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**Citation:** Prost, S., Crivellaro, C., Collingham, H., Vines, J., Taylor, N., Thackara, J. & Rogers, J. (2026). HCI for Agroecology: Agri-Tech between Grassroots and Capitalism. In: Proceedings of the 2026 CHI Conference on Human Factors in Computing Systems. . New York, USA: ACM. ISBN 9798400722783 doi: 10.1145/3772318.3791822

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**Link to published version:** <https://doi.org/10.1145/3772318.3791822>

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# HCI for Agroecology: Agri-Tech between Grassroots and Capitalism

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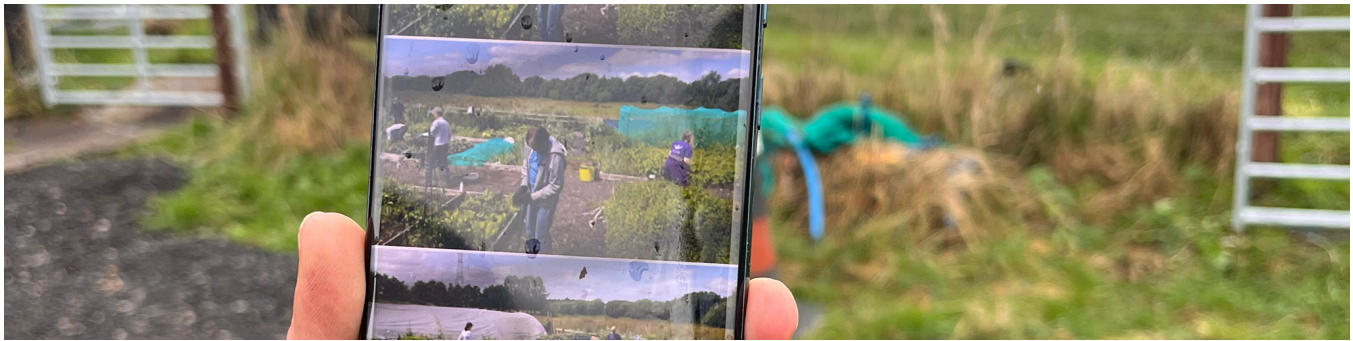
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**Figure 1: Formerly blooming market garden, now permanently flooded.**

## Abstract

Digital technologies in agriculture are typically portrayed as enabling more sustainable production while increasing productivity. Yet, commercial solutions rarely address the root causes of unsustainable farming, limiting the uptake of more radical solutions such as agroecology. We conducted fieldwork on 11 UK small-scale agroecological farms investigating their adoption of digital technologies. Far from being anti-technological, agroecological farmers are currently poorly supported by appropriate digital tools. Further, the collaborative nature of agroecological farming, market

productivity pressures, and regulatory requirements necessitate complex data practices for coordination, planning, monitoring, and learning. These data practices require labour that is often hidden and causes tension within farms. We develop these insights into a set of guiding principles for designing digital technologies appropriate for agroecology and suggest concrete design opportunities. We present a call to action for HCI to reimagine digital agriculture beyond capitalism and work with existing farmer-led grassroots networks towards technological sovereignty.

## CCS Concepts

• Human-centered computing → Empirical studies in HCI.

## Keywords

agriculture, agroecology, digital agriculture, agri-tech, sustainability, appropriate technology



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*CHI '26, Barcelona, Spain*  
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ACM ISBN 979-8-4007-2278-3/26/04  
<https://doi.org/10.1145/3772318.3791822>

**ACM Reference Format:**

Sebastian Prost, Clara Crivellaro, Henry Collingham, John Vines, Nick Taylor, John Thackara, and Jon Rogers. 2026. HCI for Agroecology: Agri-Tech between Grassroots and Capitalism. In *Proceedings of the 2026 CHI Conference on Human Factors in Computing Systems (CHI '26)*, April 13–17, 2026, Barcelona, Spain. ACM, New York, NY, USA, 18 pages. <https://doi.org/10.1145/3772318.3791822>

**1 Introduction**

*You know, we position ourselves very much in modern neoliberal capitalist society and economy as an organisation, trying to do things differently. And we're not alone in that. We find solidarity with other people, other organisations. (P19)*

Since the so-called Green Revolution in the mid-20th century, industrial agriculture has dramatically increased productivity while reducing labour costs. This has been enabled through monocultures, large machinery, chemical inputs, intensive animal farming, and corporate concentration [50]. However, it is now clear that these gains were made by externalising costs that affect human and planetary health, including malnutrition, obesity, greenhouse gas emissions, pollution, deforestation, and biodiversity loss [50]. Increasingly, this system is vulnerable to shocks, be they public health, geopolitical, or climate related [51]. More recently, digital agricultural technology (agri-tech) has been put forward as a solution to farm 'smarter' by making agricultural processes more efficient and productive, while also less wasteful and ultimately more sustainable [78]. In this tech-driven self-proclaimed 'fourth agricultural revolution' [88], big tech corporations (such as Microsoft, Amazon, IBM, and Google), big ag corporations (such as Bayer-Monsanto, Corteva, Syngenta, BASF, and John Deere), as well as a myriad of tech startups, are promoting key technologies for digital agriculture. Broadly, these include sensing and IoT devices (Gong et al., 2025), AI decision-making [4, 73], automation (drones, robots, irrigation systems) [28, 42, 85], blockchain [40] and digital marketplaces [18, 84].

However, as more progressive organisations and advocates have argued, rather than a digital revolution, these technologies represent the long tail of the Green Revolution [62, 78]. They tweak – and reinforce – the dominant, industrial and extractive way of farming, rather than bring about radical change [5]. They feed into a system that continues to waste food, relies on chemical inputs and fossil fuels, and negatively impacts human and planetary health. In addition, the introduction of corporate-driven technologies risks shifting farmers' roles to data workers [61, 90], reducing their agency by locking them into vendors and prescriptive farming practices [13, 78], and bringing about a form of surveillance agriculture [26, 91].

Agroecology has been described as the “most promising proposal for transforming unsustainable agro-food systems” [47]. While definitions vary, the Food and Agriculture Organization of the United Nations recognises 10 elements: practices and approaches based on diversity, synergies, efficiency, resilience, recycling, co-creation and sharing; the recognition of human and social values as well as culture and food traditions; and an enabling environment of responsible governance and a circular and solidarity economy [33]. Importantly, agroecology recognises indigenous and traditional

knowledge and technologies [95]. Indigenous farmers have long farmed according to agroecological principles but may call it 'natural farming' or just 'farming'. In the UK, where this study is situated, agroecological farmers often use established principles and certification standards, such as organic, permaculture, pasture-fed, or (to a lesser extent) regenerative agriculture.

Use of digital technology among agroecological farmers is selective [9, 65]. They typically rely on hand tools and small-scale machinery. Digital agri-tech as it is currently developed is largely rejected, as it is considered incompatible with agroecological values: “Technology that takes away sovereignty of the human does not serve agroecology” [65]. We situate this study at this tension between agroecological values and digital technology. Through a series of in-depth qualitative interviews with 21 farmers, growers<sup>1</sup>, workers, and directors across 11 agroecological farms in Northern England, UK, it aims to answer the following research questions:

- (RQ1) What digital technologies do agroecological farmers currently use and not use, and for what reasons?
- (RQ2) Which needs for digital technology are currently unmet?
- (RQ3) What principles should digital agri-tech align with to be considered appropriate for agroecology?

This paper has two primary contributions to sustainable HCI: 1) It presents empirical insights into the technology and data practices of agroecological farmers in Northern England as they seek to balance tensions between agroecological values, effective collaboration, and pressures of a capitalist market economy; 2) It develops a design space for responsible and appropriate design of future digital agri-tech that is in line with agroecological values, including a set of guiding principles as well as opportunities to design both within and beyond capitalist logics.

**2 Digital Technology in Agricultural Transitions**

In sustainable HCI, food production and consumption have become a major research focus over the last decade [25, 81]. As a field, it has moved from nudging consumers to change behaviours to a recognition that system change is needed to avoid climate collapse. Here we review how industrial agri-tech and practices at the intersection of agroecology and grassroots agri-tech innovation are differently positioned to work towards system change.

**2.1 Industrial Agri-Tech Visions and Realities**

The advancement of industrial agri-tech is commonly justified by the need to increase productivity and sustainability of agriculture [25]. As Barrett and Rose [7] show, the techno-optimism of policy and media documents contrasts with much more cautious perspectives of farmers. Digital agriculture promises farmers the ability to better control growing conditions and work more efficiently and in harmony with nature [6, 61, 88], but uptake of these technologies has been slow [30] and significant barriers exist. To make digital agriculture work, someone (e.g., a farmer, technologist, or data worker) needs to do 'articulation work' [61, 87], often hidden and

<sup>1</sup>Some participants identify as 'growers' if they are in horticulture (i.e., growing vegetables and fruit). A 'farmer' typically grows arable crops and/or holds livestock. For simplicity, in this paper we refer to all our participants as 'farmers'.

unaccounted labour to prepare sites, deploy sites, repair and fix issues, or clean data [7, 16]. Moreover, efficiencies are often cancelled out, as they lead to lower costs and thus increased consumption [5, 96]. Even proponents of industrial agri-tech admit that digital solutions are in their ‘infancy’ and ‘immature’ [28, 39, 40].

The adoption of industrial agri-tech has also been shown to negatively impact farmers and farm workers. Beyond the obvious risk to jobs [42, 48], there is a more fundamental risk to their way of life. Reliance on technologies risks a loss of connection between farmers and the land [67], while sensing and automation technologies change the nature of farm work, partially turning farmers into knowledge workers, following more rigid temporal rhythms than when working in nature [90]. ICT can also distance humans from the land and the specific context they are in [5], resulting in a loss of embodied and intuitive knowledge [88]. Flachs et al. [32] bring particular attention to how farm management via spreadsheets encourage farmers to prioritise efficiency and productivity metrics over harder-to-quantify aspects, such as ecological benefits, food justice, or community.

Personal and farm data is being used by commercial platforms to configure the user’s choice context to influence their decisions to buy bundled agricultural products, such as seeds, agrochemicals, and machinery [13]. Rather than supporting farmers’ capacity, agency and autonomy, they reduce these through technological lock-ins and dependencies [7, 78, 88]. Unlike traditional farm equipment, industrial agri-tech is designed and licensed to prevent repair and tinkering by anyone but authorised (and expensive) service providers [17, 61]. For example, John Deere, one of the world’s largest tractor manufacturers, ensures exclusive authorised access to repairs and modifications of its tractors through microcontrollers that require a Vehicle Identification Number (VIN). The VIN locks ensure that only authorised repairers can make changes. The same microcontrollers collect extensive data on all aspects of the tractor’s use [24]. Stone [91] extends this observation to the notion of surveillance agriculture, where the collection of vast amounts of individualised data points allows companies to both predict and manipulate behaviour. HCI researchers have studied the impacts of farm worker surveillance, including stress, increased competition, fears of disciplinary actions and job loss, as well as safety and privacy concerns [19, 25, 42, 61].

These issues suggest a farming landscape that many would find undesirable: tied into subscription fees, service contracts, and intellectual property restrictions, farmers find themselves in technofeudalism [97]. With no ownership of, and control over, their data and the platforms they use, they are dependent on big tech corporations that have little competition and regulatory oversight. Our research thus explores how we might transition towards more equitable models of technology use in agriculture, and we turn our attention to farms who already practice agroecology but still operate within the broader capitalist industrial system. These farms blur the lines between traditional and modern agriculture and might offer insights towards different relationships with agri-tech.

## 2.2 Agroecology and Technology

HCI research commonly frames agriculture in terms of conventional vs alternative, and by extension big farm vs small farm, and

high-tech vs low-tech [25, 88]. However, as Biggs et al. [8] put it, small-scale farms “are not ‘dumbed down’ versions of large farms” and thus may require different approaches to technology [15, 65]. Agroecological farmers continuously experiment with new methods, tools, and crops [6]. They also seek efficiency, but not at the cost of other values [6, 25, 45, 90]. As Barbieri et al. [5] argue, we need to redefine success as being about balance and embrace inefficiency and redundancy as natural systems do. Agroecology is therefore most closely aligned with technologies that have variously been described as ‘appropriate’, ‘convivial’, ‘permacomputing’, or ‘low tech’, among others [96]. These technologies are often community centred, small scale, decentralised or open source.

