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ORIGINAL ARTICLE

Digitalisation, politics of sustainability and new agrarian questions: The case of dairy farming in rural spaces of Italy and Sweden

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Abstract

The article analyses how and why agricultural digitalisation unfolds in contrasting agricultural sub-sectors and rural spaces in Europe, with a particular focus on dairy farming. The authors explore the differences and similarities underpinning and produced by agricultural digitalisation and how this intersects with meanings of rural development and the politics of sustainability. Building on qualitative research carried out in the regions of Uppsala (Sweden) and Calabria (Italy), the article unveils the contradictory nature of agricultural digitalisation as a process intertwined with the capitalist development of agriculture that raises key political questions. The cases of Uppsala and Calabria, in particular, show that the transformation of dairy farming through automation and digitalisation is uneven and combined, being deeply connected to how politics of sustainability and rural development are embedded—and negotiated—in specific agrarian settings. The authors discuss their empirical findings in terms of new agrarian questions in Europe.

KEYWORDS
agrarian question, dairy farming, digitalisation, rural development, sustainability

INTRODUCTION

Since the 1990s, European Union (EU) agricultural policies have aimed to combine food production goals with more careful consideration of rural development and sustainability issues (Marsden et al., 1996). However, while increasing demands for sustainable healthy food (Goodman, 2003; Murdoch et al., 2000) have created new opportunities for less intensive or alternative farming systems oriented towards local food production, the market-based reforms of the Common Agricultural Policy (CAP) have further incentivised intensification and specialisation of EU agriculture, with ensuing risks related to price volatility and power asymmetries in agro-food chains (Corrado, 2016; de Roest et al., 2018; Potter & Tilzey, 2005).

Regional responses to long-term trajectories of agrarian change in the EU have been different, ranging from reproducing agro-industrial models to building post-productivist enclaves linked to local markets and multifuncional views of rural development (Tilzey, 2009). Pre-existing agrarian structures certainly played a major role in determining the strategies adopted within the diverse agrarian settings, but these were also permeated by the growing tensions between agricultural policies and sustainability narratives at EU and global levels, where productivity goals and market-based food security are conflated with visions of sustainability in rural development (Alarcón et al., 2022).

Against this bground, rural transformations driven by digital technologies pose a set of new questions (Alarcón, 2021). Generally speaking, the digitalisation of agriculture can be described as a further step in the process through which technology is incorporated within farming systems. However, this process is not limited to the introduction of technological artefacts; it also consists of a set of practices through which new actors come into play, new interactions are established and new rules arise transforming the social structure of agro-food production (Higgins & Bryant, 2020; Lioutas & Charatsari, 2021). Digital innovation also entails the implementation of data collection procedures that, while producing *knowledge about nature*, produce *nature through knowledge* (Fama, 2019; Fama & Corrado, 2021; Moore, 2003). Furthermore, digital technologies are becoming an essential part of national rural agendas, as they are increasingly used in the design and evaluation of rural policy and for monitoring and controlling agricultural practices (Ehlers et al., 2021). Hence, while rural development programmes (RDPs) are fostering digitalisation, they are also shaped by digital technologies (Carolan, 2020; OECD, 2019; Rijswijk et al., 2021).

Academic debates about agricultural digitalisation are permeated by different perspectives on sustainability. In particular, it is possible to discern purely descriptive perspectives and normative approaches that conceive digitalisation in relation to its outcomes in terms of productivity and market possibilities for farmers. For instance, Klerkx et al. (2019) describe agricultural digitalisation in terms of new effective farm management options arising from a combination of digital data (concerning location, weather, energy use, etc.) and sophisticated tools (such as sensors, machines, drones) that allow monitoring of farming processes and inputs (including animals, soil, water and human labour). In the case of normative approaches, some authors focus on issues

related to entrepreneurship, resource mobilisation, knowledge development and diffusion, while others pay more attention to the conditions needed for the responsible use of digital innovations (Phillips et al., 2019). Here, we draw from Hackfort (2021) to address agricultural digitalisation from a more critical and analytical angle. For Hackfort (2021), 'digital agriculture encompasses both digitisation, which refers to the technical process of converting analogue information into digital data, and digitalisation, understood as the social process of adoption of computer technologies'. These social processes, as Hackfort shows, are entangled with power relations, inequalities and contested views on sustainability. Thus, from a critical perspective, it is important to analyse the role of digital technologies in reinforcing existing power asymmetries and inequalities in agriculture (Dietz & Drechsel, 2021; Rotz et al., 2019). This makes the digitalisation of agriculture a political and ecological process representing an important ingredient of the uneven patterns of the capitalist development of agriculture.

