

Article

Digital Agriculture and Labor: A Few Challenges for Social Sustainability

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Abstract: Academic and political debates on the digitalization of agriculture have addressed sustainability mainly from an ecological perspective. Social sustainability, particularly questions of labor, has been largely neglected in the literature thus far. This is particularly problematic since digitalization could fundamentally change farming practices and labor processes on farms, with possibly far-reaching consequences for rural development, rural communities as well as migrant laborers. Looking at the case study of Germany, this article asks how digital technologies are changing labor processes on horticultural and arable farms. The aim of this paper is to bring labor into the debates around agriculture and digitalization and to offer a detailed picture of the impacts of digital technologies on labor in agriculture. The case study builds on fourteen in-depth interviews conducted from June 2020 to March 2021, participant observation, and digital ethnography. The results show new forms of labor control and an intensification of the work process linked to methods of digital Taylorism, as well as risks of working-class fragmentation along age lines. A deskilling of workers or farmers due to digitalization has not been observed. The suggestion of an increased dependency of workers due to the loss of employment opportunities in agriculture is contested. The results stress the importance of designing agricultural policies that foster fair and equitable working conditions.

Keywords: digital agriculture; agrarian labor; digital Taylorism; social sustainability



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1. Introduction

Images of digitalized agriculture typically depict an idealized future, where autonomous tractors drive on their own, robots do the harvesting, drones and sensors measure and surveil every plant, and all the different components of the farm automatically exchange data and communicate with one another. The sustainability of digital agriculture is usually conveyed through the depiction of healthy plants and rich soils. If a farmer is at all included in these images, she is usually portrayed using a smartphone or a tablet and is usually on her own (Just type 'digital agriculture' and 'sustainability' into Google's image search engine to get a good impression of the images described). What is strikingly absent in these pictures are agricultural workers of any kind or a depiction of agricultural labor other than the task of looking at a screen.

Labor nevertheless remains central to agriculture. It is estimated that 1.3 billion people work in agriculture worldwide, which represents about 25% of global employment [1]. In OECD countries, where the mechanization and digitalization of agriculture are most advanced, agricultural employment has sharply decreased in the past decades to only 4.7 percent of total employment [2]. Nevertheless, in some rural communities employment in agriculture is still important for rural economies and development. Furthermore, even though total employment in agriculture has decreased, agrarian labor remains key for agricultural production and food supply, as labor shortages caused by travel restrictions in the context of the COVID-19 pandemic have shown [3]. Labor is particularly important for sustainable farming practices, such as agroecological or organic forms of agriculture, which

are often more labor-intensive due to the reduced use of pesticides and other chemical inputs. At the same time, commitment to ecological values does not necessarily mean a commitment to fair labor practices [4]. The agricultural sectors of Western Europe, as well as the US and Canada, are highly dependent on seasonal migrant workers, while exploitative and illegal labor relations are regularly reported in the media and academia [5]. Thus, in order to create an ecologically as well as socially sustainable farming system in the context of digitalization in agriculture, looking at labor and labor relations is key.

Academic and public debates around digital agriculture have widely discussed the potential benefits and downfalls of the technologies to both productivity and environmental sustainability (for an overview, see [6–8]). The social impacts, however, especially regarding questions of labor, have received hardly any attention [9]. This is surprising, as past technological advances, such as mechanization and the introduction of chemical inputs, have had a major impact on agrarian labor relations [10,11]. A few existing studies discuss the potential gains or losses of employment in agriculture due to digitalization [12,13]. Generally, these studies suggest that digital technologies might contribute to creating new highly skilled jobs in agriculture, while at the same time displacing some forms of low-skilled migrant labor. This in turn might reinforce social, economic, and racial inequities in labor and skills development [14,15]. However, farm advisors, as a more highly skilled group of workers, as well as self-employed entrepreneurs, might likewise lose their jobs or clients when machines make autonomous evidence-based decisions without human involvement [16]. Regarding the labor process itself, it has been noted that the increased use of digital technology might result in the loss or marginalization of farmers' experiential knowledge [17], which could lead to loss of enjoyment and lower work satisfaction [9]. Digital technologies might also enable new forms of labor control [18]. However, more in-depth studies into how digital technologies are actually shaping labor and labor processes in agriculture are so far missing. This article, therefore, asks how the introduction of digital technologies is changing labor processes on horticultural and arable farms in Germany.