Responding to the value mismatch between industrial agri-tech and agroecology, many grassroots organisations have recognised the potential value of digital technologies, under certain conditions [1, 20, 36, 55, 65, 68, 79]. This includes calls for alignment with agroecology principles, non-displacement of work, low tech solutions, reparability, and farmers’ participation in and control over agri-tech developments. The criticisms and demands mirror critiques from HCI on value tensions between sensing and automation on one side and experiential and embodied knowledge on the other [69, 74], the environmental footprint of ICT in permaculture [67], ill-suited technology for small-scale farming [59], and the need for tools to enhance, not replace, collaboration and autonomy [53].

While large-scale agri-tech does not appeal to small-scale agroecological farmers [9], a range of useful and appropriate technologies have been researched, designed, or proposed. One area of attention are tools for cooperation and community-building among farmers and with consumers. Examples include a dashboard to coordinate crop planning among black urban farmers [34], converting commonly used but complex planning and monitoring spreadsheets into software [54], social media for buying and selling products [80] and movement building [89], tools for cooperatives and community-supported agriculture (CSA) [10, 56, 57], and solidarity-based online markets and currencies [57, 72].

Research has also indicated some scope for automation technologies if it is used as a collaborator, not a replacement. For example, by taking over arduous tasks [74, 90], helping educate the public about farm life [62, 74], and weeding or harvesting in a polyculture context [23, 76]. Heldreth et al. [46] articulated how AI for small-holder farms in Africa need to be designed with farmers, provide actionable results, and be trained on local languages.

Finally, HCI has explored how digital technology could be leveraged to help scale agroecology. While economic productivity is not the bottom line of agroecology, it is currently hard to make a living in small-scale farming [6]. This is not due to limited market demand, but because of the price-dictating dominance of the industrial food system controlled by supermarkets. What Raghavan et al. [76] call ‘computational agroecology’ could help address some of the bottlenecks agroecology is facing in moving into the mainstream: the high level of expertise needed which is based on decades of experience and the strong reliance on manual labour. Digital tools could help train a much larger number of agroecological practitioners, for example as Norton et al. [67] and Heitlinger et al. [44] have begun to do with a plant database and seed library. These systems could be self-obviating rather than creating dependencies [67]. Specialised tools could also help with the design, construction, and

maintenance of agroecological growing sites that are adapted to the local terroir [76].

While HCI, particularly in the Global North, has focused on working with small-scale and agroecological farmers, these have typically been community-focused and non-commercial [25]. We contribute to this work by showing how farms that work with communities and grow for markets need to navigate tensions related to technology and data needs arising from collaborative and commercial practices.

### 2.3 Grassroots Innovation in Agri-Tech

While HCI has a long history at researching and collaborating with maker, hacker, and open-source communities [92], the intersection with rural or agricultural spaces has received little attention. Computing within limits, especially Illich's tools for conviviality [49] also oppose industrial productivity insofar as these "tools from below" emphasise self-assembly, self-help, reuse, and repair. Pantazis and Meyer [71] explored two cases of 'design global, manufacture local' in rural Greece. "Rooted in the agricultural commons of the past and blended with the momentum of the digital commons of the 21st century", they document how two groups plan, design, prototype, and test agricultural equipment based on designs shared in digital commons. In fact, the global commons they utilised are grassroots agri-tech innovation networks. Prominent examples include Farm Hack<sup>2</sup> (US/UK), L'Atelier Paysan<sup>3</sup> (France), and GIAN<sup>4</sup> (India). Recently, these groups have connected in the Grassroots Technological Innovation Assembly<sup>5</sup>. The Assembly serves as a platform for farmers to set problems, assess existing solutions, collaborate, share knowledge, document designs, and innovate building on traditional knowledge. Another example of commons-based peer production is the Open Food Network (OFN) [72, 75]. The OFN is an open-source platform that connects small-scale producers with consumers through local food hubs. It provides the technical infrastructure for direct sale with full farmer control over their prices and data.

These examples show how 'tools from below' can undermine the centralised power of the industrial agri-tech actors [5] and enable technological sovereignty as an integral part of farmers' food sovereignty [3]. As Carolan argues, "[f]armers might not have historically possessed advanced knowledge of computer platforms but this does not mean they are incapable of acquiring such skills" [15]. However, movements like Farm Hack and the OFN remain niches within the agroecological niche. Put simply, farmers are busy farming and struggle to make ends meet. Opportunities for infrastructuring [64] grassroots agri-tech to tip the scales of who is driving innovation remain underexplored. In this paper, we will contribute to this work by discussing such opportunities and its challenges based on farmers' need for effective tools and their limited interest in digital technology per se.

<sup>2</sup><https://farmhack.org>

<sup>3</sup><https://www.latelierpaysan.org/>.

<sup>4</sup><https://gian.org/>

<sup>5</sup><https://www.gia-agroecology.org/>

## 3 Methodology

The study presented in this paper is part of an ongoing project with agroecological farmers in Northern England. The overall aim is to co-design socio-technical innovations, including tools, networks, and infrastructures that are aligned with agroecological principles and directly address needs of farmers. Besides answering the research questions above, this first phase's objective was also to develop relations and sensitise us to the farming context. Taking a post-structuralist stance, we consider 'agri-tech' a socio-technical phenomenon that does not exist on its own but is socially constructed and situated within a politico-economic and historical context [35]. We therefore follow a qualitative research methodology to co-construct meaning and knowledge with our participants. Furthermore, we take a long-term perspective and understand our work as infrastructuring, i.e., we seek to enable collaborations for the creation, appropriation, and maintenance of socio-technical infrastructures [52]. We understand farmers as experts in their professional experience and as such as co-investigators and co-designers directly shaping the course of this project [63].

### 3.1 Relationship Building and Positionality

While the research team works and lives in Northern England, we live in urban areas and do not have farming backgrounds. We also did not hold expert knowledge in agroecology or agriculture in general at the start of this project (although we have since learned a lot from the farmers). We approached the project with backgrounds in sustainable HCI, local food networks, community-based participatory design, digital civics, and critical making. We were thus literally 'strangers at the (farm) gate' [58]. We recognise that agricultural 'innovation' has a long history of something that is done to farmers, rather than with or by farmers. Universities continue to play an important role in disseminating – i.e., sell – agricultural technologies to farmers through extension services [66]. Likewise, on-farm research often means farms are providing testing grounds for research projects rather than defining the questions and approaches. Agroecological farmers are therefore rightfully suspicious of such extractive research practices. When we began to approach farmers, we explained our intentions to develop farmer-led agri-tech innovations. We had to reassure our participants we do not want to promote or sell digital tools but to understand current practices and how their agroecological values align or contradict with how digital technologies are currently designed. In some way, our lack of knowledge about agriculture made it easier for us to remain humble and learn from the farming experts. A few farmers also said they do not use any digital technology, which, as we will see, was not actually the case. These statements reflected, however, how ubiquitous some technologies (such as mobile phones or spreadsheets) have become so that they are not seen as technologies anymore.

Initial discussions began with one of the farmers (P1) who the first author knew from previous research activities. These informal conversations shaped our research questions and ideas about 'appropriate' technology for agroecology. P1 also connected us to other agroecological farmers in Northern England. The first author also attended a local agroecological farming conference to recruit farmers. We used snowball sampling to recruit further participants based on recommendations our initial contacts gave us.

Northern England is not prime agricultural land in the UK due to climatic conditions. Most farming is livestock farming, with some arable farming. Horticulture (growing vegetables and fruit), which is already a marginal segment in the UK, is practised primarily by farmers committed to providing local food, which often overlaps with agroecological farming. While the number of agroecological farms in Northern England is unknown, sources like the CSA network's map<sup>6</sup> and the Better Food Traders map<sup>7</sup> suggest it to be around 15-20. We believe therefore that the eleven farms we interviewed make up a representative sample of agroecological farmers in Northern England.

### 3.2 Farm Tours and Interviews

The primary method used for this study is semi-structured qualitative interviews. Before the farm visit, initial contact was made in person or via e-mail. The first author then held an informal conversation over telephone to explain the purpose of the research and schedule the visit. All interviews took place in person, except the interview with P19 (F10), which took place online (without a farm tour) due to scheduling difficulties. The first author visited all other farms and conducted the interviews. Part of the interview took place while walking around the farm. The first author also took photographs during the tour to help contextualise the interviews for the other team members. The interviews lasted anywhere from 1 to 4 hours (2.5 hours on average). Some interviews involved multiple members of the same farm (see Table 1) and the first author conducted follow-up calls with P2, P9, and P10 as we ran out of time during the visit.

The interview questions covered a range of topics, including personal backgrounds, routes into farming, history of the farm, facts about the business (scale, produce, route to market etc.), current use of digital and non-digital technology, current practices of data collection, and criteria when acquiring new technologies. We also prompted our interlocutors about their opinions of and interest in a range of currently available or near-future agri-tech, including sensing, automation, farm management, sales, knowledge, and collaboration tools. Observations and informal discussions during the farm tour focused on understanding growing processes; the people, plants, animals, tools, buildings, and other infrastructure involved; and getting a sense for the physical layout and scale.

### 3.3 Farmers and Farms

Table 1 gives details about the participants, while Figure 2 presents the farms our participants work at. Our farmers had varying experience in commercial growing/farming, ranging from 2 to 40 years. Some participants, typically those of CSAs, were in directorship roles without much farming experience or involvement. However, they could provide business perspectives that were at times different from those involved in physical farm work. About half of our participants made a living primarily from farming, about a quarter from non-farming work, and a quarter were retired.

All farms are located in Northern England, as approximately illustrated in Figure 2. Farms either maintained their own or sold to

a veg box scheme<sup>8</sup>, or operated under the principles of CSA<sup>9</sup>. The livestock farms sell meat boxes only a few times a year when an animal has been slaughtered. Farm sizes vary considerably, from a 2-acre market garden<sup>10</sup> to 1000-acre grassland<sup>11</sup>. Not all land is used for food production. Eight of the 11 farms grow vegetables, fruit, and sometimes other produce like herbs or flowers. Two farms rear livestock only, and one farm is mixed. All nine farms producing vegetables follow organic standards, but only 5 are certified by one of the recognised UK certification bodies. The three livestock farms are either certified organic or pasture-fed<sup>12</sup>. All farms (except for F2 who sell to a local 3<sup>rd</sup> party veg box scheme) sell directly to customers. Customer bases range from 20 to 500. Farms report using a range of digital tools, including websites, social media, communication tools (e-mail, WhatsApp, newsletters, video conferencing) and accounting software. A ubiquitous tool are spreadsheets (typically online for easy sharing, i.e. Google Sheets). Some use more specialist tools, e.g., land mapping software and the direct sales platform Oooby<sup>13</sup>, which offers an online shop, picking and packing lists, and business analytics tools for small-scale food producers. None of the farms used sensing and automation technologies. For details, see the table in Appendix A.

### 3.4 Data Analysis

Interviews were audio recorded, transcribed, and analysed. Analysis took place in two steps. First, the research team read and discussed transcripts, creating a preliminary set of thematic areas. The first author then conducted a Thematic Analysis following Braun and Clarke [12]. They re-read the data, noting down potential codes and themes. They then conducted open (inductive) coding of the entire interview corpus using the qualitative data analysis software nVivo. They then grouped codes into high-level codes and an initial set of five themes. The research team then reviewed and discussed the themes, restructuring and merging them, which resulted in the final set of three themes. Further refinements and minor adjusting to theme names happened as we wrote up the themes for the paper itself. Overall, this process was iterative, involving frequent discussions and reviews by the research team. Importantly, we are taking the insights presented here back to farmers for agenda setting and future co-design activities.

## 4 Technology and Data on Agroecological Farms

We structure our findings around three core themes that illustrate the ways farmers navigate the tension between agroecological values and digital technology. We report on these in the following sections.

<sup>8</sup>A direct-sale subscription service, where customers receive a weekly box of vegetables based on a monetary value.

<sup>9</sup>Community-Supported Agriculture (CSA) is an umbrella term for a variety of mechanisms in which a local community is involved with a farm beyond just being customers (e.g., on-farm work, crop planning, risk-sharing) in exchange for share in the harvest.

<sup>10</sup>A market garden is a growing space of typically 1-5 acres and unsuitable for field-scale machinery (e.g., tractors).

<sup>11</sup>1 acre equals 0.4 ha or 4,000 square meters.

<sup>12</sup>Pasture-fed livestock lives on grassland all year round and is not housed.

