Inequalities and Power in Digital Agriculture

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There are several patterns of inequalities linked to the development and adoption of digital technologies in agriculture that can be observed across the globe: (1) in digital technology development; (2) in the distribution of benefits from the use of digital technologies; (3) in sovereignty over data, hardware and digital infrastructure; (4) in skills and knowledge ('digital literacy'); and (5) in problem definition and problem-solving capacities. The existing inequalities are structural and represent expressions of corporate power. From such a perspective, digitalization in agriculture is not a 'revolution' per se; rather, digital technologies mirror and reproduce existing power relations. However, there are also emancipatory initiatives that are applying digital technologies to challenge existing inequalities and to advance alternative visions of agriculture.

Keywords: digital agriculture ; inequalities ; power ; data sovereignty

1. Introduction

'Smart farming', 'agriculture 4.0' and 'digital agriculture' are largely interchangeable terms used to describe the phenomenon of increased use of data-related technologies in the farming and food production process. These technologies make use of big data, artificial intelligence, and automation along the entire commodity chain, from input production to crop production and harvesting, packaging, transportation and consumption. At the input level, they include digitally enabled genome editing and biofortification, as well as microfinance programs and insurance systems. On the farm, smart machinery is used for crop production and harvesting. Sensors are used to monitor soil moisture and plant nutrition requirements, and to detect the presence of pests and diseases. Decision support apps help farmers to apply fertilizers and pesticides when and where they are needed. Remote satellite imagery is utilized to monitor biomass growth, complemented by pictures and data collected from drones and robots scanning the fields. Farm management software is used by farmers to prepare the documentation required to comply with regulations, obtain subsidies, and market their products. Much of the agricultural data generated by these digital technologies is stored on data platforms and in clouds hosted by technology and service providers [1][2][3][4]. 'Digital agriculture' encompasses both digitization, which refers to the technical process of converting analogue information into digital data, and digitalization, understood as the social process of adoption of computer technologies [5]. The ever-greater penetration of these technologies into social and economic life brings about a digital transformation, including in agriculture, where digital technologies are contributing to a reshaping of production processes across the globe. The digitalization of agriculture is widely hailed as the next agricultural revolution [6]. However, while numerous case studies analyze specific instances of digitalization, aggregated data is scarce and little progress has been made towards a systematic overview of the adoption of different types of digital agriculture on a global scale [1]. Even less is known about the social impacts and power effects of the digitalization of agriculture. As portrayed by policies and industry, digital agriculture benefits the environment and farmers by increasing productivity. Corporate leaders and policy institutions argue that digitalization offers the solution to feeding a growing world population, while at the same time mitigating the negative environmental and climate consequences of industrial agriculture (see [7] [8]). This picture is an affirmative and positive one, generally conflict-free and with few if any downsides. In contrast, some civil society organizations adopt a more critical attitude, drawing attention to problematic impacts on, for example, labor relations and social justice. These organizations see digitalization as a threat to food sovereignty and the livelihoods of smallholders [9]. The academic literature presents a more nuanced picture. Studies highlight the social and economic opportunities, while acknowledging that digitalization also entails challenges and risks [10][11][12].

2. Inequalities in Control over Technology Development

The digital transformation of the food system is largely driven by private multinational firms. In [1], the authors identify four main groups of actors: (a) giant corporations producing agricultural inputs, such as Bayer Ag and SYNGENTA; (b) new agri-tech players from the software and big data sector, such as Alphabet, IBM, SAP, and Alibaba; (c) machinery and hardware companies, such as BOSCH and John Deere; and (d) private sector start-ups. The first two groups dominate technological innovation along the entire food commodity chain, driving the development of GMO seeds, farm management platforms, and automated warehouses [1][2]. Their economic power enables them to control the direction of technological development, including how it is used by farmers [12][13]. The leading role of agribusiness and tech firms in the development and commercialization of digital agriculture technologies consolidates economic concentration, increasing the dependency of farmers and consumers on these powerful actors as well as their control over agricultural production [13][14]. This could exacerbate the existing divide between large-scale and small-scale farms, leading to a situation where a small number of digitally equipped large-scale farms produce an ever-greater share of agricultural output [14]. Similar observations have been made with regard to the impact of Green Revolution technologies [15] in both developed [11][16][17][18] and developing countries [6].

