Paradoxes in Producing the Future of Farm Work: Anticipating Social Impact through the Lens of Early Adopters

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Agriculture is said to be undergoing a 'digital revolution' which proponents believe will improve its productivity and eco-efficiency. To that end, technological visions for digital agriculture center on a radical transformation of the nature of work that farmers do. The eventual impact of current technological changes on farmers' work will be significantly shaped by the imaginations and actions of researchers and companies currently developing digital agriculture platforms with limited rural input. Here, we explore how the future of agriculture is being anticipated and developed through the lens of early adopters of Microsoft FarmBeats. We identify a tension between the visions of seamless technical progress and the material resistances to those visions developers experience in practice.

CCS Concepts: • **Social and professional topics** → **Socio-technical systems**; • **Human-centered computing** → *Field studies.*

Additional Key Words and Phrases: social impact, hardware design, farm work, digital agriculture, networking

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1 INTRODUCTION

Drawing on interest in HCI in anticipating and improving the social impact of technology, we examine the anticipated impact of emerging digital technology for agriculture. Often referred to as 'smart farming' or digital or data-driven agriculture (DA), this work is touted as a 'fourth revolution in agriculture', with the potential to transform farm productivity, increase eco-efficiency, reduce grunt labor, and resolve uncertainties in production due to variable natural forces such as weather [22]. Such 'vanguard visions' [10] of positive impact are used to argue for this research and to enroll engineers, developers, and businesspeople in producing these technologies. For example, Steup *et al.* recently characterized advertised visions of future farms by digital agriculture startups, identifying four visions of future farmers' work these technologies claim to produce: a *vigilant farmer* who controls all aspects of her farm through data, an *efficient farmer* striving for profitability and sustainability, an *enlightened farmer* who achieves harmony with nature through data-driven insights, and an *empowered farmer* who controls her data to benefit her community [22].

Whether the adoption of continuous data collection and statistical analysis constitutes a revolution is up for debate [15]. Regardless, we note that previous revolutions have resulted in significant consolidation of farm production and economic power in the hands of a few industrial giants [8]. If the trends of past revolutions persist, the societal

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effects of the digital revolution may again manifest in further concentration of farming production and a depletion of rural economies [20]. Indeed, while the discourse about DA has largely touted the benefits of these technologies, social scientists raise questions about possible negative effects [4, 6, 24], such as their potential to further consolidate the agricultural industry, reduce farmer autonomy, and surveil farm labor. This work has driven calls to reform how DA is produced to improve its social impact [18, 22]. But these issues are largely flying under the radar in HCI. Work in HCI to address food production in the West has, similarly, with few exceptions [7, 22], focused on hobby food production in urban contexts [2, 16]. Some researchers have examined the marginalization of rural populations and communities from technology design [9, 14].

In this paper, we explore how to anticipate and design for the social impact of these tools. In particular, we focus on lead developers of new farming technologies - researchers who are adopting and adapting these tools before they are products for the open market. Since farm technology transfer typically flows from research universities and companies to production farms, we look to these lead researchers for signs of how they are envisioning future impact, how their everyday work builds towards these futures, and what social impacts may result. Our intention is to inform these developing technologies and improve their eventual social impact.

2 APPROACH

Our work is oriented around a case study of FarmBeats, an emerging technology to support digital agriculture being developed by Microsoft in collaboration with developers and farmers who are testing the technology and its potential. FarmBeats is a suite of networked technologies intended to spur adoption of data-driven agriculture, addressing limitations related to high costs of manual data collection, limited connectivity, and routine Internet and power outages in remote areas [23]. This platform allows for the collection of data from a variety of sources including moisture sensors, cameras, and drones. To address the paucity of high-speed Internet in many rural locations, FarmBeats enables connectivity within the farm by leveraging new networking strategies utilizing already-available bandwidth in Long Range Radio (LoRa) and unlicensed TV White Spaces (TVWS) [3, 17]. FarmBeats addresses weather-related outages by storing data locally on farm premises (also known as the "edge cloud") and opportunistically syncing it with Microsoft's Azure cloud storage system, which allows for data analytics and archival storage. Upon logging into the Azure cloud portal, a farmer would be able to visualize data from drone flights, heat map generators, etc. For outage resiliency, this decision support system is also replicated at the farm in an alternative FarmBeats architecture.

This work builds on the values in design (VID) approach, which develops means for technology designers to productively identify and engage with issues related to social impact in the early stages of technical design, rather than waiting until later stages of design and production when impact issues may already have been 'baked in.' [13, 21]. In this work, we examine the visions that lead developers have for the potential of FarmBeats for farms and their everyday experiences of working with FarmBeats to establish this potential. We analyze what these visions and practices might mean for the potential uptake of technologies like FarmBeats in North American agriculture. Our study consists of two major elements: our own technical work with FarmBeats, and an interview study with other lead users.