Under these premises, we conceive the digitalisation of agriculture primarily as a contested process through which digital tools and practices are politically incorporated into capitalist agriculture. From this angle, we challenge the literature portraying the digitalisation of agriculture as an important step towards the achievement of sustainability goals (Mondejar et al., 2021; OECD, 2022). In this regard, it is important to recognise that the definitions of sustainability change widely according to the different actors' interests (Brown, 2016). Hence, as Scoones (2016) suggests, diverse and contested meanings of sustainability configure the politics of sustainability. These politics, we argue, are particularly relevant for the analysis of the social and ecological transformations linked to the digitalisation of agriculture.

Upon closer inspection, the digitalisation of agriculture and rural areas in the context of global and national politics of sustainability is a phenomenon whose multiple social, political and ecological dimensions remain largely unexplored. In particular, it is important to understand how digitalisation is politically built and unfolds in specific rural settings and how the use of digital technologies in agriculture is adding elements to and enabling the consolidation of a 'new rural paradigm' and how this configures and reconfigures relations of autonomy and dependency within agricultural development (Prause, 2021; van der Burg et al., 2019; Verdonk, 2019). We refer to a paradigm where the political focus is moved from the farm level, as the production site, to rural areas, as spaces for the implementation of sustainable development policies (OECD, 2006), and where digitalisation tends to be portrayed as a possible solution to reconcile production targets with sustainability goals (Bahn et al., 2021; Barrett & Rose, 2020; Bucci et al., 2018; Luo et al., 2016; Wolfert et al., 2017).

It is worth stressing that generalisations about the digitalisation of agriculture in Europe are difficult and misleading since European agrarian settings are characterised by a great diversity of production models and technological development. Consequently, comparative analysis that focuses on the differences in agriculture and rural development paths, and also on the interdependencies between such paths in diverse EU regions, is fundamental.

Considering the above, this article analyses digitalisation in dairy farming with the aim to shed light on how and why this is transforming agriculture and rural spaces across Europe, as well as to explore how digitalisation interplays with the politics of sustainability in rural spaces. Empirically, the article focuses on dairy farming in Calabria, Italy, and Uppsala, Sweden. These regions provide us with an emblematic example of differentiated agrarian settings within the EU, and it is precisely because of their great diversity that comparing them can help to understand the context-specificity of agricultural digitalisation and to gain new insights into emerging agrarian questions.

Dairy farming is relevant for our analysis because it is the agricultural sub-sector with the highest degrees of technological innovation and digitalisation (Goller et al., 2021), being also

characterised by the negative effects of intensification and the search for sustainability (Clay et al., 2020). In the EU, dairy production is a core agricultural sector, and its market-driven transformation has been key in the CAP, even before the abolition of the milk quota system in 2015 (Jongeneel, 2011). The latter may have contributed to improved technical efficiency (Náglová & Rudinskaya, 2021) and increased productivity (Čechura et al., 2021). Nevertheless, it has also brought new and significant challenges concerning the role of dairy production in terms of rural development (Stuiver & Wiskerke, 2004; van der Ploeg, 2008) and transformed the socioeconomic structures of the dairy sector (Butler & Holloway, 2016; Vik et al., 2019). An accepted view on ongoing farm automation in the EU recognises that this increases productivity by reducing the need for human labour (Bonneau et al., 2017). Nowadays, emerging trends in the digitalisation of dairy farms are based on robotics (Trendov et al., 2019), which are labour-saving technologies that increase productivity (Bijl et al., 2007). However, the costs of robotics make its reception highly uneven, with consequent patterns of economic, social and spatial differentiation.

Indeed, the penetration of digitalisation into agriculture entails key political questions concerning how this phenomenon is entangled with the capitalist development of agriculture and the related politics of sustainability. Therefore, in this article, we look at agricultural digitalisation as a politically constructed process that also deeply influences the production and reproduction of discourses on rural development and sustainability.

Theoretically, we build on the agrarian question and food regime literature to show how processes of uneven and combined technological development in agriculture are associated with global and local agrarian change and politics of sustainability (Akram-Lodhi, 2021; Akram-Lodhi & Kay, 2010a, 2010b; Friedmann, 1993; Kautsky, 1988; McMichael, 2013b). In our view, research on new agrarian questions in Europe is much needed, given that this topic tends to be considered relevant only when referring to so-called developing countries (Akram-Lodhi, 2021). Empirically, the article uses case studies to explore the digitalisation of dairy farming and the politics of sustainability in the regions of Uppsala and Calabria.

Besides this introduction, the article is organised as follows: Section 2 introduces our theoretical framework, Section 3 explains the methodology, Section 4 presents the results and analysis of the cases and Section 5 presents the discussion and conclusions.