Innovation generally occurs when investment capital is available and responds to the needs of the investors. Because of the scale of capital investment in agriculture and the pressure this creates to produce a return on investment, most agricultural innovation is undertaken by high-tech and capital-intensive companies and directed towards their needs. This effect is self-reinforcing and favors the concentration of digital technology in the hands of ever-fewer powerful actors [2][15].

New digitally-driven biotechnologies such as genome editing as well as the large number of digital farming start-ups that are proliferating across the globe raise some hope for the democratization of access and control, in particular through significantly decreased costs [12][19]. Novel technologies might create some potential for a more level playing field; however, large corporate actors still predominate through the concentration of technological know-how and infrastructure, ownership of data, ownership of patents on new genome editing technologies [2], and the imposition of legal or technical lock-ins that prevent independent use of new technology [20]. Moreover, many successful start-ups are quickly bought up by one of the big players, as in the widely-publicized case of the purchase of Climate Corporation's farming platform by Bayer AG (formerly Monsanto) for USD 930 million in 2013 [2][10][12]. One expression of this inequality in control over technological development is the lack of interoperability, which limits the ability of information technology systems to exchange data with each other and to make use of information held by other systems [16][21]. This imposes technical lock-ins, a barrier that prevents farmers from using technology systems from different service providers in accordance with their needs. Agricultural input and machinery companies impose similar lock-ins. They extract value from the data they collect on the use of digital technologies to lock farmers into their own product ecosystems (e.g., by targeted advertising of their own farm inputs or machinery). Some farm management platforms offer multi-tiered service packages, sometimes with a free basic version designed to attract a critical number of users and thus enhance market share. Through these mechanisms, farm management platforms, like other digital platforms, create legal and technical data lock-in mechanisms that restrict the freedom of their users [20]. This means that while the costs of using the platform may be low, switching to a different provider is often expensive or even impossible (e.g., due to the incompatibility of data formats) [2][12]. This lack of control over technology considerably limits autonomous decision making by farmers regarding their choice of software or hardware. Interoperable data production technologies and data management systems with transparent terms of use are essential if they are to become effective knowledge-enhancing and decision-making tools for farmers under their own sovereignty and ownership [22].

In response to this need, and despite the overarching dominance of large corporations, some alternatives have emerged. One example from Canada is the farmer-owned Three Rivers Farmers Alliance [23], whose members have developed their own smartphone app to help organize such farming activities as harvesting and processing. The app also connects them to local customers such as shops, schools or restaurants, who can use it to place orders for delivery [16]. Another example in the United States is Ag Hub (formerly Ag Xchange), an open and corporate-neutral farm data platform that enables farmers' control of data and promotes sharing among data users [24]. It is the result of cooperation between two non-profit initiatives, the farmer-owned Grower Information Services Cooperative and the Agricultural Data Coalition, an initiative by farmers, lawyers, business groups, and researchers. It claims to be the "industry's first cloud-based platform that will be controlled by growers and open to all industry service partners and technology providers" [17].

3. Unequal Distribution of Benefits from Technologies

The way digital technology is designed contributes to the unequal distribution of its benefits. Much of agricultural big data and much of the associated infrastructure is primarily designed to service farmers who follow a productivist strategy, which aims to maximize the output of commodity export crops; this is a model based around the intensification, industrialization and externalization of agriculture [2][11]. The exclusion of farmers who adopt a different approach contributes to increased inequality not only between farmers and agribusinesses but also among farmers themselves (e.g., small scale vs. large scale, conventional vs. organic) [11]. Adoption and use of digital farming technologies is already higher on large farms dedicated to the production of commodity crops, particularly in industrialized countries with a highly concentrated farm structure [12][25]. Here digitalization deepens the digital divide between larger, capital-intensive farms and those unable or unwilling to purchase digital technologies [11][15][18]. Their adoption might further speed up the growth of larger farm holdings at the expense of smaller ones, a phenomenon already evident in the United States and increasingly also in Europe [17].