The first part of the study, informed by autobiographical design, involves our own deployment of FarmBeats technology at our university's test farms. The first and third authors are networking researchers; over the course of 18 months, we worked with FarmBeats technology to try to implement 3 different digital agriculture applications. The goal of this study was to develop a deeper understanding of the technical work involved in deploying FarmBeats, and to critically reflect on how and in what aspects the future social impact of the technology might be already immanent in the everyday practices of networking research.

For this short paper, we focus solely on the second part: an interview study to explore other lead users' experiences with the technology. While researchers and startups may put forward grand visions on the future of agriculture, it is the brittle and material interactions between different systems that ultimately propel or halt the realization of said visions. The interviews were conducted by the first author. We structured the interviews around three broad research questions.

- What are the successes, frustrations, and assumptions in deploying/modifying/extending the FarmBeats platform?
- How does the early user community facilitate/hinder the current and future adoption of agricultural platforms like FarmBeats?
- How do early adopters frame their perceptions and, ultimately, shape the future of farming?

These interviews built on the shared context of our technical work with the FarmBeats system, allowing us to raise technical questions directly or indirectly related to potential social impact. The interviews, which ranged from 50-90 minutes, were recorded and transcribed. Of the six participants, five were researchers and one was a farmer, with FarmBeats experiences ranging from 2 - 24 months. Together, the participants represented ongoing projects in three US regions (South, Midwest, Northwest), 20+ states, and nearly five years of combined FarmBeats experience.

Our own experiences with FarmBeats highlighted the enormous amount of mundane but challenging technical work involved in knitting together a set of technologies that in principle were intended to be seamless. As we worked with the data, and as we will show below, we found similar struggles were common among other lead users. Our analysis therefore came to focus on the compromises between the material struggles and grand visions of agricultural futures, and how these interactions shape the eventual social impact of said grand visions. In analyzing our results, three core paradoxes emerged about the ways researchers imagine and work to create positive social impact for agricultural technologies. These interrelated paradoxes are centered on material resistance, resource allocation, and labor. For this short paper, we focus our reporting on the first paradox.

3 RESULTS

Our findings capture negotiations and compromises that researchers undergo to realize agricultural futures. The negotiations center around two core tensions. The first is a tension between the researcher's grand visions for their extensions of FarmBeats versus the grunt work and limitations that FarmBeats and working with Microsoft impose in reality. The second tension is between the researcher's mental model of current and future farm practice versus the day-to-day realities of farm work. Given these tensions, realized futures become socio-technical compromises between rosy visions, low-level technical black holes, and the imagined and actual socioeconomic realities of farm work.

In imagining and creating agricultural futures, the participants look to FarmBeats as tool to seamlessly integrate and apply sensors, telecommunication, the cloud, and artificial intelligence (AI) toward a Utopian farming experience. As one participant sees it, "FarmBeats is one of the first products that actually delivers on the idea that you install it, you put batteries in it, you go home and see the data." (P5)

With a technical vision set, the next step is diving deep into the low-level implementation. Similar to our own experiences, our colleagues relate that, compared to an ideal of plug-and-play product, implementation poses significant hardships. In reality, before any data can can be seen on the cloud portal, one must spend numerous hours, days, or months with a "camping chair in the field" (P4) perusing through inconsistent documentation, jerry-rigging hardware compartments, pondering the feasibility of telecommunication with LoRa/TVWS radios in metal sheds, updating firmware, dealing with short-lived D-batteries due to extreme temperature cycles, etc. With regards to documentation, one colleague recounts:

> [T]he documentation was decent... but it needs revisions as the documentation that I received was for the sensor box version two, but the sensor box[es] that I received were version three. So there were inconsistencies of what they were saying [at] the different locations. Like, for the first week, I was connecting into the debug pins, rather than the actual pins to communicate to it. And I was pulling out my hair, like, why I'm not able to read anything when I send to find out the version command. (P1)

Importantly, the prioritization in resolving these early usability woes will shape the final consumer product. That is, feedback from early adopters is continuously incorporated into the system design. Interestingly, however, most of the researchers discount the discussion of these early configuration troubles in relation to how they might impact eventual users. One researcher argues:

> I think they are probably things that every user would probably go through. It was a matter of time... I don't view these as fundamental problems at all, they were just ... some minor logistics, but they took some time. (P3)