<sup>13</sup><https://www.oooby.com/>

<sup>6</sup><https://communitysupportedagriculture.org.uk/find-a-csa/>

<sup>7</sup><https://betterfoodtraders.org/buy-local-food/>

**Table 1: Farmers interviewed for this study.**

Participant ID	Farm ID	Role(s)	Experience	Primary income
P1	F1	Founding member, Volunteer	20+ years	Retired
P2	F1	Director, Worker	10 years	Retired
P3	F2	Owner, Grower	2 years	Non-farming
P4	F2	Director, Head Grower	2 years	Farm business owner
P5	F3	Farmer	50 years	Farm sales, land lease
P6	F4	Director, Grower	23 years	Farm employee
P7	F5	Director	14 years	Farm business owner
P8	F5	Grower	14 years	Non-farming
P9	F6	Director	Little	Retired
P10	F6	Director	Little	Retired
P11	F6, F1	Head Grower	40 years	Contracted as grower
P12	F7	Director	17 years	Non-farming
P13	F7	Farmer	17 years	Farm employee
P14	F8	Director	Little	Retired
P15	F8	Director	Little	Retired
P16	F8	Grower	2 years	Farm business owner, non-farming
P17	F9	Farmer	35+ years	Farm business owner
P18	F9	Farmer	14 years	Farm business owner
P19	F10	Founder, Director	Little	Farm employee
P20	F11	Director, Grower, Volunteer	30+ years	Farm employee
P21	F11	Coordinator Grower, Running Workshops	5 years	Farm employee

## 4.1 Connecting to the Land

Agroecological farming emphasises and celebrates people connecting to land, food, and nature by being and working on the land. Therefore, any technology that removes people or their connection with the natural world is viewed critically. Nevertheless, as this theme explores, farmers have a pragmatic attitude and use technology when useful and accessible.

*4.1.1 Noticing, Working, Responding.* When we asked farmers why they farm or grow, many said because they like to be outdoors, in nature. Some, like P3 and P11, even have a background in IT and chose growing to spend more time away from computers. When they are on the land, they are attentive to their surrounding and observe. They are reluctant to use sensing and monitoring tools to replace their own senses: “I’m not a fan of soil testing. I think the science is fine, but I’ve always said my eye tells me more about what’s going on. [...] I think soil testing can be a bit reductive.” (P1) Reductive, “precise” scientific measurement technology can be a gateway to the capitalist maxim of yield maximisation:

It started when [farmers] were able to weigh stuff. So when you’re able to measure starch content in your grass [...] then you chase the maximum yield from that. [...] And that’s what you’re measuring. It’s easy to measure. (P12)

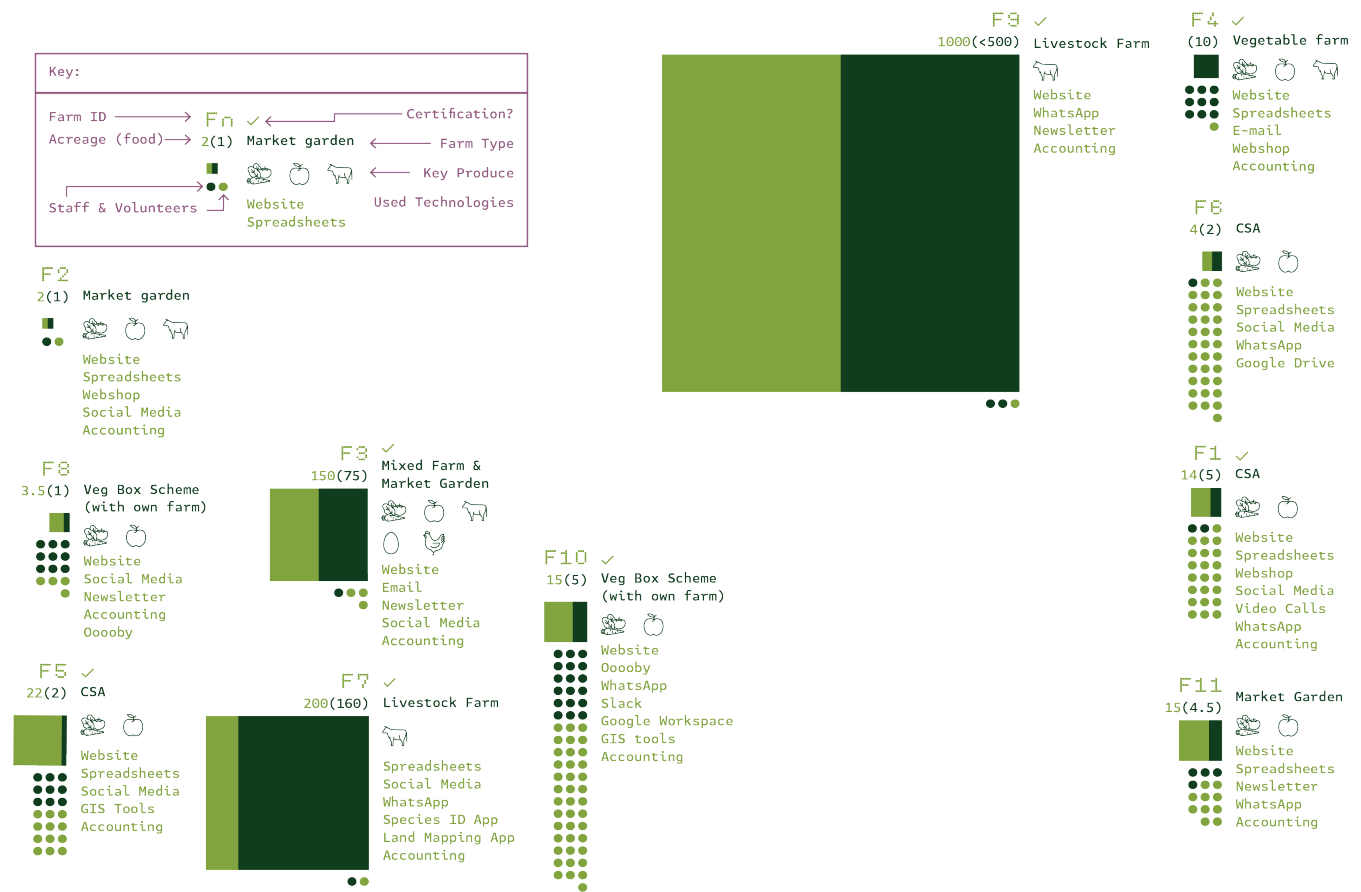
Not pursuing maximum yield, agroecology does not require precise measurement tools. Proxies and approximations are often enough. Observing birds, earthworms, invertebrates, moles, and weeds are often good indicators for soil health, without relying on soil tests.

When on the land, people also enjoy doing physical work. Manual jobs like weeding, sowing, and harvesting or moving livestock are embraced. Technology to automate these, especially robots and drones, are valued only for particularly arduous jobs. Being asked whether drones to monitor her livestock would be useful, P17 answered: “I suppose, if we were lazy. I mean, when we’re going to gather all the sheep on 500 acres, if we could see where the sheep were before we went, that would be helpful.” Currently, they “go to up the high points with a quad bike and a dog and try to find them”. But “as long as it’s a nice day, it’s very pleasant [laughs].”

Importantly, working on the land also allows people to observe and notice. If an activity was to be automated, this would reduce the opportunities to respond to animal behaviours, crop development, or disease outbreak. While watering by hand is laborious, even automated irrigation is scrutinised: “In some sense, it’s good to walk around and water because you can see what’s happening” (P3). To be responsive, experienced farmers (P5, P11, P13, P20) also do not want to stick to strict growing plans, typically implemented through spreadsheets and software, to plan and monitor crops:

One of the things I want to try and bring into that [crop growing] plan is not being too fixed about it. Just like, “Look that last lot of lettuces we planted out failed really badly. Let’s sow some more now, rather than waiting another week.” Or, “That chard is really good. Let’s not bother planting or sowing some more for another month or so.” So, just so it is a conversation rather than having too much of a fixed plan. (P20)

Software-based plans can impose a rigidity that is not compatible with being responsive to the natural world. What needs to be done



**Figure 2: Visual overview of participating farms, arranged in approximate geographical proximity in Northern England. For details, see Appendix A.**

is only loosely based on a plan and mostly informed by observation and year-long experience.

**4.1.2 Using Tools.** Farming with nature also means looking for methods and solutions in nature, rather than relying on technological approaches. P13 expresses his discontent with how market-driven practices push industrial farming towards bigger and bigger machinery: “Farming reps, and sales guys, and machinery sales guys, they’re all trying to do the same thing and sell you more kit. [...] And a lot of the time it’s just less is more” (P13). A simplistic binary of “working with” vs “controlling nature” does not hold, however. All agroecological farms use some technologies – in the broadest sense – to control nature. They dehorn cattle, control their movement through fences, use hand tools or tractors to remove weeds and erect polytunnels to control environmental conditions to extend the growing season. However, farmers carefully consider which methods are appropriate, and which are not. Appropriate technologies augment human labour or make it safe rather than replace it. An example is small-scale machinery, such as the potato planter (Figure 3), a tractor implement to make the laborious job of getting seed potatoes into the ground easier. Importantly, unlike fully automated potato planters, F1’s does not replace humans

on the land. It maintains growing as a social activity: “It’s lovely. Somebody’s sitting on the tractor, two people sitting on the side dropping the things down there” (P1).

Agroecological farmers commonly use second-hand tools and machinery for multiple reasons. While there is a level of thriftiness that some farmers enjoy (P11), it is also out of necessity as it is cheaper to buy, maintain, and repair. Most importantly, the need for human-scale technology that does not remove people from the land means that modern agricultural machinery has become inadequate. It is simply too big, too heavy, and too powerful if it has not been replaced by chemical processes altogether.

We found that non-use of subscription apps or farm robots was primarily founded in financial constraints rather than ideological considerations. When we asked farmers whether the ecological or social impact of digital technologies matter, farmers often displayed a rather pragmatic attitude: “I don’t think we’re that green. I think we’re just light green. We’re not dark green. No, we just struggle to survive, you know, so we don’t really take that into account” (P6). Farmers focus on getting food production right, rather than technology, and because of their financially constrained situation, they frequently use commercial but freely available cloud software, such as Google’s office applications and mainstream social media.

More ethical alternatives, such as building one's own or using open-source software were described as “clunky” (P1, P2), “unworkable” (P14), or “not adequately developed” (P19). For farmers, open-source technology requires a ‘technological mindset’ that most of them do not have:

I certainly got a lot of respect and love for that kind of [open source] stuff. There's nobody here amongst the four of us; there's a person missing in our team. Basically, we don't have anybody in our team who would get obsessed or get techy enough. (P20)

In some cases, volunteers step up and do some of the digital work, such as managing the website and social media accounts (F3). In general, however, farmers, like other non-technical users, have no capacity to consider more ethical technology because of differently situated interests and their financial precarity.

In summary, this theme showed how farmers use technologies selectively and pragmatically, driven both by an ethos that values human noticing, labour, and responsiveness as well as practical considerations such as the need to reduce hard work and affordability of new technology.

## 4.2 (Computer-Supported) Collaborative Farming

Agroecology is a collaborative endeavour, which requires systems to coordinate work, plan crops, record activities, monitor natural processes, learn collectively, and exchange knowledge.

**4.2.1 Coordinating, Planning, and Monitoring.** Coordinating farming activities with a heterogenous workforce can be challenging. Farms do this verbally, via WhatsApp groups, e-mail newsletters, online spreadsheets and job lists written on whiteboards. F1 and F6 represent two very distinct models of work coordination. At F6, P11 is the central node for work planning: “My way of managing it, I plan on doing everything myself, and then I delegate a job as they



**Figure 3: Potato planter. Attached to a tractor, it creates three furrows in the soil, while two workers sitting on the seats drop potatoes in.**

[volunteers] arrive.” P11 holds the knowledge of, and power over, what work needs to be done in his head. In contrast, F1 is more volunteer driven; P2 maintains a Google spreadsheet that allows for a more collective form of coordination, rather than relying on a single person to be there every day.

Digital systems, particularly online spreadsheets, also play a critical role in the complex task of planning and monitoring of diverse crops<sup>14</sup>. All farmers use tools for initial crop planning, such as spreadsheets or whiteboards, with varying levels of detail. On F3, farmer P5 firstly plans “in my head. I do try and write it down at some point.” However, this is done inconsistently. At F6, farmer P11 creates an initial crop plan on a month-by-month spreadsheet. He decides what to do each week based on the development of plants and the availability of labour. Farms that distribute work (F1, F4, F8, F11) use more detailed and complex plans on spreadsheets (see Figure 4), even if these cannot ultimately be adhered to: “You can't do farming by a week-by-week plan. And I understand that. So I try not to panic too much when it's six weeks out of date and we're that far behind” (P2).