Digitalisation and new agrarian questions

Enquiring why and how capitalism transforms agriculture is one of the basic starting points in the agrarian question literature. We draw on Akram-Lodhi & Kay's (2010a, 2010b) proposal of an agrarian question framework as a flexible approach for country-specific analyses of the material conditions governing rural production and reproduction, as well as the process of agrarian accumulation (or the lack thereof). In this regard, Akram-Lodhi and Kay note that today two key agrarian questions concern how ecology and the 'corporate food regime' (McMichael, 2013b) interplay in the processes of rural production, rural accumulation and rural politics. Thus, an agrarian question perspective helps us to critically explore the digitalisation of agriculture in country-specific contexts characterised by local politics of sustainability and the politicisation of the terms of food production through discourses on social and environmental sustainability. This, we argue, is especially relevant in agrarian contexts where digitalisation is already impacting the way farmers organise production amidst increasing political demands for the sustainability of farming.

In such terms, the agrarian question framework serves as an analytical strategy to approach the digitalisation of dairy production in relation to the overall process of technological transformation of agriculture and dairy production at the farm and political levels. For this, relevant insights come from Kautsky's analysis on the context-specificity of the implementation of technology in agriculture (1988 [1898]). First, Kautsky observed that the use of new technologies tends to increase farmers' dependency on external inputs, but agricultural technology is always situated and mediated by the farmers' concrete use of technology. Second, Kautsky noted that the process of capitalist-driven penetration of science and technology into agriculture becomes a permanent, problematic and pressing process within the farm and for the farmers (ibid, p. 297). Third, he showed that the use of new agricultural machinery and technology created the need for new skills and training of workers, this being also connected to the fact that machinery and technologies in agriculture both eliminated jobs and created new jobs.

Key in Kautsky's analysis of the agrarian question is his focus on tendencies and counter tendencies in relation to how capital transforms agriculture—and, hence, labour, property and technology underpinning food production and processing. This analytical premise is important to understand internal contradictions in the development of capitalism vis-à-vis agriculture,and also for the analysis of political antagonism between industrial capitalist agriculture and other alternative agricultural models.

Following Smith (2020), we add to our agrarian question framework a focus on the uneven and combined development of capitalism in agriculture. This allows us to consider temporal and spatial scales through which digitalisation transforms agriculture and to grasp the counter tendencies arising from this process. As suggested by critical studies on technology, the ambivalence of technology must be carefully considered (Alarcón & Chartier, 2018; Feenberg, 1990) to understand more deeply the changes in social and ecological relations of production that lie behind the digitalisation processes in the context of sustainability (Lange & Santarius, 2020).

To specifically situate our cases in the wider context of dairy farming and the politics of sustainability, we draw on food regime analysis (FRA). Originating in the work of Friedmann and McMichael (1989), FRA is a key contribution to the theorising of contemporary agrarian questions. As stated by Akram-Lodhi (2021, p. 276), the changes in rural areas connected to the hegemony of capital and the financialisation of agriculture imply that 'it is necessary to situate agrarian questions within the world-historical context of the food regime'. The latter, according to McMichael (2020), is currently characterised by food trade relations through international markets involving a plurality of actors including states, international organisations originating in trade agreements and food corporations. Within FRA, the incorporation of environmental considerations and opposing views on sustainability within agro-food systems by food corporations, states, social movements and other actors, has been understood in the terms of an emerging corporate-environmental food regime (Friedmann, 2005), which has been specifically identified in the EU context (Levidow, 2015).[1]

Hence, FRA allows us to interrogate political relations between the digitalisation of dairy farming and tensions in the corporate-environmental food regime. Previous FRA and dairy production research have shown that an important factor in the reconfiguration of food regime relations was the action of dairy cooperatives to protect and strengthen their market position (Pritchard, 1998). This happened in a context where smaller domestic dairy cooperatives with extensive market reach were key players and neither regional cooperatives nor international capital played an important role in defining the terms of the deregulation of the dairy sector (ibid). The expansion of cooperatives and strengthening of transnational corporate influence in the dairy sector were mutually compatible because food corporations found it profitable to outsource their dairy inputs

from producer cooperatives. When it comes to analysing digitalisation through a food regime lens, Prause et al. (2021) show that 'digitalisation of food production is a phenomenon along the entire commodity chain' and argue that to understand how digitalisation impacts the organisation of the agro-food system, it is crucial to overcome the tendency to focus on digitalisation at the input and farm level.

The materialisation of political views on agricultural digitalisation in the context of a corporate-environmental food regime is a process where not only are corporate actors important players but also the interests of a multiplicity of actors trying to define the political terms of rural digitalisation and sustainability come into play. Understanding food regime reconfigurations as outcomes of the agency of multiple actors, including corporate and environmental actors, in addition to the agrarian question framework presented above, calls for an empirical examination of the uneven and combined development of agriculture and digitalisation processes, to avoid falling into deterministic approaches. As definitions of sustainability are at the centre of food regime reconfigurations and contemporary agrarian questions, in our case, we paid special attention to the politics of sustainability.