I addressed this research question by designing an explorative case study on labor relations in Germany's horticultural and arable farming sector. Germany provides an interesting case study due to its diverse farm structure, its early engagement with digitalization in agriculture that goes back to the 1980s, as well as recent attempts by the German government to explicitly foster digitalization in agriculture as a key strategy for rural development and ecological sustainability [19]. Germany is also home to several companies that develop and sell digital products and services for agriculture, from big player Bayer to several small and mid-sized companies and a lively start-up scene and is thus at the forefront of digitalization in agriculture in Europe. The case study furthermore complements the few existing studies on labor and digital agriculture that have predominantly looked at countries where large-scale industrialized farming is the norm, like Canada or the US [14,15], compared to which Germany's farm structure, especially in the western parts, is generally more varied and of a smaller scale.

The aim of this paper is to bring labor into the debates around agriculture and digitalization and to show a detailed picture of the impacts of digital technologies on labor in agriculture. Theoretically, I build on the labor process theory (LPT) from industrial sociology, which has already been successfully adopted and used to analyze labor in the agrarian sector [20,21].

The paper is structured as follows: I will first give a brief overview of my methodology. I will then lay out my theoretical framework, before turning to my case study research in Germany. I will begin by giving an overview of labor relations in Germany's agricultural sector, with a focus on horticulture and arable farming. I will then identify how digital technologies are currently shaping labor processes, looking at the consequences for seasonal workers, permanently employed workers, and family farmers who work on their own farms. In the conclusion, I will discuss the implications of digital technologies for agrarian labor, identify areas of future research, and point to some policy implications of my research.

2. Materials and Methods

This paper is conceptualized as an explorative case study since few studies on the impact of digitalization on agrarian labor currently exist. It is based on 14 semi-structured, in-depth interviews conducted from June 2020 to March 2021; a three-day participatory observation on a family farm, where the owner-operator had recently purchased digital farm machinery equipment; as well as documents provided by labor organizations, NGOs, German administrative units, and media articles on the topic. I also engaged in methods of digital ethnography, trying out relevant digital agricultural tools, such as online maps and digital platforms, and researching their privacy and access agreements. I also researched the functions of relevant digital machinery and robots online and examined video feeds showing how these tools work, as well as the descriptions and sales pitches of the companies that produce them. Finally, I looked at recently published surveys regarding labor in Germany's agricultural sector, as well as on the state of digitalization.

I conducted interviews with six distinct yet interrelated groups of actors: (1) farm managers and owner-operators who have adopted one or multiple digital technologies; I interviewed two horticultural farmers who employed between 15 and 30 seasonal workers, as well as one farmer engaged in arable farming who depended solely on his own and his family's labor; (2) two permanently employed farm laborers; (3) two family laborers that worked part-time on the farms owned by their families; (4) four representatives of labor organizations working with and for seasonally employed migrant workers; (5) two individuals from firms that engineer and manufacture digital technologies for use in agriculture; and (6) one agricultural advisor. All interviewees have been rendered anonymous.

Missing from the interview sample are clearly interviews with seasonal migrant workers themselves. Their absence is due to the increased difficulties in conducting on-farm fieldwork during the COVID-19 pandemic. I had to conduct all interviews, except one, via phone. Seasonal workers are notoriously difficult to contact, even for labor organizations working closely with them for many years. Labor organizations mainly rely on direct field visits to get in touch with seasonal migrant workers; such visits have reduced drastically during the pandemic [3]. I was, therefore, unable to conduct any site visits and thus direct interviews with seasonal workers themselves. However, I was able to conduct several in-depth interviews with employees and activists from labor organizations who have worked closely with seasonal workers over the past decade. The information they provided can fill in some of the gaps that the absence of seasonal workers from the sample generated.

3. Labor Process Theory and Technological Development

To answer my research question, I built upon labor process theory, particularly its writings on the links between technologies and the labor process. LPT is not a coherent framework but rather an analytical perspective that builds on a Marxist analysis of the capitalist production process and focuses on the role and experiences of labor, as well as the capital-labor relationship. Building on a Marxist analysis of the transition from the manufacturing period to industrial production, LPT assumes that in a logic of accumulation, capital constantly revolutionizes the production of goods and services [22]. This revolutionizing entails constant changes in the technical design of the production process whenever new innovations are integrated [23]. The technical design, as the physical aspect of production, shapes the labor process [24].

3.1. Technologies and Control over Labor

Control over labor is a key concept in LPT, and technologies have been analyzed as a central tool in this control. Starting from the distinction between labor power, i.e., the capacity to work, and labor, as the entity that enters the production process, LPT assumes that employers need to establish and uphold control over labor [25].

Control over labor is usually implemented through management systems and is often facilitated by technologically-based labor surveillance and close measurement of worker

performance. Richard Edwards refers to technological control as a control mechanism which “... involves designing machinery and planning the flow of work to minimize the problem of transforming labor-power into labor as well as to maximize the purely physically based possibilities for achieving efficiencies” [26] (p. 112).