**Figure 4: Printout of F4's crop plan hung up in the shed.**

Besides spreadsheets, slightly larger farms also use more advanced tools, such as land mapping tools, e.g., the Land App (F5, F7), Magic Map (F7), or QGIS (F5). At the market garden scale, F11's previous garden manager P21 used a home garden planner app (called Garden Planner) to introduce a visual, spatial element to planning that spreadsheets lack.

Collaborative farming also requires monitoring and documenting crop health and development to intervene if needed, harvest on time, and prepare the next crop. Other recordings include weather events, crop rotation, yields, and infrastructure and machinery maintenance. Like for planning, we found two different approaches to monitoring: centrally, in a farmer's head, and distributed in spreadsheets. While admitting not being good at documenting observations, P13 recognises its value:

<sup>14</sup>This involves schedules and location for seeding, transplanting, and harvesting for at times 50+ varieties of crops across the season, also considering soil types, weather, and crop rotation.

Documenting everything that you [see], I know it's my big, one of my biggest weak points. I've got a lot of stuff in my head that I can pull out at any point but actually having it down on paper or on the screen is important to do. And yeah, that bit puts me off, more than anything, because I'd rather be out here. (P13)

We observed that experienced and knowledgeable farmers struggle or actively resist documenting and sharing their knowledge on paper or digital form. In one case, we observed visible tensions between the farm cooperative's head farmer and the directors board. While for the experienced farmer documentation was unnecessary as they walked the fields every day anyway, for the directors this created a power asymmetry and vulnerability if anything were to happen to the farmer. Where documentation took place, spreadsheets were again the most common tool used (F1, F6, F7, F10, F11). However, manually filling in spreadsheets means additional work, which overworked farmers or volunteers often do not have the capacity for: "We've got the technology for that [i.e., spreadsheets]. It's just we don't have the hours, you know. Nobody's actually doing something like that" (P10).

**4.2.2 Learning and Exchange.** Technology is also commonly used for learning and knowledge exchange. However, knowledge needs to be localised, as soil types and weather conditions largely determine farming practices. The impacts of climate change require them to learn and adapt to extreme wind, rain, and drought. As an extreme example, F5 had to relocate its market garden as its original site got increasingly flooded since 2017 and is now permanent wetland (Figure 1). They are now exploring wetland farming methods to adapt to these changes. Farmers also increasingly invest in local drainage, reservoirs, and irrigation systems and experiment with new crops to adapt to climate change. When asked, many farmers did express interest in learning not only by monitoring farm activities, crops and animals (as discussed above), but also climatic conditions, soil health, nutrients, biodiversity, and wildlife. However, these measurements are again not automated but carried out manually, and as such require people power. Therefore, monitoring for learning purposes on farms is fragmented at best, and often non-existent.

Aside from monitoring, farmers and volunteers learn informally through working alongside another. Formal training, like P20's permaculture courses, are the exception. Several participants mentioned that formal agricultural education as taught at universities and colleges, while improving, is still largely conventional and does not equip graduates with agroecological thinking and skills.

Knowledge exchange with other farmers is equally fragmented. Direct neighbours often practice conventional farming that our participants have little in common with. While agroecological farmers did not feel taken seriously previously, often classed as "hobby farmers" (P7), with a shift in UK agricultural subsidies towards nature restoration, attitudes begin to change. P7 reported that her conventional neighbour now reaches out to her to ask for advice for wetland management. To feel less isolated, network organisations, such as Pasture for Life, the CSA Network, the Soil Association, and the Landworkers' Alliance play important roles in community building and organisational learning. They organise events, provide experts advice, maintain online knowledge resources, and

run WhatsApp groups and online fora for informal peer-to-peer exchange. Farmers also expressed interest in regional collaboration and sharing through cooperative ecosystems. These could include coordinated crop planning across multiple small farms to grow a greater diversity and consistent supply of crops, regional marketing and distribution networks, and sharing tools and machinery. While these ideas could utilise digital platforms to enable distributed collaborative work, they have not been taken up due to a lack of capacity.

In summary, this theme illustrates current needs and opportunities for effective and accessible digital technologies to enable collaborative farming, including the coordination of work, planning and monitoring of crops, learning and knowledge exchange, as well as regional collaboration among agroecological farms.

### 4.3 Food and Land as Commodities

While agroecology questions the commodification of food and the transactional relationships it fosters, farmers today still operate in a capitalist market economy. For agroecological farming to be not just a lifestyle but also a livelihood brings about additional requirements for production, sales, as well as access to certifications and funding.

**4.3.1 Interfacing with Markets.** Growing for a market requires a level of consistency in production and in turn planning and monitoring. P12 wants to prove that pasture-fed beef can be a viable business model, so she had to monitor the development of their cattle more consistently to avoid keeping them for longer than needed: "It's only now that we've set ourselves this task of getting the data to find out if this is a viable concern [i.e., business]. That's what's forcing our hands. [...] You need to keep your margins, right? You don't want to keep an animal any day longer than when it's ready" (P13).

Narrow sales margins mean that all<sup>15</sup> interviewed farms also have taken on the extra labour of selling directly to customers. Ideological and scale issues aside, selling to the supermarket system would not give them the prices they think their products are worth. Weekly veg box subscriptions are typically administered via e-mail, spreadsheets, and standing orders. While flexible, spreadsheets are usually self-made and have little analytical functionality built in. Therefore, some of the larger box schemes (F8, F10) use Ooooby, although this comes with a subscription fee that not all farms can afford, as well as the dependency on an external technology provider. Linking back to the first theme, F10 had to carefully consider risks and impacts before joining Ooooby:

We don't think they're evil or bad. What we're concerned about is somebody else evil and bad coming along and munching them up and eating us in the process, right? Because that does happen in the tech sector all the time. (P19)

Interfacing directly with customers also involves managing expectations around the cost and qualities of produce from small farms and dealing with skewed expectations based on what their customers are used to when buying from supermarkets. During our visit to their farm, P17 argued that food is undervalued by the UK's society. Rather than making food more affordable, she thinks "it's

<sup>15</sup>Except for F2, who supply a local 3<sup>rd</sup> party veg box scheme.

not unreasonable to expect to spend 50% of your income on food” (current UK average is 11.2% [70]). Participants also reported that many people are so disconnected from how food is grown that they expect it to be washed like in supermarkets: “But people won’t even touch the potatoes. They wanted gloves to pick the potatoes up because they were dirty and the carrots were dirty” (P7). This disconnection is compounded by lack of cooking skills and low-price expectations. In response to these challenges, customer education usually happens in a rather light-touch and informal way through personal conversations during pick-up and volunteering, sharing of recipes, e-mail or printed newsletters, and social media posts as part of their general marketing and communication with customers.

Despite having a willing and ‘converted’ customer base, participants reported they make efforts to accommodate customer expectations of convenience. Most veg box schemes and some CSAs buy in extra produce, including imported out-of-season or exotic food to increase variety all year round. Farms also allow their customers to customise their veg boxes to increase consumer choice. Door-to-door delivery is convenient for customers but particularly costly, hence only a few farms (F9, F10) offer this option. Most farms either deliver to pick-up points or require customers to collect from the farm. As such, participants practise a fine balance between educating customers and being responsive to some of their expectations which might be set by years of shopping at supermarkets.

**4.3.2 Accessing Certification and Subsidies.** All interviewed farms broadly follow agroecological principles, however the labels they use vary. Some are officially certified as organic or pasture-fed (in the case of livestock). Besides consumer trust, one of the primary reasons to be certified is to set a premium price. Some farms do not get certified for reasons of costs, paperwork, lack of flexibility, or because they believe they do even better than the organic standard. Selling direct also means that consumer trust can be established through personal connection. Certified farms are subject to a yearly in-person inspection by the certification body, during which purchase, activity, and harvest records are reviewed. These can be paper-based or electronic. P7, P12, and P17 first keep records on paper in the field or polytunnel and then transfer them to an Excel spreadsheet on their computer. P5 keeps records on paper only. While some feel well set up to avoid extra paperwork, for others the certification causes headache: “There is a lot of paperwork with the organic system. [...] Yeah. It’s paperwork. I think it’s a headache” (P5).

Despite premium prices, margins for farms remain low. Economic diversification is often promoted for financial security of agroecological farms (Moeller et al., 2023). While these include non-farming activities such as providing training and workshops, farm tourism, leasing parts of their land, or off-farm paid work, a common route are funding and subsidies. Since the EU exit, the UK government has shifted their agricultural and land-management subsidies from area-based payments to rewarding nature restoration. These, however, require complex data gathering, including land mapping and photographic evidence of actions undertaken. For example, F9 received funding to put 8,000 dams into drains that in the past were installed to drain peatland. This needed to be photographically evidenced:

They wanted to see photographic evidence, apparently, of the peat dams. And I said, “What? I’m supposed to follow around and take 8000 photos of peat dams?” And apparently, I can do 10% or something. I mean, it all sounds quite ridiculous to me. (P17)

This example illustrates how digital technology, such as automated drones to take aerial photography could be useful to provide such evidence. However, data accessibility is important. F12 has been recording biodiversity data using mainstream identification apps. This data is locked up in multiple proprietary platforms and cannot be combined or easily extracted to be included as evidence:

Like, Chirp-o-Matic. I know it’s not a platform specifically set out for that, but I’ve recorded birdsongs for three or four years now. I’ve done nothing with it. And the same with plant species. I’ve got, you know, Picture This Mushrooms and Picture This Insects and Picture This Plants, and they’re all just sitting on my phone in a totally inaccessible junk box. If it was all on one [place], “This is my farm”, [it could be used on social media or funding applications]. (P12)

While some of the farms we interviewed welcome income through subsidies (F8), others see these as forms of land commodification:

There’s a whole secondary market now for carbon and biodiversity data that is allowing offsetting, is allowing a futures market to develop around buying out biodiversity net gain for the future. And this whole process of commodification that comes in very, very quickly after the digital technology, or maybe even is the rationale for that digital technology to be implemented. (P19)

Agroecological farmers are thus walking a fine line between their commitment to farming with nature and the need for technology and data collection to interface with markets and state mechanisms of commodification, such as certifications and subsidies.

## 5 Designing for Agroecology within and beyond Capitalism

Agroecological farmers carefully negotiate agroecological values and market pressures, which is reflected in their use and non-use of technology. This begs the questions what and how technology could be designed – both within the status quo and beyond by imagining and working towards more radical agri-tech alternatives.

### 5.1 Hidden Data Labour

If there is one digital tool that stands out across the many areas of agroecological farm work we observed – spanning coordination, planning, monitoring, communicating, selling, and reporting – it is the humble spreadsheet. This echoes previous findings from the US [32], where COVID-19 lockdowns created high demand for local food and pushed farmers and distributors to manage their growing operations and sales with spreadsheets. Even if demand for local food has since decreased again, spreadsheets are everywhere, and given the criteria above, it is easy to see why. While some of our participants dislike them, for many they are the best tool available: they are affordable, accessible, and offer flexibility in use, yet have

powerful functions built in when needed. Of course, they have their limits and more complex data analysis requires mathematical or programming skills. In some cases, there could therefore be an opportunity to turn spreadsheets into custom software, as Klein and Raturi [54] do through spreadsheet audits, but there is also the risk that farmers might lose the flexibility and agency over designing and adapting their own spreadsheets.

However, the common use of spreadsheets is also indicative of the labour that goes into filling them in. As we have seen across the themes, data recording and analysis requires additional unwanted work, which is often hidden and unaccounted for. We have seen that pretty much all data recording on the farms is done manually. Biodiversity surveys, soil test, carbon audits, crop monitoring, record keeping – this data is manually entered into the ubiquitous spreadsheets, not collected by IoT devices as one might imagine on a data-driven farm. Contrary to Flachs et al. [32] we did not find that our farmers adjusted their practices based on the quantitative insights the matrix structure of spreadsheets affords (e.g., profitability, efficiency). Rather, spreadsheets were the appropriate tool in their ambition to be more efficient and profitable. Their commitment to agroecology remained strong, although lack of capacity to act on data may also play a role. Specifically, we observed two data-action gaps. First, even if they were to collect data more consistently, most farmers do not have the capacity to analyse the data in depth, for example crop development from season to season or sales data. Second, even if in-depth analysis was available, they would not necessarily be able to respond to it, for example to biodiversity, soil, sales, or social media engagement data.

Hidden data labour also occurs when managing customer relations. As shown, our farmers were directly engaged in marketing, sales, and education. Similar efforts were observed by Steup et al. [89] in the context of US farmers markets. Like at farmers' markets, our farmers have to balance customer education and convenience carefully. However, the difference in distribution model (veg box scheme, CSA) means that even more of the educational work is done digitally (newsletters, social media). And unlike on farmers markets, most of the farmers we interviewed undertake the extra labour of accommodating customer expectations, including buying in complementary produce from wholesalers, planning weekly veg box contents, or providing recipes. Most of this work requires digital data labour and is often carried out by unpaid volunteers.