Starting from the conceptual approach presented above, our empirical analysis focuses on the interactions between the digitalisation of dairy farming, local politics of sustainability and ecological dynamics that influence the political definition of new agrarian questions within the corporate food regime.

Methodological approach

The study was carried out between 2020 and 2021 in Calabria, Italy, and Uppsala, Sweden. The choice of two highly different contexts serves the goal of analysing differences and similarities between ongoing agricultural digitalisation processes in the EU and how these processes are linked to the politics of sustainability. For this, we selected two areas that we have already analysed in previous research and that ensured us the possibility for fieldwork.

The research was based on interviews with key actors, study visits and analysis of reports and documents issued by local, national and EU agencies. The interviews were semi-structured, and we used common, but flexible, interview guides methodologically designed for the purposes of comparative analysis. The case of Uppsala builds on two interviews with staff working with rural development at the Uppsala County Board, two interviews with staff working on environmental strategies and rural development at one rural municipality in the Uppsala region, two interviews with staff working with integration policies at the Uppsala County Board and six interviews with local farmers. The case of Calabria builds on two interviews with staff working at the Regional Breeders Association (ARA), two interviews with staff working with rural development policies at the Council for Agricultural Research and Analysis of Agricultural Economics (CREA; under the Ministry of agriculture, food and forestry) and five interviews with local farmers. Due to corona virus pandemic (COVID-19), some interviews were conducted digitally. Tables 2 and 3 in the research context section (see below) illustrate the main characteristics of the farms included in the study.

To select the participants, a purposive sampling approach was adopted based on our prior knowledge of the two contexts. Thus, we decided to draw from the information we already had to create a sample as representative as possible of the local dairy sector and also try to compensate for the limited inference of the study due to the relatively small number of participants. Other participants were selected considering their professional role and their potential to act as key informants.

Interviewees were asked to mention examples of actors and farmers they deemed relevant for the purposes of the study. The examples we were given (including by the first farmers we contacted) are very well-known farms that had also been involved in some of our previous research.

Questions to the farmers aimed to garner general information about their activities, the digital technologies they adopted, the reasons for (and the obstacles to) innovating digitally, the risks and the opportunities related to digitalisation and how this is affecting their economic performances, their workforce and their ecological impact. Questions to other participants focused on their perception of the current socioeconomic and political situation of agriculture and of how digital innovations interact with problems related to sustainability, the labour market and rural development. We explicitly included open-ended questions to allow interviewees to present their views on the contexts of farming and production, labour and development in agriculture and on the future of agricultural and rural development in their areas. Follow-up questions allowed us to clarify the views of the interviewees and also gain more in-depth qualitative data for the purposes of our research.

All the interviews were transcribed, and excerpts from the transcribed interviews were coded using the following keywords: technology, digitalisation, agriculture, dairy farming, sustainability, labour, innovation, costs and production. This procedure was followed by a more focused reading and interpretation of the interviews to analyse the relations among these keywords. Since our work was not guided by a specific hypothesis, data collection and analysis were informed by the knowledge acquired over the course of the research. In both cases studied, specific topics and issues related to our research question arose. Each case was first analysed separately. Second, we had research meetings to jointly analyse the interviews and topics emerging from the cases, starting from a thematic focus on the Swedish and Italian terms equivalent to technology, digitalisation, agriculture and dairy farming.

We also selected and analysed official reports, agriculture news in specialised local magazines and Organisation for Economic Co-operation and Development (OECD) and EU rural policy reports. Rural policy documents and local news on agricultural issues were thematically analysed with a focus on the digitalisation of agriculture and dairy farming. Additional information was gathered through a systematic review of a leading magazine of the Federation of Swedish Farmers focused on agricultural development and technology and official reports issued by CREA and the Italian rural network for rural development. The analysed documents are listed in the Appendix.

Research context

The agricultural models of Calabria and Uppsala differ significantly as synthetically shown by the data provided in Figures 1 and 2 and Table 1 .[2]

Uppsala has diversified agriculture including grain and meat production and a growing movement of organic and ecological farming. Yet, especially compared to Calabria, the region shows a high level of land concentration, an agrarian structure based on large farms increasingly oriented towards agricultural specialisation (Wästfelt & Eriksson, 2017) and diversity in farming approaches (Marquardt et al., 2022).