Existing socio-economic and spatial asymmetries in digital infrastructure development contribute to unequal access to the internet and impact the ability of farmers to use digital technologies [8]. These include the growing urban–rural divide, whereby rural areas are at a disadvantage in this respect compared to urban ones in many parts of the world, in addition to other disparities among different groups of smallholder farmers, including gender inequality [26]. Such inequalities are reinforced by the pressure on farmers to comply with regulations (e.g., global food safety standards or requirements for receiving agricultural subsidies). These compel farmers to adopt digital technologies in order to remain in the supply chain and compete with other early adopters [17]. For individual farmers, the costs of digitalization are not recoverable and, in contrast to conventional farm machinery (e.g., tractors), there is only a small resale market for digital infrastructure. This is partly because items of digital farming equipment such as sensors or drones are often customized and cannot be adapted for other uses. In addition, hardware prices are falling, so farmers have little motivation to buy or sell second-hand. As a consultant study highlights, the price for an automotive LiDAR sensor for self-driving tractors declined by 90% between 2010 and 2017, from USD 75,000 to USD 7000 [27]. Farmers assume all the financial risks of investing in digital services and devices to compete on the market [17] while the technology providers benefit from data freely provided by farmers, which has high use value as an input for the further development of data-based services. While the farmers still own the fields, they cede control over their data to the service providers. Farmers then have to pay the same service providers to access digital information generated in part from their own farm data, which they fed into the system without receiving any remuneration [18][20]. Rotz et al. [18] consider that this “unpaid work under digital capitalism” turns farmers into “digital labourers” who, moreover, have to pay “rent” to access data they themselves have produced. Thus, the financial returns on investments in implementing and using digital platforms are unevenly distributed. They are received by input suppliers, or technology providers, who benefit from reduced transaction and product optimization costs, and only to a lesser extent by farmers themselves [21][28].

4. Uneven Sovereignty over Data and Hardware

Digital agriculture increasingly depends on the extraction and analysis of large amounts of data. As stated in the previous section, agricultural data is often collected and stored using infrastructure manufactured, owned, and controlled by large companies providing digital technology, machinery, or other inputs to farmers [2]. Both access to this data and control over its use are very unequally distributed. Technology providers, in particular, enjoy “a privileged position with unique insights into what farmers are doing around the clock, on a field-by-field, crop-by-crop basis,” over large areas of the world [13]. For example, by 2018, the Climate Corporation platform Climate Field View had more than 100,000 registered clients in the United States, Canada and Brazil, who together farmed about 120 million acres [2][10]. Some machinery manufacturers (such as John Deere or AGCO) place “legal and digital ‘locks’ on hardware and software packages” that they sell to farmers [29]. This prevents farmers from accessing the data which these companies collect from the fields and from fully using their products. Sometimes, the full extent of the data collected and the uses it is put to are hidden from farmers in accordance with privacy and access agreements that the companies require them to sign [11].

In most cases, by signing such user agreements, farmers making use of a digital platform hand over control of their data to the provider company. These agreements drawn up by the data aggregators not only authorize data collection, but also limit farmers’ access to the data and place restrictions on its further use [18]. Theoretically, farmers own the data they generate. However, the aggregated data is property of the company that collects, processes, and stores it [30]. Thus, in reality, farmers usually do not have full control of the data they generate. The end-user license agreements drawn up by the companies give rise to an unequal relationship, authorizing a ‘data grab’ that has been described as a form of dispossession [17]. Many platforms do not disclose their back-end processes to customers, and withhold information about how customer data is used and for what purposes. This uneven sovereignty reflects and at the same time is partly a result of the differences in bargaining power of the parties involved. It shows the weaker position of the farmers, due to the fact that data about a single farm has less economic value than aggregated big data compiled by the technology providers [20].

Even in cases where farmers can access their own data, their data sovereignty often remains limited because they lack the tools and capacity to analyze it. Thus, farmers’ growing reliance on farm data management platforms such as Climate Field View increases their dependency on the firms providing these services. Farmers are sometimes not even aware of the legal content of the terms and conditions they agree to [22]. Studies of the legal regulation of farm management platforms in the European Union and United States, and of the voluntary codes that service providers have signed up to, illustrate the legal complexity of relationships among agricultural data users and providers. They also show that ownership is almost exclusively governed by private license agreements, in some cases based on existing voluntary codes of conduct [20][22][30]. It remains unclear who actually produces the data and has the right to decide on its further use, “as farmers may be data originators in one relationship with their advisor but then the advisor becomes data originator when dealing with agribusinesses who provide digital services” [22]. This might be one reason why there is currently no effective policy regulation in place in the United States or in the European Union to protect and strengthen farmers’ sovereignty over the data generated on their farms. In contrast, in the European Union, the existing and rather “outdated” legal framework actually “enhances the position of the agricultural technology providers and third-party aggregators” [30], thereby legitimizing the ‘data grab’ discussed in the previous section [17].