The hidden data labour we observed aligns with previous discussions of invisible work [78] and 'articulation work' [61, 87]. It is unglamorous and often unwanted extra work, especially by the experienced farmers who prefer to just manage everything in their head, but in turn they limit possibilities for collaboration, knowledge sharing, and collective resilience. Therefore, if we are conceiving new digital technologies for small-scale agroecological farmers, we need to consider the new kinds of data work these might incur. We also understand this data labour as an extension of bureaucratic capitalism transforming natural and social life into machine-readable data, increasing surveillance, and creating new avenues for value extraction and control within markets and states [61, 91]. As P19's quote opening the paper shows, agroecological farmers experience this tension firsthand. It is therefore crucial to consider how technology is positioned along this tension.

## 5.2 Appropriate Digital Agri-Tech Beyond Binaries

Across the three themes, we illustrated how farmers use digital technology flexibly and pragmatically. They are, as P19 said, 'trying to do things differently while still operating within neoliberal capitalist society and economy'. They therefore do not think in the agricultural and technological binaries others have pointed out [9, 25, 88]. They are both community-focused and commercial, which makes some tools inadequate and inaccessible (e.g., drones, robots) but requires others (e.g., spreadsheets, sales apps). Different from industrial agriculture, they work with nature but also need to produce a consistent crop, which requires attentive care and rigorous planning and monitoring. While they do not control nature to the extent of killing it, they certainly strive to control environmental variables (where they can) to improve their production. They do not reject digital technology on ethical grounds alone (e.g., because of its environmental impact as Norton et al. [67] found). Instead, reasons for use or non-use of digital technology are entangled with business needs, practical considerations, and ethical principles.

Below, we distil a set of 12 technological values that the agroecological farmers expressed through their observed practices and statements in the interviews. These could act as guiding principles for farmers, designers, and manufacturers to design and adopt appropriate digital agri-tech. We feel confident they echo and align with the demands expressed by civil society organisations [1, 20, 36, 55, 65, 68, 79] as discussed in Section 2.2. We grouped them along four categories: necessity, practicality, accessibility, and sustainability.

*Necessity:* 1) The first question to be asked is whether a technology is needed in the first place. Technology for its own sake is useless; it needs to provide tangible benefit. 2) Low tech options are preferred. This is both for sustainability (see below) and practical reasons (e.g., repairability, lack of electricity). 3) Technology should not replace human labour, but support and enhance it.

*Practicality:* 4) Technology needs to be robust and work outdoors (in the rain, cold, mud), which makes touchscreens questionable. 5) It needs to work with diverse crops (polycultures rather than monocultures). 6) It needs to allow flexible working in line with natural cycles and the variability of human skills, interests, and availability.

*Accessibility:* 7) Technology needs to be affordable; continuous costs through subscription services are to be avoided. 8) Tools should be simple and easy to use, by having only the features they need. 9) Tools and data need to be accessible by many users on a farm and if desired on other farms.

*Sustainability:* 10) Tools should be efficient and minimise energy and resource use. 11) It should be easy to self-assemble, maintain, and repair the technology. If tools are bought in, farmers need commitment to continuous support and maintenance. 12) New tools need to be responsive and adapt to existing practices and interoperate with existing systems, rather than requiring new practices, extra (data) labour, or further technology.

We recognise that many of these principles resonate with discussions in other domains. Some echo debates about automation more

broadly (e.g., AI to enhance not replace humans [14]), others echo principles used in community-based participatory design that foreground questions of governance and sustained use over time [22]. Others yet, like that technology should respond to concrete needs and benefits, are the basis of human-centred design. Yet, these principles are poorly applied or understood in industry and HCI (e.g., formally politically driven design agendas have become watered down and depoliticised, such as Participatory Design [11]). Putting these principles into practice is therefore critical, especially when designing within capitalism, for which we make some suggestions next.

### 5.3 What We Could Design within Capitalism

Beyond the general values around agroecologically appropriate technology and considerations for data work, we present a call to action for HCI researchers to collaborate with farmers to co-create tools that they need to do things differently. We offer some suggestions based on our findings paired with existing research. Here, we focus on their reality of operating within capitalism. We will explore how we could think beyond capitalism in Section 5.5.

*Automated data recording and administrative tasks:* To reduce the hidden data labour of manual data recording, analysis, and the paperwork needed to apply and provide evidence for certifications and subsidies, we can see potential for IoT and ICT systems to automate some of the work. However, as much of AI ‘automation’ is carried out on the back of yet other invisible data labour (e.g., data labelling) [2], we are pessimistic about an ethical use of current AI, although developments like Mozilla’s Public AI<sup>16</sup> could provide alternatives where people are appropriately remunerated for their work. Recording might include activities, plant health, harvest logs, application of inputs such as mulch, maintenance of infrastructure and equipment, soil conditions, biodiversity, crop nutrients, as well as environmental and climatic conditions. This data could also be used for learning, community building, collaboration, promotion, and political advocacy. However, in order for it to be appropriate for agroecology, we may need different types of sensors and systems so that they do not replace human observation, noticing, and learning about the land [62, 74]. For example: site-specific installations, where data (e.g., environmental, financial, aggregate data) can be visualised as part of a landscape, along the lines of a weather-vane (e.g., through kinetic installations, architectural treatments, smart materials, or zero-tech outputs like windmills or drooping tree branches) and passively registered by farmers, replacing the need for dedicated time spent at a digital device.

*Automation of work:* There are only minimal opportunities to automate agroecological work. The most direct opportunities are small-scale irrigation in polytunnels as well as certain crop management jobs when labour is short or tasks are particularly hard [77, 90]. Robot weeders, for example, would need to be small-scale, capable of manoeuvring uneven soils, and understand polycultures, which they are currently not capable of [23, 28]. As above, humans should not be replaced. In addition, the high investment costs of most automation technologies would need to be resolved, which limits the potential for automation within a community setting. Areas for

development of automation could focus on maintaining the aesthetics of the farmers experience, and minimising unwelcome data and administrative work, e.g., an audio interface designed to summarise and communicate key farm data to workers, not requiring them to stop their chosen manual, embodied, and somesthetic work alongside nature. As above, this audio could even be interwoven with the surrounding soundscape of the farm as ludic sonifications.

*Collaboration:* As we have shown in the findings, collaboration is a key, but perhaps sometimes overlooked, aspect of agroecological farmers. The resistance that some farmers showed to use existing digital tools (such as spreadsheets) to distribute and share work coordination, crop planning, and monitoring points to opportunities for more suitable and accessible tools. Any solutions would need to balance carefully the flexibility of spreadsheets with the more advanced functionality and intuitive user interface that custom software could offer [54]. Collaboration could also be extended beyond the farm gate to coordinate crop plans [34], exchange seeds [44, 82], and share tools and equipment. Passive tracking, for example, of which tools are in common use, in need of repair, or no longer functional through simple presence/need sensors in tool stores could allow for local networks of farms to more easily facilitate tool-sharing without the need to manually update spreadsheets.

*Learning and knowledge exchange:* As we have shown, agroecological learning is currently mostly informal by working alongside experienced practitioners. While we recognise the importance of hands-on, experiential learning, we agree with Raghavan et al. [77] that one of the limitations of agroecology currently is the lack of experts to learn from. For participants, the various WhatsApp groups, mailing lists, and online fora are important for knowledge exchange. However, knowledge is fragmented across multiple channels and often short-lived. Examples of much larger and structured knowledge and exchange networks for agroecological transitions include the Andhra Pradesh Community Managed Natural Farming<sup>17</sup> in India with 8 million members; the Honey Bee<sup>18</sup> network and library of grassroots agroecological innovations, also in India; or BILIM<sup>19</sup>, an agroecology community from Eastern Europe, Central and Western Asia. These are sites HCI researchers can work with and learn from to create similar networks elsewhere. Distributed data collection could be an area of interest here, for example, the use of large language models (cognisant of the caveats mentioned above) for transcription, which could record, collate, and articulate insights from conversations with experts around the farm over time into meaningful, site specific data-sets which can be preserved and shared.

*Tools for markets:* While agroecology questions food as a commodity and asserts it as fundamental right, as we have shown, it still operates in a market economy. As selling to the mainstream supermarket system is untenable, alternative market mechanisms could benefit from HCI research. While there are existing platforms, including Ooooby in the UK, Crop Fit<sup>20</sup> in India, and Open Food Network in multiple countries [72], we see design opportunities

<sup>17</sup><https://apcnf.in/>

<sup>18</sup><https://honeybee.org>

<sup>19</sup><https://bilim.network/>

<sup>20</sup><http://www.cropfitindia.org>

<sup>16</sup><https://www.mozilla.org/en/research/library/public-ai/>

to break out of the consumer-producer binary. For example, the Belgian Pluk<sup>21</sup> app not only enables CSAs to sell food, but also to promote volunteering opportunities and events on the farm. More specialised sales operations, including the planning of weekly box contents, recipe collections for unusual vegetables and cuts of meat, mapping of delivery drop-off points, and shared delivery infrastructure for small-scale food producers are other opportunities HCI could explore with farmers.

#### 5.4 How We Could Design with Farmers

Agroecological farmers cannot gain food sovereignty – the right to determine what and how food is grown appropriately – without technological and data sovereignty, i.e., their right to determine appropriate technologies and control over their data [21]. Our findings show a tension in which way this sovereignty is to be practised. On the one hand our insights demonstrate the need to build technological literacy and capabilities among farmers to enable them to adopt and adapt open-source systems in ways that are responsive to their needs. On the other hand, farmers often felt they did not have choice but to engage in data-work and use digital technology, highlighting power inequities at play in technological progress in farming as discussed by Barrett and Rose [7]. Still, some farmers did not have an interest in technology, others recognised its potential benefits, others still were firmly advocating for the value of working with their hands and the land. Therefore, rather than facing the choice between designing technologies for farmers or turning them into programmers, we propose that HCI researchers can work with existing farmer-led grassroots agri-tech organisations, such as Farm Hack and the Grassroots Technological Innovation Assembly [21] to anticipate and explore the potential positive and negative short and long-term consequences of technologies in agroecological practices before any co-design begins. Many grassroots and open-source efforts can fail to anticipate and meet the challenges that communities face when adopting, appropriating, configuring, repairing, and maintaining open-source-software, as other domains, including digital civics, have shown [22, 41].

For the outputs and the outcomes stemming from these efforts to work sustainably in the long-term, we must go beyond the ad-hoc hacking or co-design event. Recently, “commoning” approaches have been put forward in HCI as potential ways to enable co-production of digital innovation and to tackle benefits, unintended harms, and governance issues tied to digital transformations and the required skills and resources needed to envision, develop, and maintain digital innovations [83, 93]. Taking these approaches would benefit farming contexts like ours as to nurture “on-farm” innovations that centre of farmers’ aspiration, needs and values; and that foreground questions of data governance, technical capabilities, maintenance, and responsibility from the outset [38]. Yet, our findings show that farms like the ones we engaged with do not necessarily have a diverse enough volunteer base and relations with actors and organisations with a passion for sustainable farming *and* the technical skills, interests, and capabilities required to co-produce and maintain digital tools that meet the farmers’ objectives. Yet, given significant investment and policy moves towards the so-called fourth agricultural revolution and high-tech farming [7], a

concrete strategy for HCI here would be to design the appropriate socio-material infrastructures to enable the creation of spaces and the development of new relations and collaborations [52] between farmers, designers, technologists and policy actors (beyond the hack). Drawing on the Scandinavian notion of living labs [27], in which designers live and work in the community they are seeking to benefit, one way to infrastructure could be on-farm research residencies. Resisting an immediate urge to design and innovate, HCI researchers might simply engage in an unstructured mix of ‘parallel play’ (doing their everyday academic work remotely while being co-located with farmers), volunteering, and ethnographic work. This would enable researchers to develop deep relationships and a sensibility for farm life and work before structured co-design projects or grant proposals are developed. This approach is to ensure that design is enacted with care as opposed to being driven by technological hype.

This kind of infrastructuring work could also include small conventional farming communities that are also at the receiving end of the digital transformation [7] and create opportunities to anticipate social impacts that may be difficult to pinpoint before and in the course of design as to inform policy as well as socially responsible trajectories of technological development [100]. Indeed, as we have learnt, some tensions and challenges farmers face also stem from poorly conceived policies and lack of political influence; we have also learnt about conventional farmers’ desires to learn from agroecological practices, and research has flagged how also conventional small farms’ cherished practices and knowledge are at risk due to the rapid adoption of high-tech [7]. Here, there is an opportunity for HCI to create spaces of dialogue and influence that could potentially have much wider socio-political impact or to enable the scaling out of peer-to-peer knowledge.