In Fordism, technologically-enabled pacing of the labor process through the assembly line was combined with technologically-enabled constant surveillance and performance measurements, as well as small-scale tasks and detailed instructions based on a machine-enabled division of labor, hierarchical control, and close supervision of workers—a system that was popularized by Frederick Taylor and became known as Taylorism [27].

Control is thus often closely coupled with the aim of intensifying the labor process. In analyzing the Fordist production model, Braverman famously theorized that technological development and a division of labor contribute to an intensification of the labor process [28]. Braverman showed how the introduction of the Fordist assembly line serves as a key technology to pace the actions of workers and intensify their output. A tendency of technological developments to intensify the labor process in capitalist production, due to the imperative to reduce labor costs, has been supported by other authors as well [23].

Several authors suggest that post-Fordist production models favor different forms of labor control, namely a strategy that is based on cooperation, the valuation of creativity and qualifications, and often an increased autonomy for workers within the production process [29]. However, recent studies looking at the implementation of digital technologies in labor processes in the service and industrial sectors have argued, on the contrary, that these technologies have given rise to new forms of Taylorist methods of workplace surveillance and control, which have been dubbed ‘neo-Taylorism’ or ‘digital Taylorism’ [30,31].

3.2. Dependency and Working-Class Fragmentation

Control over labor also aims to achieve the dependency of workers on their employers. Dependency is determined by two broad factors: first, the ability of workers to organize, and second, whether workers have alternative sources of needs satisfaction, meaning essentially whether laborers can find employment elsewhere [24]. The implementation of new technologies can have a negative impact on the possibility of finding employment elsewhere through the substitution of usually low-skilled labor with machinery, which increases the reserve labor army that must compete for the fewer remaining jobs [32]. Regarding digitalization in agriculture, it has likewise been argued that this will lead to a loss of low-skilled jobs [14,15]. It is contested, however, whether these low-skilled jobs will be fully, or only partly, replaced by higher-skilled jobs.

Labor process analysis also shows that the implementation of new technologies might lead to increased fragmentation of the workforce, which might in turn inhibit workers’ ability to organize. Divisions within the working class encompass categories of gender, race, ethnicity, and age. However, fragmentations within a particular labor force can also be based on different skills, tasks, and occupations. New technologies require new skills, which may lead to new categories of workers that receive different wages (e.g., machine operators vs. manual harvesters), fulfill different tasks, are at times spatially separated, or are represented by different unions [33]. An increasingly fragmented labor force is harder to organize and will increase the dependency of workers on their employers.

3.3. Technologies and De-Skilling

Returning to the works of Braverman, there is a lively debate in LPT on whether technological development contributes to a de-skilling of the workforce. Braverman suggests that the Fordist production model enables a small-scale division of labor that makes complex skills and crafts unnecessary and even undesirable [28]. Thus, the real subordination of the worker is completed in Fordist production processes, where skills and crafts are no longer needed since they are replaced by automation and complex machinery [32]. Braverman thereby follows Marx’s interpretation of the development of the modern industrial production model, which shows that the introduction of modern machinery enables

the replacement of skilled professionals who have learned particular crafts by unskilled children, women or migrants from rural areas or other countries, who handle only the most basic and simple tasks [22] (Chapter 13).

Braverman's arguments about technological development leading to a de-skilling of workers are contested within LPT. Looking at digital technologies and their implementation in the automotive industry, Pardi suggests, in line with Braverman, that "digital wearable devices might pave the way to the deskilling of maintenance and other forms of technical work" [34] (p. 386). Similar arguments have been made for other industries, including the agricultural sector, regarding, for example, the replacement of knowledge about plants with smartphone applications [18]. However, as others have pointed out, there is no imperative that technological developments within the production process must lead to deskilling [23]. New technologies, including digital devices, rather could lead to skill development, including in agriculture [35].

Whether or not technologies intensify the control of capital over labor, lead to an intensification of the work process and deskilling and contribute to a fragmentation of the working class is contingent upon several factors. Impacts depend on the technologies used, the economic sector, and the concrete production processes where they are implemented, as well as the political institutions and power relations that structure the worker-employer relationship [24]. The latter points to the importance of workers' agency when analyzing control. While workers' agency is largely absent from the earlier writings of LPT, the second wave of writings does stress the importance of labor agency in shaping control and the labor process more generally. Workers can and do resist control practices, both in the forms of collective organizing and unionizing, as well as through more individual forms of resistance, which might include everyday forms of resistance such as working slowly or sabotaging machinery [27].