In addition to being dispossessed of “their” data, farmers are sometimes denied sovereignty over the machines and equipment that they purchase. Legal locks in form of license agreements prohibit farmers from repairing their smart tractors themselves, and compel them to use only approved service providers. This is a consequence of legislation originally intended to prevent digital piracy, but that now makes it illegal for farmers to fix tractor engines or any other part of the equipment that is digitally controlled [16][26][31].

These inequalities have provoked some grassroots resistance. In the United States, farmers organizations are demanding the right to own their data and to repair their own farm equipment [32]. The US-based Right-to-Repair movement advocates for repair-friendly legislation backed up by standards and regulations (e.g., to guarantee purchasers the right to access information about products that they own, including the right to unlock software) [33]. The movement supports farmers’ demands for the legal right fix their own farm equipment [12][26].

Farm Hack [34] is another initiative that links up farmers across the globe via an online platform where they can share experiences of assembling and repairing the hardware and software used on their farms [12][35]. Farm Hack collectives directly challenge inequalities in proprietary technology regimes in agriculture [14]. FarmOS is a tool developed by the Farm Hack community that is intended to overcome “technological inequities by introducing greater diversity into the digital agricultural socio-technical system” [13]. The free and open platform was developed in close cooperation with farmers, and can be hosted, installed and further developed by anyone who has the capacity (e.g., coding skills) to do so [13][35]. It enables farmers to stay at least partially independent of large corporations and to regain or maintain sovereignty over how their data is shared [2][10][13][17]. FarmOS and similar initiatives such as the OpenAg Data Alliance, Joindata, FarmLogs, and DJustConnect collect and use data “for and by farm owners without ag-input company ownership” and under their own sovereignty [36]. These initiatives provide alternative, low-cost open-source software on shared platforms that acknowledge farmers’ ownership of their data and operate outside of corporate control [10][16][17].

5. Inequalities in Technology-Related Knowledge and Skills

Increasing digitalization requires skills that are not accessible to all [37]. Even if agricultural data were completely ‘open-source’ and under farmers’ legal sovereignty, not all farmers possess the knowledge and skills required to process and analyze the data, or to correctly interpret the results [21]. The adoption of digital technologies requires farmers to invest time and money in learning new skills in order to gain a basic understanding of information technology systems and of how to interpret data outputs (e.g., for the identification of in-field management zones, which requires longitudinal data collection) [38]. As farmers become even more reliant on the use of digital technologies to guide their farming practices, lock-ins become self-reinforcing. Without help to develop the requisite knowledge and skills, they lose the ability to make decisions independently, or to repair their own digital equipment and machinery [12][18]. This new knowledge is needed to understand and analyze digital data. Few farmers have the financial resources to employ or hire employees with digital skills, which in any case may be hard to find in rural areas. Those that can hire such employees gain a competitive advantage over other farmers; thus, digitalization is likely to exacerbate existing inequalities (e.g., between small and large farms) [38]. Some studies portray this as a further manifestation of the urban–rural divide, whereby farmers in remote rural areas find it more difficult to access the skills needed to participate in digitalized agriculture than those based close to urban areas [8][39].

The increasing reliance on technical experts and technology may result in a loss of tacit knowledge if the cognitive processing of information is delegated to machines or algorithms [40]. Some fear that farmers will become even more dependent on the software and platform providers as they lose the ability to “read” their plants and animals without them [41]. On the other hand, delegation of some operational and basic activities to may leave farmers more time for “higher level” learning processes [40]. Digitalization may entail a readjustment of labor allocation on farms [42], possibly involving a reduction in the human labor force [26]. It is still unclear to what extent farmers’ knowledge and human labor will be replaced by algorithms and automatons, or complemented by them. There is not much evidence of deskilling of farmers or farm laborers due to digitalization thus far [43]; however, studies find that “digital tools are used to increase surveillance and control” of the labor process on the farm, making it more transparent for employers. Increased surveillance and control over the workforce could possibly limit the will and ability of farm workers to collectively organize. This would further deepen the existing class inequality between labor and capital, in particular in the case of poorly unionized areas and for seasonal or migrant workers [43].