We believe that a commoning [93] and infrastructuring [52] approach as outlined above would be essential to create the conditions to ensure farmers can reap the benefits not only from co-produced digital tools in the long term, but also from spaces of political influence able to reshape technological trajectories and wider agri-cultural practices as well as shape policies that are responsive to the concrete challenges they live with every day.

#### 5.5 Envisioning Agri-Tech Worlds Beyond Capitalism

In “Capitalist Realism”, Fisher [31] argues that the belief that capitalism is the only viable economic system has become so powerful that it has become impossible to even imagine alternatives. The visions of the data-driven and fully automated farm permeate the agri-tech industry [78, 88], media [98], and government [94]. Despite claims otherwise [98], these visions have yet to materialise, but this does not appear to derogate their power. We see, however, an important contribution for HCI and design research to provide alternative visions beyond the capitalist realism that farmers and HCI researchers find themselves in. In their review of speculative design in sustainable HCI, Soden et al. [86] note that four common benefits speculation offers are the possibility to “discuss hopeful and optimistic futures”, “question values and ethics embedded in current practices”, encourage “public discourse”, and allow “personal narratives about [...] the future to emerge”. However, they also point out

<sup>21</sup><https://plukapp.com/>

that it is important to consider what aspects of current trajectories are mutable and which are left fixed. Dominant systems of politics, economics, and consumption that are left unchanged not only reveal assumptions but also risk “casting current social and material relationships as inevitable”. Gamboa [37] asserts that HCI is stuck in an imagination crisis. Reviewing human-robot interaction literature, she highlights how “technology is often seen as an autonomous agent of change with intrinsic power to influence human lives and institutions”. As discussed, HCI research on agricultural robots, drones, and AI is no different in perpetuating this technological determinism. However, as Gamboa urges us, HCI researchers must resist feeding into these imaginaries of technological inevitability. Instead, we can, using critical speculation, such as Haraway’s SF<sup>22</sup> [43] and collective organising, imagine and promote other worlds that break with the dominant narratives of technological progress and allow us to choose alternative means-end systems [29]. We add that while discourse is a great starting point, we cannot stop there. HCI is not only stuck in an imagination crisis, but its interventions, which often stop at the design or workshop level, are never going to suffice for what bringing about alternative worlds.

We therefore call on HCI researchers to speculate about *and build* alternative, hopeful visions of the future of agriculture and agri-tech, in which democratic governance, farmer livelihoods, social and more-than-human connections, and indigenous knowledge are respected and valued [95, 99]. This includes to imagine new roles for ourselves as researchers within our communities, as we did in Section 5.4. We ask: In what worlds are robots collaborators that do arduous, dangerous, or menial tasks and collaborate with human farmers and workers on the land? In what worlds does AI not make decisions about farming, but takes over boring, repetitive administrative work? In what worlds do soil sensors not report reductive numbers about moisture, pH value, and mineral content, but make tangible the life below our feet by telling stories about soil as a living organism [60]? In what worlds is computing hardware not extracted from earth and powered by oil but grown, harvested, and composted? In what worlds can social networks facilitate food exchange not as a commodity but as a basic human right? In what worlds has technology supported agroecological farmers teach and collaborate with industrial farmers to transition to agroecology? In what worlds has appropriate technology helped agroecology to move from niche to mainstream [76]?

## 6 Conclusions

While heralded as the ‘fourth agricultural revolution’ and the solution to a sustainable intensification of food production, digitalisation of agriculture mostly exacerbates existing power dynamics and extractive practices. The current reality and future vision for small-scale agroecological farming is incompatible with full-scale automation. Consequently, the agroecological farmers we spoke to in this study use digital technologies variably (RQ1). Common use includes accessible ICT, such as spreadsheets, websites, WhatsApp, social media, and e-mail newsletters. Some farmers use more specialised tools, such as the sales platform Oooby or land mapping

<sup>22</sup>Referring to science fiction, speculative fabulation, string figures, speculative feminism, and science fact as interdependent, tentacular ways of thinking and making other possible worlds.

software. The use of spreadsheets for a wide variety of planning and monitoring tasks needs to be particularly highlighted. None of the farms use what the agri-tech industry would recognise as agri-tech: IoT sensors, drones, robots, or decision-support systems. The manual labour that goes into maintaining spreadsheets points to unmet needs around more accessible, less labour-intensive data recording systems (RQ2). There are limited opportunities for automation if it does not disconnect humans from the land, as well as more effective learning and knowledge exchange platforms geared specifically towards agroecological farmers. In addition, we found that there is a lack of sales tools that move beyond the produce-consumer binary. However, it is important to note that, as P13 put it simply, “often less is more”. New tools need to arise from concrete farmer needs not technological opportunity. Based on these insights, we developed 12 design principles for agroecological appropriate digital tech along four categories: necessity, practicality, accessibility, and sustainability (RQ3).

This paper offers two contributions. First, we presented empirical insights about agroecological farmers’ use of digital technology and data in Northern England. We showed that farms have strong ecological and community values yet also need to survive and want to thrive in a capitalist market economy and neoliberal regulatory system. They use agricultural tools that support them noticing, working, and responding to the land they farm. We also identified specific data recording needs that arise from farming collaboratively, i.e., for work coordination, crop planning and monitoring, and learning and knowledge exchange. Further requirements arise from needing to sell directly to consumers and access certifications and subsidies. We discuss these findings from several angles. First, we identify a set of pragmatic design principles that could guide the design of agroecologically appropriate agri-tech. We also highlighted the hidden labour that arises from the ubiquity of manual data recording in spreadsheets. Second, we present concrete design opportunities for HCI to co-design socio-technical systems that respond farmers’ needs while having to work within capitalism. We suggest an infrastructuring approach to work with farmers long-term on co-designing and building agroecologically appropriate tools without requiring them to become technologists themselves. We also offer design provocations to think beyond the current capitalist agri-tech trajectories. Together, they make up a design space to envisage and build optimistic futures where farmers are able to counteract the dominant narrative of big agri-tech.

## Acknowledgments

We would like to thank all our participating farmers for their time and engagement. Thanks go to Mafalda Gamboa for her critical reading of an earlier draft and for contributing the idea of research residencies. We also thank the anonymous reviewers for their constructive feedback. This research activity was funded by UKRI EPSRC as part of the Centre for Digital Citizens (EP/T022582/1).

## References

- [1] Francesco Ajena, Nicola Bossard, Chantal Clément, Angelika Hilbeck, Bernadette Oehen, Jim Thomas, and Eugenio Tisselli. 2020. *Agroecology & Digitalisation Traps and Opportunities To Transform the Food System*. Technical Report. IFOAM Organics Europe. 56 pages. [www.organicseurope.bio](http://www.organicseurope.bio)
- [2] Moritz Altenried. 2020. The platform as factory: Crowdwork and the hidden labour behind artificial intelligence. *Capital & Class* 44, 2 (6 2020), 145–158.