Precisely because these everyday challenges that swallow up researchers' time and attention are considered irrelevant to eventual end users, issues around eventual societal impact seem fundamentally divorced from their ongoing work, not worthy of discussion until a system is fully functional. Upon asking a researcher for any questions on their part before we start the interview, they discounted their ability to contribute to discussions of social impact:

> [N]ot anything in particular. *[Laughs]* But just a heads-up I would like to give you is that we are still trying to set up the system and have it working without any issues. Due to Covid-19, like, we were planning to get everything set up by end of May, but due to some logistical issues, we didn't get all the components, the sensors, the boxes themselves, and everything. Finally, we were able to gather everything ... around the first week of July, mid-July, and I have only set up one sensor box over here, and still trying to get the sub-Edge device on the university network. (P1)

Participants' projections of when a self-setup kit for FarmBeats and similar technologies might be available varied from five years to two human generations away. In the worst case, pessimistic outlooks are ascribed to material barriers that the technology currently poses. In the short term, our colleagues imagine the necessity of continuous compromises between Microsoft and early adopters to move the technology toward seamless deployments in production farms. One researcher remarks:

> [M]aybe this partner need[s] to adjust things in the hardware part... or they need, they, I mean FarmBeats or Microsoft needs to adjust something in their web platform to talk with a specific sensor that they don't have in the list. (P2)

4 DISCUSSION

From these results, we see emerging a *paradox of material resistance*, which involves a tension between the larger goals of a positive agricultural revolution and the mundane, messy realities of trying to get a technology to work in practice. While researchers and startups may put forward grand visions on the future of agriculture, it is the brittle and material interactions between different systems that ultimately propel or halt the realization of said visions.

On one hand, researchers dream up seamless integration of hardware and software toward a simple, usable digital farming experience. That is, one installs FarmBeats, puts batteries in a sensor box, and goes home, where computer vision algorithms automatically indicate which plants are water stressed and triggers their irrigation. The future of farm work imagined by researchers is akin to the *efficient farmer* described by Steup *et al.* [22]. Instead of spending time in the field watering crops, the *efficient farmer* is remotely making business decisions and enjoying family time.

On the other hand, we observe researchers and early adopters spending weeks and months fighting the material resistances in creating a simulacra of said futures. The struggles take many shapes including clerical work (perusing inconsistent documentation), computer engineering (updating firmware and debugging hardware components in the field), logistical negotiations (powering a base station in a metal shed), etc. This invisible configuration and maintenance grunt work is categorically antithetical to the claim that, equipped with data driven insights, the *efficient farmer* would enjoy time savings.

To understand the material constraints disguised as documentation and maintenance concerns, it is necessary to juxtapose the goals of the technology designers (FarmBeats) and lead developers (for now, researchers). More concretely, FarmBeats releases tightly coupled hardware and software products for the academic community to "test drive" in their research test beds. However, the limited release conflicts with the academic ethos of physical and algorithmic tinkering. Tinkering is a core value and a vehicle for innovations in the engineering disciplines. Except, in this instance, the FarmBeats designers constrain the ways that FarmBeats can be integrated with other systems. For instance, at current writing the FarmBeats sensor boxes do not support more than one instance of a sensor type. This forces developers to use multiple sensor boxes if they want to use two sensors of the same type. As a result, the final systems and their social impacts are the products of researchers navigating these material resistances and constraints. In other words, the future of farm work is actually produced through a hybrid of researchers' early design imaginations and the material limitations imposed by individual enabling components such as FarmBeats.

We see three key implications of this paradox for future farm use of automated systems like FarmBeats. First, the prior adoption of similar systems in rural regions makes clear that technology typically undergoes evolution and appropriation to fit the social-technical norms of its deployment location and community [1, 11]. This sentiment was shared by the one interview participant with active farming experience, referring to their own rewiring of a John Deere planter to work better for their particular area. Plug-and-play deployment could hamper this type of tinkering, which is common in rural regions [12]. Second, we see the challenges of engaging developers in considering social impact in early decisions, since the majority of researchers do not consider a social impact discussion worth their time until the system is fully functional, i.e. the future is already here. Finally, we see the potential for hindsight bias. That is, once the system is fully functional and deployed, significant challenges are discounted as minor logistical inconveniences that will not be equally experienced by end users. This outcome seems unlikely in practice given that, for a variety of reasons, rural infrastructure is more prone to breakdown and less likely to be repaired than urban infrastructure [5]. It remains unclear whether this attitude is attributable to the fact that the technology under review is not market-ready. Or rather, it may be a by-product of computer science research where material resistances are often set aside as invisible work [19], and lingering issues and challenges like social impact are often left open as 'future work' .

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