4. Agrarian Labor in Germany

Germany's agricultural sector is characterized by a high degree of mechanization as well as increasing land concentration and an ongoing reduction of the total number of farms. In 2016, the Federal Ministry for Food and Agriculture counted around 275,400 farms that managed around 16.7 million hectares of agricultural land [36]. Ecological farming is on the rise with about 27,200 ecologically certified farms, which is more than twice as many as in 1999. The latter were cultivating about 7.5% of Germany's farmland in 2016.

As in all OECD countries, employment in agriculture in Germany has drastically decreased in the past 70 years. As Figure 1 shows, in the early 1950s, about a quarter of all employees worked in the primary sector. In the 1980s, this was about 5%, and in 2019 only 1.3% [37].

Agrarian labor in Germany is conducted by two different categories of workers: permanently employed workers and seasonally employed workers—usually migrant workers from Eastern Europe. Furthermore, many farmers are self-employed and operate smaller farms as owner-operators full-time or part-time. In 2016, about 940,100 people worked in agriculture in Germany on a full-time or part-time basis [36]; owner-operators made up about half of the agricultural workforce, while the other half is made up of permanent employees (ca. 204,600) and seasonal workers (ca. 286,300). Furthermore, the past two decades have seen an increase in the outsourcing of agricultural machinery use and the associated labor to specialized service companies, which has given rise to new companies in the agrarian sector as well as new employment opportunities; however, no statistical data is available on the size of this group [36].

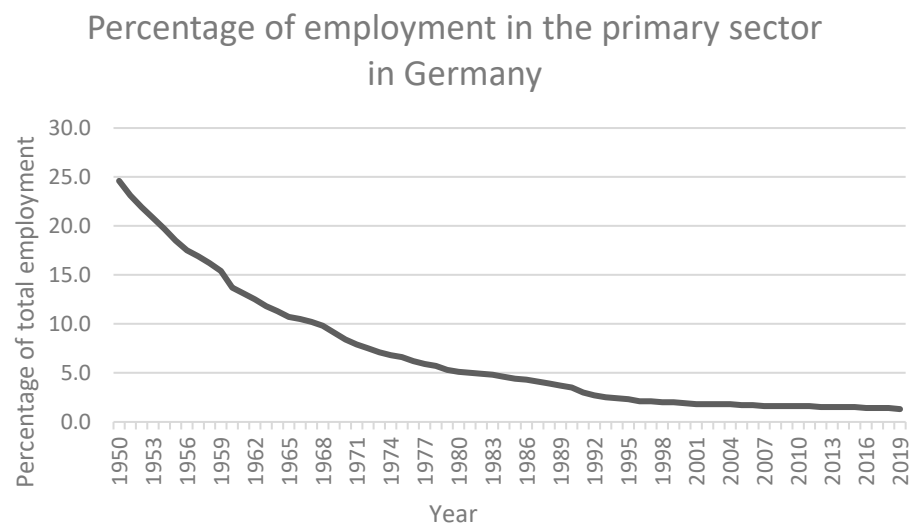


Figure 1. Source: Statistisches Bundesamt (2020), own illustration.

The most labor-intensive area of Germany's agricultural sector (excluding animal husbandry) is the cultivation of horticultural crops such as fruit, vegetables, flowers, and ornamental plants. It is estimated that around 98,000 workers are permanently employed in the horticultural sector, as well as the large majority of the seasonal workforce [36], though there are no official statistics on the make-up of the seasonal workforce in Germany. The labor organization Initiative Faire Landarbeit suggests that most seasonal workers come from Romania and Poland, while additional workers come from Bulgaria, Serbia, Croatia, and other Central and Eastern European countries, as well as students from Ukraine. The most common form of employment relationship is short-term employment, since no social security contributions need to be paid when the employment lasts less than 70 days. In 2020, this regulation was extended to 115 days due to border controls and travel restrictions in the context of the COVID-19 pandemic, which led to a labor shortage of seasonal workers in the agricultural sector. Seasonal workers from EU member states and employers can conclude employment contracts directly because of the free movement of workers. Furthermore, the German government has negotiated placement agreements with several non-EU countries such as Georgia and Ukraine, which facilitate the employment of seasonal workers from these countries.

Seasonal workers are usually directly employed by the agricultural businesses themselves, while the contracts are often arranged by agencies for a fee [3]. In 2015, the German government introduced a general minimum wage, which should also be paid to seasonal migrant workers. In January 2021, the minimum wage was 9.50 Euros per hour. Seasonal agricultural workers are usually paid a combination of minimum wage and piecemeal wages (additional income for harvesting over a certain amount of produce per hour). How much workers are expected to harvest during an hour and where the threshold is set to receive piecemeal wages on top of the minimum hourly wage depends on the employer (interview with a horticultural farmer, 23 September 2020; interview with an organization supporting agrarian workers, 6 November 2020).