- doi:10.1177/0309816819899410
- [3] Miguel A. Altieri. 2009. Agroecology, Small Farms, and Food Sovereignty. *Monthly Review* 61, 3 (2009). <https://monthlyreview.org/2009/07/01/agroecology-small-farms-and-food-sovereignty/>
  - [4] Olusesan Michael Awoleye, Oluwamayowa Adebisi, Idowu Ademola Atoloye, Atanda Samuel Oladejo, Abiodun T. Atoloye, Cornelius Talade Atere, and Victoria Tanimonure. 2025. Leveraging Artificial Intelligence-Powered Virtual Assistant for Information Retrieval in Indigenous Agriculture: Insights from Nigeria. In *Proceedings of the 48th International ACM SIGIR Conference on Research and Development in Information Retrieval*. ACM, New York, NY, USA, 3095–3097. doi:10.1145/3726302.3730265
  - [5] Lindsay Barbieri, Sonya Ahamed, and Sam Bliss. 2019. Farming within limits. *Interactions* 26, 5 (8 2019), 70–73. doi:10.1145/3348795
  - [6] Jeffrey Bardzell, Shaowen Bardzell, and Ann Light. 2021. Wanting To Live Here: Design After Anthropocentric Functionalism. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. ACM, New York, NY, USA, 1–24. doi:10.1145/3411764.3445167
  - [7] Hannah Barrett and David Christian Rose. 2022. Perceptions of the Fourth Agricultural Revolution: What's In, What's Out, and What Consequences are Anticipated? *Sociologia Ruralis* 62, 2 (4 2022), 162–189. doi:10.1111/soru.12324
  - [8] Heidi Biggs, Tejaswini Joshi, Ries Murphy, Jeffrey Bardzell, and Shaowen Bardzell. 2021. Alternatives to Agrilogistics: Designing for Ecological Thinking. *Proceedings of the ACM on Human-Computer Interaction* 5, CSCW2 (2021), 1–31. doi:10.1145/3479557
  - [9] Heidi R. Biggs, Jefery Bardzell, and Shaowen Bardzell. 2021. Watching Myself Watching Birds: Abjection, Ecological Thinking, and Posthuman Design. In *Conference on Human Factors in Computing Systems - Proceedings*, Vol. 16. Association for Computing Machinery. doi:10.1145/3411764.3445329
  - [10] Susanne Bodker, Henrik Korsgaard, and Joanna Saad-Sulonen. 2016. 'A farmer, a place and at least 20 Members': The development of artifact ecologies in volunteer-based communities. In *Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing - CSCW '16*. ACM Press, New York, NY, 1140–1154. doi:10.1145/2818048.2820029
  - [11] Susanne Bødker and Morten Kyng. 2018. Participatory Design that matters - Facing the big issues. *ACM Transactions on Computer-Human Interaction* 25, 1 (2 2018), 1–31. doi:10.1145/3152421
  - [12] Virginia Braun and Victoria Clarke. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology* 3, 2 (1 2006), 77–101. doi:10.1191/1478088706qp063oa
  - [13] Sally Brooks. 2021. Configuring the digital farmer: A nudge world in the making? *Economy and Society* 50, 3 (2021), 374–396. doi:10.1080/03085147.2021.1876984
  - [14] Tara Capel and Margot Brereton. 2023. What is Human-Centered about Human-Centered AI? A Map of the Research Landscape. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, Vol. 22. ACM, New York, NY, USA, 1–23. doi:10.1145/3544548.3580959
  - [15] Michael Carolan. 2017. Agro-Digital Governance and Life Itself: Food Politics at the Intersection of Code and Affect. *Sociologia Ruralis* 57, S1 (12 2017), 816–835. doi:10.1111/soru.12153
  - [16] Michael Carolan. 2020. Acting like an algorithm: digital farming platforms and the trajectories they (need not) lock-in. *Agriculture and Human Values* 37, 4 (2020), 1041–1053. doi:10.1007/s10460-020-10032-w
  - [17] Michael Carolan. 2020. Automated agrifood futures: robotics, labor and the distributive politics of digital agriculture. *The Journal of Peasant Studies* 47, 1 (1 2020), 184–207. doi:10.1080/03066150.2019.1584189
  - [18] Michael Carolan. 2022. Digitization as politics: Smart farming through the lens of weak and strong data. *Journal of Rural Studies* 91 (4 2022), 208–216. doi:10.1016/j.jrurstud.2020.10.040
  - [19] Akash Chaudhary, Stefany Arevalo Escobar, Dulce Zayas, and Norman Makoto Su. 2025. Normalizing Grit: The Futility of Personal Informatics for Farm Workers and Climate Change. In *Proceedings of the 2025 CHI Conference on Human Factors in Computing Systems*. ACM, New York, NY, USA, 1–17. doi:10.1145/3706598.3713643
  - [20] Civil Society and Indigenous Peoples' Mechanism (CSIPM). 2023. *CSIPM Vision Statement on Data for Food Security and Nutrition*. Technical Report. <https://viacampesina.org/en/data-for-food-security-and-nutrition-csipm-vision-statement/>
  - [21] Maya Cohen. 2023. *Grassroots Technological Innovation Assembly*. Technical Report. [https://www.scholacampesina.org/grassroot\\_innovation\\_assembly\\_report/](https://www.scholacampesina.org/grassroot_innovation_assembly_report/)
  - [22] Ned Cooper, Tiffanie Horne, Gillian R. Hayes, Courtney Heldreth, Michal Lahav, Jess Holbrook, and Lauren Wilcox. 2022. A Systematic Review and Thematic Analysis of Community-Collaborative Approaches to Computing Research. In *CHI Conference on Human Factors in Computing Systems*. ACM, New York, NY, USA, 1–18. doi:10.1145/3491102.3517716
  - [23] Lenora Ditzler and Clemens Driessen. 2022. Automating Agroecology: How to Design a Farming Robot Without a Monocultural Mindset? *Journal of Agricultural and Environmental Ethics* 35, 1 (3 2022), 1–31. doi:10.1007/s10806-021-09876-x
  - [24] Cory Doctorow. 2023. *The Internet Con: How to Seize the Means of Computation*. Verso, New York. <https://www.versobooks.com/en-gb/products/3035-the-internet-con>
  - [25] Olivia Doggett, Kelly Bronson, and Robert Soden. 2023. HCI Research on Agriculture: Competing Sociotechnical Imaginaries, Definitions, and Opportunities. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*. ACM, New York, NY, USA, 1–24. doi:10.1145/3544548.3581081
  - [26] Olivia Doggett, Matt Ratto, and Priyank Chandra. 2024. Migrant Farmworkers' Experiences of Agricultural Technologies: Implications for Worker Sociality and Desired Change. *Conference on Human Factors in Computing Systems - Proceedings* (5 2024). doi:10.1145/3613904.3642263/SUPPL[\_]FILE/3613904.3642263-TALK-VIDEO.VTT
  - [27] Pelle Ehn, Elisabet M Nilsson, and Richard Topgaard (Eds.). 2014. *Making Futures: Marginal Notes on Innovation, Design, and Democracy*. MIT Press, Cambridge, MA, 351 pages.
  - [28] Alex Elias, Maria J. Galvez Trigo, and Carolina Camacho-Villa. 2025. Analyzing Previous Human-Robot Interaction Implementation in Agriculture: What Can We Learn from the Past?. In *2025 20th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*. IEEE, 123–131. doi:10.1109/HRI61500.2025.10974051
  - [29] Andrew Feenberg. 2012. *Questioning Technology*. Routledge, London, 272 pages. doi:10.4324/9780203022313/QUESTIONING-TECHNOLOGY-ANDREW-FEENBERG/RIGHTS-AND-PERMISSIONS
  - [30] Robert Finger. 2023. Digital innovations for sustainable and resilient agricultural systems. *European Review of Agricultural Economics* 50, 4 (2023), 1277–1309. doi:10.1093/erae/jbad021
  - [31] Mark Fisher. 2009. *Capitalist realism: is there no alternative?* John Hunt, Hants, 81 pages.
  - [32] Andrew Flachs, Ankit Raturi, Megan Low, Valerie Miller, Juliet Norton, Celeste Redmond, and Haley Thomas. 2024. Digital tools for local farmers: Thinking with spreadsheets in the wake of the COVID-19 pandemic. *Culture, Agriculture, Food and Environment* 46, 1 (6 2024), 36–47. doi:10.1111/cuag.12316
  - [33] Food and Agriculture Organization of the United Nations. 2018. *The 10 Elements of Agroecology: Guiding the Transition to Sustainable Food and Agricultural Systems*. Technical Report.
  - [34] Lauren Forbes, Sai Meenakshi Hariharan, and Annu Sible Prabhakar. 2025. Using Participatory Design in the Development of the Homegrown Dashboard System for Farmer Collaboration and Contract Management. In *Proceedings of the Extended Abstracts of the CHI Conference on Human Factors in Computing Systems*. ACM, New York, NY, USA, 1–7. doi:10.1145/3706599.3719682
  - [35] Nick J Fox. 2014. Post-structuralism and Postmodernism. In *The Wiley Blackwell Encyclopedia of Health, Illness, Behavior, and Society*, William C. Cockerham, Robert Dingwall, and Stella R. Quah (Eds.). Number January. Wiley-Blackwell, Chichester.
  - [36] Friends of the Earth Europe. 2024. Digital farming and peasants' struggle for autonomy. <https://friendsoftheearth.eu/news/digital-farming-and-peasants-struggle-for-autonomy/>
  - [37] Mafalda Gamboa. 2025. Robots are Increasingly: Imagination Crisis in Human-Computer Interaction Research. In *Proceedings of the sixth decennial Aarhus conference: Computing X Crisis*. ACM, New York, NY, USA, 216–222. doi:10.1145/3744169.3744189
  - [38] Peter Glick and Clara Crivellaro. 2023. MyCareBudget: Co-creating a Healthcare Digital Commons with and for Disabled Citizens and their Unpaid Carers. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*. ACM, New York, NY, USA, 1–16. doi:10.1145/3544548.3580934
  - [39] Jue Gong, Jie Chen, Zixi Chen, Hongyi Chi, and Jianglong Liu. 2025. Overview of the Application Progress of Digital Twins in Agriculture. In *Proceedings of the 2025 International Conference on Digital Management and Information Technology*. ACM, New York, NY, USA, 295–303. doi:10.1145/3736426.3736473
  - [40] Meilin Guo, Heng Tang, and Xiaoyan Guo. 2024. Blockchain Technology Enabling Applications in Smart Agriculture. In *2024 International Conference on Big Data and Digital Management*. ACM, New York, NY, USA, 1–0. doi:10.1145/3696500.3696542
  - [41] Andrea Hamm, Yuya Shibuya, Stefan Ullrich, and Teresa Cerratto Cerratto Pargman. 2021. What Makes Civic Tech Initiatives To Last Over Time? Dissecting Two Global Cases. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. ACM, New York, 1–17. doi:10.1145/3411764.3445667
  - [42] Benjamin V Hanrahan, Carleen Maitland, Timothy Brown, Anita Chen, Fraterne Kagame, and Beatrice Birir. 2021. Agency and Extraction in Emerging Industrial Drone Applications. *Proceedings of the ACM on Human-Computer Interaction* 4, CSCW3 (1 2021), 1–21. doi:10.1145/3432932
  - [43] Donna J. Haraway. 2018. Making Kin in the Chutlucene: Reproducing Multi-species Justice. In *Making Kin Not Population*, Adele E. Clarke and Donna (Eds.). Prickly Paradigm, Chicago, IL, 67–100.
  - [44] Sara Heitlinger, Nick Bryan-Kinns, and Rob Comber. 2018. Connected seeds and sensors: Co-designing internet of things for sustainable smart cities with urban food-growing communities. In *Proceedings of the 15th Participatory Design*

- Conference: *Short Papers, Situated Actions, Workshops and Tutorial - Volume 2*, Vol. 2. ACM, New York, NY, USA, 1–5. doi:10.1145/3210604.3210620
- [45] Sara Heitlinger, Nick Bryan-Kinns, and Janis Jefferies. 2013. UbiComp for grassroots urban food-growing communities. In *Proceedings of the 2013 ACM conference on Pervasive and ubiquitous computing adjunct publication - UbiComp '13 Adjunct*. ACM Press, New York, New York, USA, 589–594. doi:10.1145/2494091.2497617
- [46] Courtney Heldreth, Diana Akrong, Jess Holbrook, and Norman Makoto Su. 2021. What does AI mean for smallholder farmers? *Interactions* 28, 4 (7 2021), 56–60. doi:10.1145/3468004
- [47] Angelika Hilbeck and Bernadette Oehen. 2018. Agroecology – the Most Convincing Proposal for Transforming Unsustainable Agro-Food Systems. *Rural* 21 51, 2 (2018), 8–10.
- [48] Sune Holm, Søren Marcus Pedersen, and Tseganesh Wubale Tamirat. 2024. Robots in agriculture – A case-based discussion of ethical concerns on job loss, responsibility, and data control. *Smart Agricultural Technology* 9 (12 2024), 100633. doi:10.1016/j.ATECH.2024.100633
- [49] Ivan Illich. 1972. *Tools for Conviviality*. 1–126 pages. [http://clevercycles.com/tools\\_for\\_conviviality/](http://clevercycles.com/tools_for_conviviality/)
- [50] IPES-Food. 2016. *From Uniformity to Diversity: A paradigm shift from industrial agriculture to diversified agroecological systems*. Technical Report. International Panel of Experts on Sustainable Food Systems. doi:10.1299/jsmmeds.2022.32.1208
- [51] IPES-Food. 2020. *COVID-19 and the crisis in food systems : Symptoms, causes, and potential solutions*. Technical Report April. 1–11 pages. [http://www.ipes-food.org/\\_img/upload/files/COVID-19\\_CommuniqueEN.pdf](http://www.ipes-food.org/_img/upload/files/COVID-19_CommuniqueEN.pdf)
- [52] Helena Karasti. 2014. Infrastructuring in participatory design. In *Proceedings of the 13th Participatory Design Conference on Research Papers - PDC '14*. ACM Press, New York, NY, 141–150. doi:10.1145/2661435.2661450
- [53] Jared Lee Katzman, Aarti Israni, Samartha Okyne, Holden Winton, and Tawanna R Dillahunt. 2025. Technological Tensions In Urban Food Sovereignty: Insights from Detroit’s Farmers. In *Proceedings of the Extended Abstracts of the CHI Conference on Human Factors in Computing Systems*. ACM, New York, NY, USA, 1–8. doi:10.1145/3706599.3719828
- [54] Hannah E Klein and Ankita Raturi. 2025. Conducting Spreadsheet Audits as a (re)Design Method: A Bird Biodiversity Decision Support Tool Case Study. In *Proceedings of the Extended Abstracts of the CHI Conference on Human Factors in Computing Systems*. ACM, New York, NY, USA, 1–7. doi:10.1145/3706599.3706696
- [55] La Via Campesina. 2025. The Challenges Digitalisation Brings to Peasant Agroecology: An ECVC perspective. <https://viacampesina.org/en/2025/05/the-challenges-digitalisation-brings-to-peasant-agroecology-an-ecvc-perspective/>
- [56] Airi Lampinen, Moira McGregor, Rob Comber, and Barry Brown. 2018. Member-Owned Alternatives: Exploring Participatory Forms of Organising with Cooperatives. *Proceedings of the ACM on Human-Computer Interaction* 2, CSCW (2018), 1–19. doi:10.1145/3274369
- [57] Marvin Landwehr, Philip Engelbutzeder, and Volker Wulf. 2021. Community Supported Agriculture: The Concept of Solidarity in Mitigating Between Harvests and Needs. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. ACM, New York, NY, USA, 1–13. doi:10.1145/3411764.3445268
- [58] Christopher A. Le Dantec and Sarah Fox. 2015. Strangers at the Gate: Gaining Access, Building Rapport, and Co-Constructing Community-Based Research. In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing - CSCW '15*. ACM Press, New York, 1348–1358. doi:10.1145/2675133.2675147
- [59] Gilly Leshed, Maria Håkansson, and Joseph Jofish Kaye. 2014. "Our life is the farm and farming is our life": Home-work coordination in organic farm families. In *Proceedings of the 17th ACM conference on Computer supported cooperative work & social computing*. ACM, New York, NY, USA, 487–498. doi:10.1145/2531602.2531708
- [60] Jen Liu, Daragh Byrne, and Laura Devendorf. 2018. Design for collaborative survival: An inquiry into human-fungi relationships. *Conference on Human Factors in Computing Systems - Proceedings* 2018-April (2018), 1–13. doi:10.1145/3173574.3173614
- [61] Jen Liu and Phoebe Sengers. 2021. Legibility and the Legacy of Racialized Disposition in Digital Agriculture. *Proceedings of the ACM on Human-Computer Interaction* 5, CSCW2 (10 2021), 26. doi:10.1145/3479867
- [62] Szu-Yu (Cyn) Liu, Shaowen Bardzell, and Jeffrey Bardzell. 2019. Symbiotic Encounters: HCI and Sustainable Agriculture. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. ACM, New York, NY, USA, 1–13. doi:10.1145/3290605.3300547
- [63] Ezio Manzini. 2015. *Design, when everybody designs: An introduction to design for social innovation*. MIT Press, Cambridge, MA. 241 pages.
- [64] Sanna Marttila and Andrea Botero. 2017. Infrastructuring for cultural commons. *Computer Supported Cooperative Work (CSCW)* 26, 1-2 (2017), 97–133. doi:10.1007/s10606-017-9273-1
- [65] Aymas Mason, Pat Thomas, and Lawrence Woodward. 2024. *Agroecological Intelligence: Establishing criteria for agroecologically appropriate technology*. Technical Report. A Bigger Conversation. [https://abiggerconversation.org/wp-content/uploads/2024/05/ABC\\_Agroecological-Intelligence-Report\\_Final\\_280524.pdf](https://abiggerconversation.org/wp-content/uploads/2024/05/ABC_Agroecological-Intelligence-Report_Final_280524.pdf)
- [66] Chris Maughan and Colin Ray Anderson. 2023. "A shared human endeavor": farmer participation and knowledge co-production in agroecological research. *Frontiers in Sustainable Food Systems* 7 (2023). doi:10.3389/fsufs.2023.1162658
- [67] Juliet Norton, Birgit Penzenstadler, and Bill Tomlinson. 2019. Implications of grassroots sustainable agriculture community values on the design of information systems. *Proceedings of the ACM on Human-Computer Interaction* 3, CSCW (2019), 22. doi:10.1145/3359136
- [68] Nyéléni. 2019. The digitalization of the food system. *Nyéleni Newsletter* 37 (2019), 6. [www.nyeleni.org](http://www.nyeleni.org)
- [69] William Odom. 2010. "Mate, we don't need a chip to tell us the soil s dry": Opportunities for designing interactive systems to support urban food production. In *Proceedings of the 8th ACM Conference on Designing Interactive Systems - DIS '10*. ACM Press, New York, 232–235. doi:10.1145/1858171.1858211
- [70] Office for National Statistics. 2024. Family spending in the UK: April 2022 to March 2023. <https://www.ons.gov.uk/peoplepopulationandcommunity/personalandhouseholdfinances/expenditure/bulletins/familyspendingintheuk/april2022tomarch2023>
- [71] Alekos Pantazis and Morgan Meyer. 2020. Tools from below: Making agricultural machines convivial. *Greek Review of Social Research* 155 (2020), 39–58. doi:10.12681/grsr.24828
- [72] Vangelis Papadimitropoulos and Haris Malamidis. 2023. Prefiguring the counterhegemony of open cooperativism: The case of Open Food Network. *Journal of Rural Studies* 101, June (2023), 103067. doi:10.1016/j.jrurstud.2023.103067
- [73] Rui Pedro Porfirio. 2024. Studying the Impact of Explainable AI in Digital Agriculture Solutions. In *Companion Publication of the 2024 Conference on Computer-Supported Cooperative Work and Social Computing*. ACM, New York, NY, USA, 43–46. doi:10.1145/3678884.3682046
- [74] Sebastian Prost, Henry Collingham, and Jon Rogers. 2024. Digital Technologies for Smallholder Agriculture: Tensions and Speculations. In *Designing Interactive Systems Conference*. ACM, New York, NY, USA, 261–265. doi:10.1145/3656156.3663714
- [75] Sebastian Prost, Clara Crivellaro, Andy Haddon, and Rob Comber. 2018. Food democracy in the making: designing with local food networks. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems - CHI '18*, Vol. 2018-April. ACM Press, New York, NY, 1–14. doi:10.1145/3173574.3173907
- [76] Barath Raghavan, Bonnie Nardi, Sarah T. Lovell, Juliet Norton, Bill Tomlinson, and Donald J. Patterson. 2016. Computational agroecology: Sustainable food ecosystem design. *Conference on Human Factors in Computing Systems - Proceedings* 07-12-May- (5 2016), 423–435. doi:10.1145/2851581.2892577
- [77] Barath Raghavan and Daniel Pargman. 2016. Refactoring Society: Systems Complexity in an Age of Limits. In *Proceedings of the Second Workshop on Computing within Limits*. ACM, New York, NY, USA, 1–7. doi:10.1145/2926676.2926677
- [78] Gloire Rubambiza, Phoebe Sengers, and Hakim Weatherspoon. 2022. Seamless Visions, Seamful Realities: Anticipating Rural Infrastructural Fragility in Early Design of Digital Agriculture. In *CHI Conference on Human Factors in Computing Systems*. ACM, New York, NY, USA, 1–15. doi:10.1145/3491102.3517579
- [79] Mute Schimpf, Philip Seufert, and Barbara van Dyke. 2023. *Remote Control and Peasant Intelligence: On automating decisions, suppressing knowledges and transforming ways of knowing*. Technical Report. 49 pages.
- [80] Emrys Schoemaker, Reem Talhouk, Catherine Kamanu, Eoghan McDonough, Chris McDonough, Eliza Casey, Adam Wills, Finn Richardson, and Jonathan Donner. 2022. Social Agriculture: Examining the Affordances of Social Media for Agricultural Practices. In *ACM SIGCAS/SIGCHI Conference on Computing and Sustainable Societies (COMPASS)*, Vol. Par F18047. ACM, New York, NY, USA, 476–489. doi:10.1145/3530190.3534806
- [81] Sabrina Scuri, Marta Ferreira, Nuno Jardim Nunes, Valentina Nisi, and Cathy Mulligan. 2022. Hitting the Triple Bottom Line. In *CHI Conference on Human Factors in Computing Systems*. ACM, New York, NY, USA, 1–19. doi:10.1145/3491102.3517518
- [82] Seed Exchange Kenya. [n.d.]. Diverse Seeds from Real farmers. <https://seedexchangekenya.org/>
- [83] Anna Seravalli. 2018. Infrastructuring urban commons over time: learnings from two cases. In *Proceedings of the 15th Participatory Design Conference on Full Papers - PDC '18*, Vol. 1. ACM Press, New York, NY, 1–11. doi:10.1145/3210586.3210593
- [84] Tanya Singh, Pritam Singh, and Meena Dhanda. 2021. Resisting a "Digital Green Revolution": Agri-logistics, India's New Farm Laws and the Regional Politics of Protest. *Capitalism, Nature, Socialism* 32, 2 (2021), 1–21. doi:10.1080/10455752.2021.1936917
- [85] Ashutus Singha, Hira Lal Gope, A. K. Mohibul Islam, Md Masum Billah, Md Mehedi Hasan, and Shohag Barman. 2024. Integrating IoT-Based Smart Irrigation Systems to Optimize Crop Yield and Water Management for Sustainable Agriculture. In *Proceedings of the 3rd International Conference on Computing Advancements*. ACM, New York, NY, USA, 123–130. doi:10.1145/3723178.3723195
- [86] Robert Soden, Pradnaya Pathak, and Olivia Doggett. 2021. What We Speculate About When We Speculate About Sustainable HCI. In *ACM SIGCAS Conference*