6. Unequal Definition and Problem-Solving Capacities

The capacity to define and shape the future of agriculture is unequally distributed among actors. The productivist industrial agricultural model is often presented by its proponents as key to achieving food security. However, it is criticized by movements for food sovereignty and small-holder farmers' alliances, among others, who call for a structural transformation toward agroecology or community-based organic farming. Several scholars argue that the digitalization of agriculture is highly entrenched in productivist farming systems and exacerbates their negative environmental effects, while increasing the concentration of corporate power over the food system through multiple lock-in effects and path dependencies [2][11][12][31][44][45]. The economic power of corporate agribusiness actors allows them to shape public discourse, whereby the environmental benefits of digital technologies are highlighted and the externalities often ignored [2][12].

These divergent visions of sustainable agriculture are linked to different assessments of the power of technology alone to solve sustainability problems, and regarding the social and ecological benefits and risks of digital precision technologies such as genome editing. The emphasis in the policies of high-tech agribusiness solutions on structural food system challenges demonstrates the power of corporate actors to define problems and their solutions. This makes it hard for alternative ideas such as those of the food sovereignty movement, which identifies agro-industrial structures as the root cause of food and environmental crises and associated local and global inequalities, to get a hearing, [15]. Less capital-intensive solutions to food security challenges are marginalized from the discourse on sustainable agriculture and starved of investment [31]. These inequalities are apparent, for example, in food security discourse, which tends to focus on productivist approaches and digital technology as the solution. The digitalization of agriculture might further entrench this narrative and lead to the sidelining of alternative, low tech, or non-technology-based responses to crises in the food system. This would make it more difficult for proposals to combat unequal access to food and the means of food production to gain a hearing, as pointed out by proponents of the food sovereignty concept. However, such technological fixes suit powerful actors from agribusiness, because they contribute to maintaining the status quo and to diverting attention away from the need to transform agriculture and challenge long-standing inequalities [15][46].

The inequalities in the ability to define problems and solutions are revealed in a recent analysis of high-level policy documents showing how international organizations such as the Food and Agriculture Organization or the World Bank envision future food systems. These organizations support the status quo, whereby industrial agriculture plays a dominant role in the food system, and prioritize the maximization of food output through the use of digital technology and "climate-smart" farming solutions. Organizational policy papers see digital technologies in agriculture as 'inevitable', since they are driven by technological innovation, and as 'needed' both to combat poverty and inequality and to cope with an increasingly unpredictable climate [8]. High-tech visions also attract much larger private and public investment than alternative agroecological approaches because they are seen as the most effective way to increase food security [8][31]. This is why some authors question whether the coexistence of the two systems, organic and agroecological on the one hand and conventional "Agriculture 4.0" on the other, is even possible. These authors argue that powerful actors will continue to dominate the trajectory of agricultural development, leading to the marginalization of alternative approaches given in [47]. Others argue that the two systems may be more complementary than is generally assumed by scientists and politicians, because farmers themselves will find ways to make them work together [15][48]. Discourse on "digital agroecology" explores avenues towards the use of digital technologies in order to advance core principles of agroecology, including equity, justice, participation, and co-construction of knowledge in agriculture [49]. As indicated by the findings of this review, small-scale and agroecological farmers are indeed inclined to adopt digital solutions that are open and affordable, such as those made available through the FarmHack network and other grassroots initiatives. In addition to affordability, these solutions are attractive to farmers because they are easy to apply and facilitate the sharing of knowledge. The democratic ownership of knowledge is explicitly welcome [49][50].

In addition to these grassroots initiatives, a number of companies are developing digital products tailored to the needs of agroecological, community-oriented or small-scale farmers [1][16][51]. In East Africa, the digital start-up WeFarm claims to have set up the largest farmer-to-farmer digital network, with more than a million users in Kenya and Uganda. WeFarm allows farmers to share questions, information, and advice through promotion of solutions that draw on local agricultural knowledge rather than marginalize it. The German-based company Rukola Soft [52] offers a planning tool for vegetable cultivation customized to the needs of community-supported agriculture [2]. Plantix is a free mobile app that promotes knowledge sharing and mutual learning among farmers [53]. It is used by small-scale farmers to diagnose and solve problems such as pest damage, plant disease, and nutrient deficiencies, and has links to La Via Campesina, the International Peasants' Movement, which campaigns for food sovereignty in the Global South [31].

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