5. Digitalization and Changing Labor Processes in German Agriculture

Digitalization is one of the key strategies put forward by the German government to renew Germany's agricultural sector [38]. Digitalization is hailed by the Federal Ministry for Food and Agriculture as contributing to more sustainable and environmentally friendly agriculture, while at the same time enhancing productivity and profitability. Digitalization is also portrayed as a key technological development to take over physically challenging and monotonous work in agriculture and thus make the sector more attractive for the younger generation [19]. The digitalization of agriculture is subsidized by the German

government through various funding initiatives for research and development, as well as for the expansion of digital infrastructures in rural areas.

While no comprehensive statistical data on the use of digital technologies in German agriculture exist, a survey from 2020 based on the responses of 500 farms, including livestock farming, suggests that about 80 percent of farms use some form of digital technology [39]. The most widespread digital technologies in Germany's agricultural sector are GPS-supported agricultural machinery (used by 45% of respondents) and smartphone applications (apps) (used by 40% of respondents). Smart-machinery-supported site-specific applications for pesticides and fertilizers were used by 32% of respondents and sensors by 28%. Robotics and drones were used by 12% and 11% respectively. Additionally widespread were digital solutions for farm management, such as the use of digital communication tools and digital field management systems, each used by about half of the respondents [39].

Furthermore, workforce management software is widely used, especially on farms that employ a large permanent or seasonal workforce [40]. One company offering software to manage seasonal workers' contracts, pay slips, and social security requirements claims that more than 40% of all seasonal workers in Germany are currently managed using its software solution [41]. Many other employers most likely use similar tools offered by different companies. This usually includes mobile or desktop applications for setting up contracts, recording work time and performance, and for work documentation. Some companies also offer a combination of software tools and harvesting machines. This enables the precise measurement of the working time and speed of a worker in the field; the data is then sent automatically to the workforce management software to calculate each worker's total amount of work time. Increasingly common is also the use of barcode or QR scanners that attribute each box of harvested produce to a single worker (interview with a digital farming company, 25 August 2020); [40]. Boxes are sometimes weighed using digital scales and some farms are using automated optical sorting machines. The weight and quality of the harvested produce can then be digitally transferred into the workforce management system, which then calculates each worker's total wages based on the working hours recorded and the amount of produce harvested.

This overview shows that there is a large variety of digital technologies used in agriculture, which will naturally influence labor processes in very different ways. The following section can therefore only offer general tendencies regarding the impact that the use of digital technologies is having on labor processes in German agriculture since such impacts vary greatly depending on the technologies used, the crops that are farmed, farm size, the number of employees, the organization of the farming process, as well as the agency of the farmers, employers, and workers themselves.

5.1. Digital Taylorism on the Fields?

A common theme that emerged throughout the interviews was that digital technologies are used for new forms of labor control through digitally-enabled surveillance and performance measurements. These new forms of labor control may lead to an intensification of the labor process in agriculture.

In the case of seasonal workers, digital technologies are used on some farms to closely monitor their working hours, as well as the total amount of the product that they harvest, in order to calculate their wages. One farmer who uses the above-described combination of workforce management software and harvesting machines described the process thus: "Big brother is watching you [...] you have to make it clear to employees that I don't have to stand next to you, I can still see what you're doing" (interview with a horticultural farmer, 23 September 2020). He reported that if workers take a cigarette break while harvesting, the harvesting machine used by the worker will report the break and will deduce the break time from the worker's total working hours used to calculate her wages (interview with a horticultural farmer, 23 September 2020). This close surveillance of work time is crucial for the farmer to keep labor costs as low as possible. The above-cited farmer reported that in the first-year test using the digital tools for work time measurement, the recorded

work time was 20 min less than previously recorded (interview with a horticultural farmer, 23 September 2020). The use of barcode or QR scanners that attribute each box of harvested produce to one specific worker can likewise contribute to increased surveillance since poor quality can now be traced easily to specific workers [40].