- on *Computing and Sustainable Societies (COMPASS)*. ACM, New York, NY, USA, 188–198. doi:10.1145/3460112.3471956
- [87] Susan Leigh Star and Anselm Strauss. 1999. Layers of Silence, Arenas of Voice: The Ecology of Visible and Invisible Work. *Computer Supported Cooperative Work* 8 (1999), 9–30.
- [88] Rosemary Steup, Lynn Dombrowski, and Norman Makoto Su. 2019. Feeding the World with Data: Visions of Data-Driven Farming. In *Proceedings of the 2019 on Designing Interactive Systems Conference*. ACM, New York, NY, USA, 1503–1515. doi:10.1145/3322276.3322382
- [89] Rosemary Steup, Arvind Santhanam, Marisa Logan, Lynn Dombrowski, and Norman Makoto Su. 2018. Growing tiny publics: small farmers' social movement strategies. *Proceedings of the ACM on Human-Computer Interaction* 2, CSCW (11 2018), 1–24. doi:10.1145/3274434
- [90] Rosemary Steup, Paige White, Lynn Dombrowski, and Norman Makoto Su. 2022. "A Reasonable Life": Rhythmic Attunement and Sustainable Work at the Intersection of Farming and Knowledge Work. *Proceedings of the ACM on Human-Computer Interaction* 6, CSCW2 (11 2022), 1–22. doi:10.1145/3555577
- [91] Glenn Davis Stone. 2022. Surveillance agriculture and peasant autonomy. *Journal of Agrarian Change* 22, 3 (7 2022), 608–631. doi:10.1111/joac.12470
- [92] Nick Taylor, Ursula Hurley, and Philip Connolly. 2016. Making Community: The Wider Role of Makerspaces in Public Life. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. ACM, New York, NY, USA, 1415–1425. doi:10.1145/2858036.2858073
- [93] Maurizio Teli, Marcus Foth, Mariacristina Sciannambro, Irina Anastasiu, and Peter Lyle. 2020. Tales of institutioning and commoning: Participatory design processes with a strategic and tactical perspective. In *ACM International Conference Proceeding Series*, Vol. 1. ACM, 159–171. doi:10.1145/3385010.3385020
- [94] UK Department for Business and Trade. 2025. The UK's Modern Industrial Strategy 2025. <https://www.gov.uk/government/collections/the-uks-modern-industrial-strategy-2025>
- [95] UPPCS Magazine. 2025. Agroecology and the Role of Indigenous Technologies. <https://uppcsmagazine.com/agroecology-and-the-role-of-indigenous-technologies/>
- [96] Marloes de Valk. 2021. A pluriverse of local worlds: A review of Computing within Limits related terminology and practices. *LIMITS Workshop on Computing within Limits* (6 2021). doi:10.21428/BF6FB269.1E37D8BE
- [97] Yanis Varoufakis. 2024. *Technofeudalism: what killed capitalism*. Vintage. 281 pages. <https://www.penguin.co.uk/books/451795/technofeudalism-by-varoufakis-yanis/9781529926095>
- [98] John Vidal. 2015. Hi-tech agriculture is freeing the farmer from his fields. <https://www.theguardian.com/environment/2015/oct/20/hi-tech-agriculture-is-freeing-farmer-from-his-fields>
- [99] Alexander Wezel, Barbara Gemmill Herren, Rachel Bezner Kerr, Edmundo Barrios, André Luiz Rodrigues Gonçalves, and Fergus Sinclair. 2020. Agroecological principles and elements and their implications for transitioning to sustainable food systems. A review. *Agronomy for Sustainable Development* 40, 6 (12 2020), 40. doi:10.1007/s13593-020-00646-z
- [100] Qian Yang, Richmond Y. Wong, Thomas Gilbert, Margaret D. Hagan, Steven Jackson, Sabine Junginger, and John Zimmerman. 2023. Designing Technology and Policy Simultaneously: Towards A Research Agenda and New Practice. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems*. ACM, New York, NY, USA, 1–6. doi:10.1145/3544549.3573827

## A Participating Farms

Farm ID	Farm Type	Acreage (food)	Workers + volunteers	Produce	Farming Principles	Weekly customers	Route to Market	Use of digital technology
F1	CSA	14 (5)	2 + 22	50+ varieties of vegetables, fruits, beans, hay	Organic certified, agroforestry	20	veg box subscription, online sale	Website, spreadsheets, custom webshop, social media, video conferencing, WhatsApp, accounting
F2	Market garden	2 (1)	1 + occasional	vegetables, fruits, herbs	Organic (not certified)	15-100	3 <sup>rd</sup> party veg box	Website, spreadsheets, webshop, social media, accounting
F3	Mixed farm and market garden	150 (75)	1 + 3 + occasional	vegetables, fruits, herbs, flowers, beef, lamb, chickens, eggs	Organic (certified)	38 (veg), meat 6x year	crop share subscription, farm shop	Website, email, member newsletter, social media, accounting
F4	Vegetable farm	10 (10)	9 + occasional	50+ varieties of vegetables, fruits	Organic (certified)	300	veg box subscription, markets	Website, spreadsheets, e-mail, webshop, accounting
F5	CSA	22 (2)	9 + 12	50+ varieties of vegetables, fruits	Organic (certified)	n/a	n/a (donated)	Website, spreadsheets, social media, GIS tools, accounting
F6	CSA	4 (2)	1 + 33	vegetables, fruits	Organic (not certified)	60	crop share subscription, farm shop	Website, social media, WhatsApp groups, Google Drive, spreadsheets
F7	Livestock farm	200 (160)	1 + occasional	beef	Pasture for Life certified, Extensive grazing	15 (6x per year)	meat box, restaurants, butchers	Social media, WhatsApp, Online, species ID apps, Magic land mapping app, accounting, spreadsheets
F8	Veg Box Scheme (with own farm)	3.5 (1)	9 + 4	vegetables, fruits	Organic (mixed certified)	200	Crop share subscription	Oooby, Website, social media, newsletter, accounting
F9	Livestock farm	1000 (<500)	2 + occasional	beef, sheep, turkeys	Pasture for Life certified, Extensive grazing	up to 100 3x per year	Livestock market, meat boxes (direct sale), restaurants	Website, newsletter, WhatsApp, accounting
F10	Veg Box Scheme (with own farm)	15 (5)	18 + 40	vegetables, fruits, bread	Organic (certified)	500	veg box subscription	Website, Oooby, WhatsApp, Slack, Google Workspace, GIS tools, accounting
F11	Market garden	15 (4.5)	4 + 10	vegetables, fruits	Organic (not certified)	60	veg box subscription	Website, spreadsheets, newsletter/ mailing list, volunteer WhatsApp group, accounting