As in the rest of Sweden, dairy farming is a key agricultural sub-sector, although it has experienced a sharp decline over the past four decades (Figure 3). This has been compensated by a constant increase in yields led by an extensive use of technological innovation. The increasing volumes of milk produced and sold in the market meant regular and relatively secure earnings

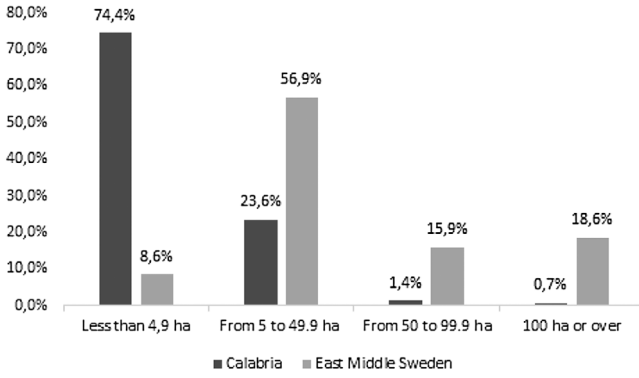

FIGURE 1 Farm distribution by agricultural size—Eurostat

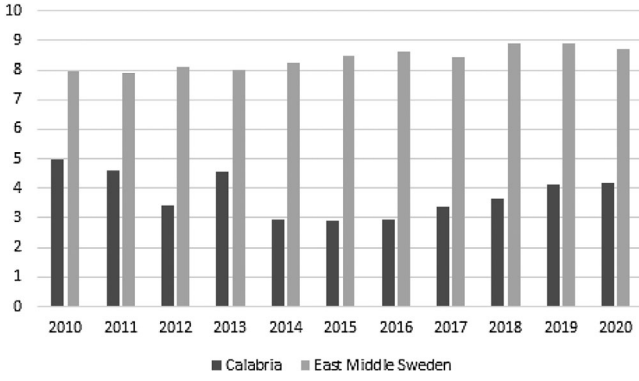

FIGURE 2 Average annual yield per cow (1000t of milk)—Eurostat

TABLE 1 Dairy production in Calabria and East Middle Sweden—Eurostat

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Dairy cows (1000 heads)											
Calabria	18,61	18,27	26,09	19,20	32,30	31,31	36,00	32,68	26,87	24,12	24,65
East Middle Sweden	57,82	57,28	56,27	55,85	55,31	53,31	51,93	52,03	47,67	46,92	48,68
Milk production (1000 t)											
Calabria	92,68	84,41	89,16	88,01	95,51	91,41	106,97	109,79	98,72	99,22	102,78
East Middle Sweden	460,41	453,56	455,16	446,71	456,75	451,75	446,98	439,37	425,25	416,52	424,92
Average milk production per cow (1000 t)											
Calabria	4,98	4,62	3,42	4,58	2,96	2,92	2,97	3,36	3,67	4,11	4,17
East Middle Sweden	7,96	7,92	8,09	8,00	8,26	8,47	8,61	8,44	8,92	8,88	8,73

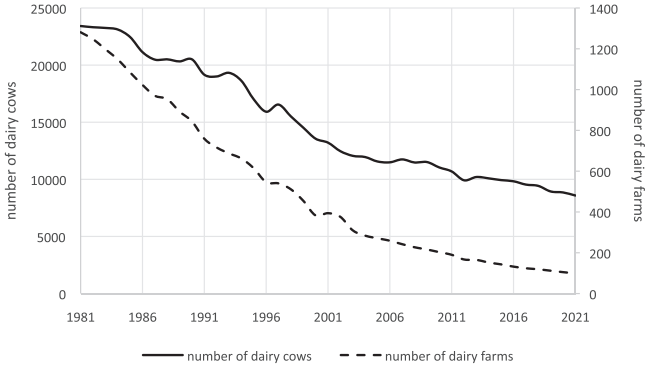

FIGURE 3 Trends in numbers of dairy cattle and dairy farms in Uppsala. Own elaboration with data from the Swedish Board of Agriculture (2021)

for the farmers. This became a driver of local development but also increased local dependency on the dairy sector (Table 2).

A strategy adopted in Sweden has been to further foster productivity in dairy farming through the incorporation of ever-new technologies and machinery (Martiin, 2011). The first milking robots were introduced in 1998, and in 2012, there were 1100 farms with robots, which produced about 33% of the milk in the country on about 22% of the dairy farms (OECD, 2018). Investments to install robots and transform dairy facilities were largely possible through financing from the RDP, and from 2007 to 2009 the average investment support from the RDP was about 16% of the total cost of investments (ibid). Sweden is home to a leading multinational company operating in the field of technological development for the dairy sector (DeLaval), which fosters conditions for the digitalisation of local agriculture.