New digital surveillance techniques have also been reported by permanently employed machine operators to intensify their work. One interviewee who used to work as a machine operator on a large-scale farm before joining his father's farm reported: "The boss sat in the office, saw on his computer where his tractors were, what the drivers were doing, how fast they were driving, how the machines were set, etc. And then, of course, he could also benchmark the employees, how efficiently they worked, how quickly they maneuvered into the corners" (interview with a family farm operator and former permanent farm employee, 9 November 2020). This constant surveillance was described by the interviewee as a source of intensification of the work process due to the constant pressure to optimize: "As an employee, you're not so relaxed, because you're always under pressure to optimize and you're looking for ways to, well, I don't know, not stop to go to the bathroom or something. Just to work more efficiently. [...] And we, as young, motivated employees, of course, took our meal, for example, while driving. That's a huge saving for the boss in terms of machine costs and personnel costs. [...] it was disconcerting, I have to be honest [...]" (interview with a family farm operator and former permanent farm employee, 9 November 2020).

The use of such digital technologies can thus lead to an intensification of the labor process in the harvesting of fruit and vegetables, but also in harvesting field crops, for both seasonal workers and permanent employees. Casual breaks outside of the formally prescribed break times can now be directly and automatically deducted from workers' wages, while constant surveillance of work performance can also contribute to pressure on employees to forego legally prescribed breaks. Such close monitoring of each worker's performance might also have an effect on his being offered a new employment contract in the following year (interviews with horticultural farmers, 28 September 2020; 23 September 2020).

Farmer-operators who work for themselves on their family farms and do not have employees, however, did not report that they felt an intensification through the use of digital devices. From a recent survey on digitalization in Germany's agricultural sector, 82% of respondents stated that digitalization contributes to reducing the physical strain of the work [39], which corresponds with the data from my interviews. All farmers interviewed also stated that they spend increasingly more work time in the office compared to the work time on the fields. While not all farmers linked this trend to digitalization, those farmers who used drones, mapping, and variable-rate technologies stated that they perceive that these digital technologies increase the trend to spend more time working from the office, since feeding the tools the necessary data as well as analyzing it is time-intensive (interview with a family farm part-time operator, 20 November 2020; interview with a family farm operator and former permanent farm employee, 9 November 2020).

These findings suggest that whether or not digital technologies lead to an intensification of the labor process is linked to who controls these technologies. Farmer-operators who are self-employed and work and manage their farms independently perceive digital technologies as supporting and facilitating their work. For workers who do not control how digital technologies are used but are rather subjected to them, digital technologies are more likely to lead to an intensification of the labor process, to a loss of autonomy, and to increasing control over them.

5.2. Digital Technologies and Transparency from a Labor Perspective

Beyond the intensification of the labor process, digital technologies might also increase the vulnerability of seasonal workers to wage theft. Organizations working to support and organize seasonal workers stated that seasonal workers have increasingly reported that they fear that their employers might be using digital tools to cheat them when it comes to the calculation of their wages (interview with an organization supporting seasonal migrant

workers, 10 November 2020). Through the introduction of digital scales and tools that automatically record and calculate work hours, seasonal workers are less able to follow how these calculations are being made and how measurements are taken (see also [42]). There is currently no proof that digital technologies are being used to facilitate wage theft in Germany. There are, however, reports of wage theft being facilitated by digital technologies in other contexts. In Canada, for example, computer timesheets have been reported to miscalculate wages [42]. However, farmers who employ seasonal workers suggest that digital technologies might actually have the opposite effect: by digitalizing the measurement of work time and workers' output, employers can no longer cheat, since everything is now automatically and digitally reported (interview with a horticultural farmer, 23 September 2020; interview with a digital farming company, 25 August 2020).

Workers' concerns nevertheless speak to the wider issue that digital technologies contribute to the increased control of employers over workers through surveillance, but also by making aspects of the labor process more opaque as a result of the information being concentrated at the level of farm management. While the digitalization of agriculture is generally hailed as a tool to increase transparency along supply chains, this is not necessarily true from a labor perspective, especially for seasonal workers, who might lose access to key information such as physical records of work time or harvested products. Furthermore, for permanent employees who operate digital machinery, it might not be possible to know what information is actually being recorded about them and their work by their employer, or how farm management is using this information.

5.3. Agricultural Skills and Working-Class Fragmentation

Claims from some studies within the LPT literature that digital technologies lead to a de-skilling of the workforce [34], and similar arguments from the literature on digital agriculture that these technologies might lead to a loss of farmers' agricultural and ecological knowledge [18], were not supported by my interview data. Farmers who employed seasonal workers and used digital technologies stressed that they still needed skilled workers and that they put considerable effort into training their seasonal workforce (interview with horticultural farmers, 23 September 2020; 28 September 2020). A skilled workforce is especially important for the harvesting of fresh fruits and vegetables, which need to be harvested quickly in a brief time period and have to comply with the tough quality standards of large customers such as supermarket chains and wholesalers [43].

