoods especially in rural areas" (FAO, 2020b p.3), it is necessary to ask whether an emancipatory version of smart farming could do any better. What might be the intricacies of building innovation processes that reconfigure the sociotechnical relations of smart farming within the 'planetary cognitive ecology' (Hayles, 2017) to enable all food producers, not only those in the global north heartlands of smart farming, to eat data?

In the context of significant inequalities in the ability of digital pioneers and laggards to take advantage of smart life, a minimum insistence of an emancipatory version of smart farming should be that adopting digital technologies works from the ground up to create incremental adjustments via information-intensive iterative processes that target systemic or structural change. In effect, the task should be to find models of emancipatory smart farming that use algorithmic affordances to pursue 'productive resistance' (Ettlinger, 2018) to dominant formations, such as the corporate food regime. The point here is, plainly, that new and potentially radical arrangements of digital platforms, devices, and software are waiting to be established. Thus, as outlined in the final column of Table 1, arrangements of devices, software, and practice that lead to something akin to emancipatory smart farming are at least conceivable. Departing from the mainstream model of smart farming, emancipatory smart farming arrangements will use technology to support agroecological and regenerative food production in a food sovereignty framework. Such arrangements would need to consist of hackable devices that users can repair. Open source software would be a requirement. If digital platforms are involved, for example to pool computational resources, they would be run as platform cooperatives. Users' privacy would be built-in by default. To the extent that data emerging from emancipatory smart farming arrangements will have value, it will be shared and held according to principles of data sovereignty. In all of these respects, therefore, emancipatory smart farming would depart significantly from mainstream practices. Further, striking differences pertain to innovation processes. An emancipatory smart farming arrangement would need to be constructed from the bottom-up in a participatory approach that empowers food producers to remain independent of ATPs. Ultimately, its aim would be to undermine, resist and overcome systemic challenges facing food producers. The point here is that, with novel innovation processes, it should be possible for even the most oppressed food producers to participate in the creation of emancipatory smart farming practices that engage digital technology in transformative ways.

6. Conclusion

The rush to make everything 'smart' is playing out across the world. In cities and, as I have discussed, on farms in places such as Australia, Canada, the Netherlands and India, there is widespread evidence of new arrangements taking shape, although there remains significant scope to conduct further research on the quantitative significance of these developments. Against this backdrop, the preceding discussion has emphasized the risk that smart farming has led, and will continue leading, to misconfigured innovations that intensify problems experienced by food producers throughout the world. But the paper has also suggested that a reimagined process of emancipatory smart farming innovation might produce more effective configurations. An objective for future research should be to examine whether food producers can develop the scope and power to learn from the mistakes made by actually existing smart farming arrangements to develop emancipatory alternatives. A key focal point should be to shed light on efforts to make astute use, and indeed exploit the possibilities, of technological developments on the horizon. The challenge, in the end, is to probe the possibilities for 'smart' life to be established while avoiding the risks of generating further misconfigured innovations.

Table 1
Key features in mainstream and emancipatory smart farming practices.

	Mainstream smart farming	Emancipatory smart farming
The overriding ethos guiding use of the technology is:	Productivist, extractive, profit-oriented	Agroecological, regenerative, food sovereignty-oriented
The devices, instruments, or machines are:	Locked	Hackable
The software environments and apps are:	Proprietary	Open source
When it involves digital platforms, they are:	Private/oligopolistic	Cooperative
Matters regarding a farmer or peasant's privacy are an:	After-thought or disregarded entirely	Built-in by default
Value generated by users' data should be:	Expropriated/grabbed	Shared/sovereign
The approach toward technology development is:	Top-down, paternalistic	Bottom-up, participatory, incremental, iterative
Smart farming arrangements of devices & software are intended to make users:	Dependent on Agricultural Technology Providers (ATPs)	Independent of ATPs
Systemic challenges facing food producers are:	Reinforced	Undermined/resisted/overcome

Author statement

Alistair Fraser: Conceptualization, Methodology, Writing, Investigation, Reviewing and Editing.

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