Calabrian agriculture, on the contrary, is characterised by high labour intensity, low productivity, low propensity to invest and a low degree of openness (Castellotti & Lo Vecchio, 2014). However, agriculture has a significant weight in the local economy, accounting for 5.4% of the total added value—against 2.1% of Italy's—and employing 13.6% of the active population—against 3.7% at the national level (ISTAT, 2020). The livestock sector plays a minor role but still generates more than 10% of the added value. The local agrarian structure is highly fragmented: The average farm area is less than 4 hectares, compared to 7.9 at the national level, and the average economic size is 14,277 euros of standard output—against a national average of 30,514 euros. The modernisation processes that followed the introduction of CAP in the 1960s—with the spread of mechanisation and chemical inputs—allowed agricultural productivity to increase slightly but also led to a dramatic decline in utilised agricultural area and employment in the primary sector, particularly affecting small farmers (Fonte & Cucco, 2015). Dramatic and continuous emigration flows have caused a severe decline and progressive ageing of the rural population. These dynamics have differently affected mountain and plains areas, whose farming is organised differently and integrated into markets. From the 1980s onwards, the growing integration of local agriculture into global markets has further transformed the Calabrian rural landscape, exposing local farmers to new risks and threats, but also bringing them new development opportunities stemming from the increasing consumer demand for sustainable, healthy and locally embedded food (Corrado, 2018).

RESULTS

Uppsala

Today, distinctive processes in dairy farming in Sweden are ongoing struggles for a fair price to be paid to dairy farmers, increasing problems regarding rules and economic prospects for dairy production, and the intersections between rural politics and the implications of sustainability and climate politics in dairy farming (ATL—Lantbrukets affärstidning, 2021). Though the dairy sector is taking measures to better position dairy farming in the context of the climate crisis (Framtidens Jordbruk, 2021), the challenges it faces are numerous, and they originate from the difficult task of compatibilising climate mitigation goals and dairy farming as a main source of greenhouse gas emissions. A main actor in dairy farming in Sweden is the dairy cooperative ARLA. ARLA is a farmer-owned transnational cooperative and with 2200 associated farmers is the largest dairy cooperative in Sweden. ARLA's 5-year strategy from 2020

embraced sustainability and digitalisation as key goals for its activities and as a strategy for growth (ARLA, 2021).

In 2016, the price of milk paid to farmers reached its lowest historical level after a price reduction that ARLA started in 2014. This has led to the perception of a crisis in dairy farming, which is reinforced by the decreasing number of dairy farms, abandonment of dairy by farmers and even difficulties in selling dairy farms (ATL—Lantbrukets affärstidning, 2021). In 2021, arguments of the dairy farmers in negatively receiving announcements of higher prices for their milk were also based on the fact that they were faced with increasing costs for fuel and repair facilities, among other higher costs of production (ATL—Lantbrukets affärstidning, 2021). This long-lasting struggle for the right price of milk is also associated with competition in the international market, and there is a tendency towards imports being a larger proportion of the dairy products consumed in Sweden (Swedish Board of Agriculture, 2020). Though there are competitive advantages for dairy farming in Sweden, the sector is characterised by a tendency towards fewer and larger dairy producers, and while during the last 10 years the number of milk producers has decreased by 41%, the number of cows has decreased by only 20% (ibid.). In parallel, technological development and increased productivity in dairy production is also part of an international agenda. This is well represented in how the Organisation for Economic Co-operation and Development addresses issues of innovation and agriculture in Sweden by recognising the increased agricultural productivity in the country while still pushing for more productivity (OECD, 2018).

In this scenario, Uppsala's development plans consider digitalisation as a key path for regional development and the regional digital agenda requires that all municipalities have a strategy for 'how to succeed with broadband expansion, both in urban areas and in rural areas' (Uppsala region, 2020). Thus, digitalisation is advancing in the region, and there are expectations that this will enable better living conditions and economic prospects in rural spaces. Rural prospects from digitalisation are presented by a rural development municipal officer, who when asked about digitalisation, stated:

> The technology that is coming can keep track of what needs to be done out on the soils right now. You can see what the crop looks like with drones and all the different techniques to investigate it. So, it will be more resource efficient. I think that the machines will go by themselves without a driver.… But that will demand even fewer people, but other kinds of people will be needed […]. I also believe that the whole sustainable life becomes more important as well. (Interview, rural development officer 1_U)

While this view is framed in broad terms of new opportunities for agricultural development, recognition of changes in rural labour is important. In this regard, interviews with dairy farmers show a more differentiated view on how technology and digitalisation unfold in the region. Three of the interviewed farmers represent similarities and differences in dairy farming and technological development, which are summarised in Table 2

Below we empirically analyse three key processes showing how the interplays between the digitalisation of agriculture and different views of sustainability become a key political problem in the development of dairy farming in Uppsala. These processes are local differentiation in the adoption of dairy technologies, technology as new possibilities and new problems for farmers and contradictions in the politics of rural development.