Permanent employees, as well as farmer-operators, likewise did not report a loss of skills, and instead stressed that they were gaining additional skills through the use of digital technologies, such as handling complex machinery and their software programs (interview with an arable family farm operator, 17 July 2020; interview with a family farm part-time operator, 20 November 2020; interview with a family farm operator and former permanent farm employee, 9 November 2020; see also [44]). One farmer reported that he and his father had actually expanded the family farming business and opened up a side business as a service provider for digital mapping technologies using drones (interview with a family farm part-time operator, 20 November 2020).

The farmers' perception that they were gaining skill sets instead of losing skills and knowledge might be linked to the digital technologies they were choosing to use. Other authors have pointed out that digital decision support systems for farming might pose a bigger risk to farmers' experiential knowledge [17,18]. These technologies were not being used by my respondents. However, farmers in the Global North have been using external knowledge and some forms of external data for a long time [45]. Collaboration between farmers and farm advisers, chambers of agriculture, regulators, supply chain actors, and other farmers in decision-making processes is standard practice in German agriculture. Similarly, accessing the information on the web and using data on weather, seed varieties, or weeds, for example, were common practices before the emergence of digital platforms, digital support systems, and applications designed for the agricultural sector. Thus, using digital tools—for example, in identifying weeds and deciding on which

pesticides to use—instead of calling a consultant was not perceived as a major change or contributing to a loss of knowledge or skills (interview with an arable family farm operator, 17 July 2020; interview with a family farm part-time operator, 20 November 2020; interview with a farm advisor, 14 May 2020).

This suggests that the dangers of de-skilling and the loss of agricultural knowledge linked to the implementation of digital technologies in agriculture may be overstated, at least when it comes to industrialized farms in the Global North. Here, farmers rather perceive the use of digital technologies as a continuation of the mechanization of agriculture that has been occurring in the past decades. The use of digital technologies such as drones and sensors offer them easier access to information and sometimes additional knowledge about their fields. However, this does not automatically lead to a loss of knowledge about their land or agricultural practices and skills (see also [45]).

The new skills needed to use digital technologies might, however, play a role in further fragmenting the agrarian labor force. The ability, or lack thereof, to use digital tools and learn digital skills might enhance the divide between the older generation of both farmers and farm workers and the younger one (interview with a regional chamber of agriculture, 12 November 2020; interview with an organization supporting agricultural workers, 5 November 2020). One farm worker noted that the implementation of digital machines on the farm he was employed at, and the constant monitoring that came with it, led to increased competition amongst the workers and contributed to a fragmentation of the workers along age lines: “If you were a bit tech-savvy, you naturally delivered better work [...] we [referring to the young employees] were in a bit of competition with the [...], old employees who worked there” (interview with a family farm operator and former permanent farm employee, 9 November 2020).

5.4. Digital Technologies and Labor Dependency

Robotics and further automation such as optical sorting machines have been argued to be key drivers in replacing especially manual and low-skilled labor in agriculture [14,15]. In line with this argument, German farmers see digital technologies as an important tool to reduce the business costs of their farms in the long run [39], of which labor costs are an important part within the horticultural sector. High labor costs, which have increased due to the implementation of a minimum wage in 2015, as well as the difficulties in finding skilled labor, are key motivations for farmers to invest in robotics and further automation (interviews with horticultural farmers, 28 September 2020; 23 September 2020). Robotics are not yet widespread in Germany. However, a survey conducted by Bitcoin and the German Farmers Federation found that almost a third of the respondents planned to invest in robotics in the near future [39]. Rather than the rupture or revolution that digital agriculture is often claimed to be, digital technologies appear to be acting as a continuation of long-standing efforts in agriculture to develop labor-saving machinery and devices. Farmers who had already invested in robotics or automated sorting machines reported that they had been able to replace parts of their manual workforce. However, none of them had been able to replace manual labor completely (interview with a horticultural farmer, 28 September 2020); [46]. Even though robotics and automated sorting processes are not yet capable of replacing manual labor entirely, they might offer a partial solution to the need for a stable and cheap labor supply in agriculture, by making certain workers obsolete [14] (p. 201).

As such, the implementation of robotics and further automation might increase the dependency of the seasonal workforce on their employers in the future, as less manual labor is needed, and workers can no longer easily choose between different employers. Nevertheless, the German agricultural sector is currently rather marked by a labor shortage, both in terms of seasonal as well as permanent employees [47]. Seasonal migrant workers used to come mainly from Poland, Germany’s immediate neighbor. However, in recent years workers have been increasingly migrating seasonally from countries further east, such as Romania, Ukraine, and even Georgia. This can in part be attributed to the decrease in the prosperity gap between Germany and Poland and with it the decrease in dependency of Polish workers on seasonal jobs in German agriculture. Thus, while robotics and

automation might increase the dependency of seasonal workers on their farm business employers in the long run, currently their impacts appear to be limited. Furthermore, if the prosperity gap between Western and Eastern Europe decreases further, it is possible that migrant workers from other Eastern European countries will be absorbed by other sectors of their national economies, similar to the development in Poland.

6. Discussion and Conclusions

This exploratory study has investigated how digital technologies are shaping labor processes in Germany's horticultural and arable farming sector. It shows that digital technologies are being used to increase surveillance and control over both the permanent and seasonal labor force and to intensify the labor process. Furthermore, the study shows that while digitalization is being praised as a key tool to make agricultural production and the food system more transparent, this is not necessarily true from a labor perspective. For workers, it can be challenging to understand, track and control what data is being collected and reviewed about them and their work performance, and how this data is used to calculate their work time and wages. Such findings are not unique to Germany, having also been reported in other contexts. In Canadian greenhouse farming, for example, workers are asked to wear smartwatches to monitor their performance, while robots and harvest machines are being used to pace the speed of workers [42]. Digital Taylorism has thus arrived on the farms and fields. This is not altogether surprising. Taylorist methods have mainly been studied and criticized with regard to the industrial sector and more recently the digital economy [30,31,48]. Yet, research in agricultural science has been calling for and investigating the application of Taylor's 'scientific management' for farming in Europe since as far back as the 1920s [49].

While this exploratory study highlights some important changes regarding labor control through digital technologies, more systematic research is needed to grasp how such new control practices impact agrarian workers' agency and worker organization. The constant surveillance of agrarian workers, particularly seasonal workers, might negatively impact their ability to organize. In sectors that are poorly unionized, as the agricultural sector in Europe, everyday interactions between workers during work breaks can be essential for organizing among themselves and for facilitating contacts with labor organizations on their field visits (interview with organizations supporting agrarian workers, 6 November 2020). This might become increasingly restricted as constant surveillance techniques, as well as an intensification of the work process, reduce the chance of interactions during working hours.

The loss of skills and experiential agricultural knowledge that has been postulated as one consequence of the digitalization of agriculture did not feature prominently in my interview data. Farmers in particular, but also permanently employed workers, stressed on the contrary that they were gaining new skills and expanding their knowledge about soil quality, for example, through the use of digital technologies. However, for an older generation of farmers and workers, learning such new skills might be more challenging than for a tech-savvy younger generation, which might contribute to working-class fragmentation along age lines.

Finally, my study supports arguments that robotics and automatic sorting devices might in the future replace manual labor that is mainly conducted by seasonal migrant workers today. However, at the current state of digitalization in agriculture, finding a skilled seasonal workforce is still a key challenge for farmers in Germany, as it is in other OECD countries [50]. Farming robots have not yet widely been adopted in German agriculture, and even the currently available robots cannot yet completely replace manual workers doing the same job [46]. Furthermore, it remains to be seen how well robots and autonomous machines are actually able to deal with the more varied and often small-scale farm structure that we still find in many places in Western Europe [40].

Industrial agriculture is a key contributor to the climate crisis. The EU and other OECD countries have identified the agricultural sector as a key target area to lower CO₂

emissions and stop the loss of biodiversity. Digital technologies are in this context seen by policymakers as a key technological solution to make agriculture more environmentally sustainable and to establish so-called climate-smart agriculture [51]. However, as this article has shown, digital technologies in agriculture are also contributing to a reorganization of the labor process in agriculture. Thus, in order to design and implement digital technologies that can successfully foster a sustainable agrarian system in Europe, sustainability needs to be understood not only in ecological but also in social terms see also [9]. One path in this direction might be to incorporate the ‘just transition’ framework into the agricultural sector. Unions have been calling since the 1970s for a ‘just transition’ towards a post-carbon future that includes social demands around fair and equitable work, employment, and working conditions [52]. This call is also relevant for the agricultural sector today, for both farmers and agrarian workers.

Social sustainability, however, needs to be actively supported by agrarian policies. Labor is expensive and farmers are facing strong price and quality pressures from supermarkets and wholesalers, which can make it challenging to guarantee fair and equitable work conditions. Thus, in order to provide an alternative to simply replacing manual labor with robotics and automation, we need new policy proposals that allow for ‘decent work’ in agriculture. High labor costs must be made affordable for sustainable farming businesses, for example through a different system of European CAP subsidies on a per workforce basis rather than a per hectare basis. This might favor more labor-intensive sustainable agricultural production practices that contribute to improving agriculture’s impact on the environment and which also provide new employment opportunities in rural communities (see e.g., [53]).

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