TABLE 2 Main characteristics of three cases of dairy farms in the Uppsala region

	Characteristics	Technology
Farmer 1_U	100 ha used for pasture and 580 ha used for cultivation Of the total area of the farm, 95% is accessed under lease agreements 200 cows Associated with an ecological dairy cooperative with seven other similar farms in the Uppsala region	Milking machines
Farmer 2_U	220 ha of agricultural land and 120 ha of forests, owning only 46 ha of agricultural land and 20 ha of forests and renting the rest from other farmers 75–80 cows Associated with ARLA KRAV-certified farm[a]	Milking robots
Farmer 3_U	30 ha of agricultural land. In addition, lease agreements for another 70–80 ha 100 cows Associated with ARLA The farm does not have KRAV certification	Milking machines

[a]The KRAV label stands for food produced without artificial chemical pesticides, good animal welfare, reduced climate impact, increased biodiversity and better working conditions.

Local differentiation in the adoption of dairy technologies

Differences between dairy farms are not only due to the use of milking robots or to the type of cooperative to which the farmers belong. For example, two of the interviewees, while both being associated with and selling their milk to ARLA, differ in their approach to the incorporation of technology and digital innovations. In this regard, one key issue is that the incorporation of milking robots implies important investment decisions for dairy farmers. As farmer 2_U, who during the interview in 2021 was in the process of procuring a new milking robot, explained, after 10 years of using a milking robot, they were now upgrading the system due to the maintenance costs of the older robot. Thus, the costs of replacing the 10-year-old robot were assessed in relation to the maintenance costs of the robot. While the farmer has learnt how to solve several problems with the milking robot, they sometimes need expert technicians to repair it. The company supplying the robot is DeLaval, which sells the technology and provides technical support. Along with the process of digitalisation of the farm, they have also grown by renting lands from other local farmers. While this farmer expressed a positive view on technological development, he highlighted that the costs of the new technologies are a problem. He explained that they have partly addressed this problem by exchanging machinery and labour with other farmers. This co-operation among farmers is rooted in personal connections and means he and the other farmers can avoid buying all new machinery in the market. His assessment of the relations between transformations in agriculture associated with technological development mixes social concerns with the fact of this development of agriculture:

> There are large fields and big machines and you see almost no farmers in the area. I think this development is definitely not good. We have participated in it as well because we went up from having 20 cows in 2010 to about 75–80 cows today. But I think that it would be good if you could in some way control that development to instead favour the development of smaller farms. I realise that it may not seem logical, but if I take a holistic view, I think we will get more people working in agriculture and a closer contact between the consumer and agriculture. (Interview, dairy farmer 2_U)

In developing his answer, farmer 2_U focused on environmental concerns and how he believes that often their role as farmers producing food is not understood when dairy farming is criticised. Based on the organic KRAV certification of his farm, he argues that there are no substantial differences between how they produce and production by other ecological dairy farmers, including those in ecological cooperatives and not associated with ARLA. He was positive towards ecological dairy farming cooperatives and explained that they are taking important measures towards more sustainable farming as well.

Farmer 3_U also belongs to ARLA. He moved from The Netherlands in 2017, prompted by the lower costs connected to dairy farming in Sweden. Farmer 3_U expressed several critical stances towards excessive use of machinery and digitalisation in dairy farming. One issue here is disaffection with being dependent on credits to acquire new machinery:

> I thought that we needed a new baler because the one we have is old and needs repairs often, and it gets expensive to repair it. So, I thought about buying a new baler and I went to talk to the seller. And he said that it might cost me 1.1 million [SEK]. I said that is a lot of money. No, he said, now instead of paying it within 5 years [with a credit], you can pay it within 10 years [a 10-year credit] […] I think that 90% of all the machines that you can buy, you need credit for this […]. (Interview, dairy farmer 3_U)

In addition, farmer 3_U claimed to be more autonomous than other farmers in the area, as his farm does not depend on milking robots. To illustrate this point, he explained that in the case of a power outage, he is less affected than other farmers using milking robots and digital devices, who may be forced to stop the entire production system for hours. Farmer 3_U also sees the potential of lower technological development in his farm to reduce costs. This approach includes the acquisition of second-hand agricultural machinery. The views of farmers 2_U and 3_U show that the digitalisation of dairy farming brings new questions about autonomy and dependency for farmers, and it shows that their assessments of the effects of new technologies on their farms run in parallel with views about their sustainability as dairy farmers and the sustainability of rural areas.

Technology and digitalisation as new possibilities and new problems for farmers

We can highlight here that views of technology and digitalisation expressed in the interviews show that digitalisation both opens new possibilities and creates new problems for farmers. In the case of labour, the high level of technological development of agriculture was associated with specific skills that the farmers would require from new workers. As one cattle farmer said:

> The machines have become more complicated [...]. There are more technologically advanced tractors and harvesters [...]. And then there are fewer machines, so it puts greater demands on the person or people who work with them. [...] We cannot put someone to practise with the harvester that we have here. You need an initial period of training, which takes many years. (Interview, cattle farmer U_4)

Similarly, a member of the ecological dairy cooperative explained that:

> The technology is expensive and has to deliver much in a short time, and it can be difficult to find staff with competences, you want to use the machine's full potential from the beginning [...]. (Interview dairy farmer 1_U)

In this view, labour relations are crucial to how digitalisation and technology transform agriculture at the farm level in a way that requires very specific skills and makes it difficult to increase employment in agricultural tasks on the farm. This indicates that the digitalisation of agriculture in Uppsala takes place in a context where agriculture at large is already deeply transformed by technological development and the use of advanced agricultural machinery for increased productivity. For dairy farmers, in particular, this leads to a difficult balance between maintaining the pace of technological development and digitalisation, technical requirements for the employment of new workers and their capacity to sustain dairy farming in a market characterised by price volatility and environmental regulations.

Contradictions in the politics of rural development

A common concern expressed by the three interviewed dairy farmers relates to the effects of the price of milk. Even in the case of ecologically produced milk, which is defined by certifications, the premium price has become unclear. Farmer 3_U, for example, explained that there are no incentives for him to start with the ecological certification of milk production, as ARLA is not buying more ecological milk due to low demand in the markets. On the other hand, farmer 1_U, who was part of an ecological dairy cooperative, also mentioned that the price has stagnated due to more ecological producers delivering certified milk to the market. The fact that market prices and increasing costs of dairy production are a central problem for dairy farmers indicates first that the different meanings of sustainability for individual farms contrast with dairy farming where profits are linked to the capacity to further digitalise at the farm level, and second, that politics are central in the local definitions of sustainability within food production.

On the other hand, our analysis indicates that the views of farmers presented above contrast with how The Swedish National Food Programme (2016) and the Strategy for a Sustainable Digitalisation (Swedish Government, 2017) aim at combining sustainability and climate change goals with employment possibilities and the strengthening of Sweden's competitive advantages. Key goals defined in these policies are competitive innovations that can provide value for society, companies, the environment and people and can be disseminated. Here, digitalisation is envisioned in its potential to improve living and working conditions in sustainable rural areas. The role of the state in the digitalisation of agriculture is articulated by the Swedish Board of Agriculture (2017) in terms of support for the spread of innovations in rural areas (p. 15), provision of infrastructure and, if needed, provision of capital to especially support new techniques and small companies (p. 22).

TABLE 3 Main characteristics of five cases of dairy farms in Calabria

	Characteristics	Technology
Farmer 1_C	600 ha of agricultural land 3000 dairy cows 120 ha for kiwi production Agritourism 200 employees	Milking robots Precision farming tools Photovoltaic Biogas plant
Farmer 2_C	150 ha of agricultural land 100 cows 25 employees Agritourism, artisanal brewery, on-farm processing, direct sales point. One of the main promoters of a network of local farms aimed at supporting rural tourism	Milking parlour Management software
Farmer 3_C	150 ha of agricultural land 50 dairy cows 90 employees (most are seasonal workers) Other than organic milk, it produces strawberries, vegetables and ice cream. Direct sales point	Milking parlour Precision farming tools
Farmer 4_C	200 ha of agricultural land 250 cows Five permanent employees and 50 seasonal workers Agritourism, direct sales point, on-farm processing (up to 32 different types of product)	Milking parlour Precision farming tools
Farmer 5_C	260 ha of agricultural land 900 dairy cows 120 employees Agritourism, on-farm processing, direct sales point	Milking parlour Precision farming tools Photovoltaic Biogas plant

Analysing this in light of the views of the farmers presented above suggests that there are emerging contradictions between the different meanings and expectations from the digitalisation of agriculture in rural development, the experiences of farmers and their relations of autonomy and dependency in relation to technology and the politics of sustainability expressed in food and digitalisation policies in rural spaces of Uppsala.

Calabria

As mentioned earlier, over the past few decades, Calabrian agriculture has experienced dramatic transformations with highly contradictory outcomes. Local farms' responses to the continuous drop in profit margins, depopulation and labour shortage have been different, including off-farm employment, cost reduction through the exploitation of migrant labour, farm diversification and innovation along different patterns. Automation and digital technologies are still hardly widespread, but there are also dynamic farms, such as those we analysed, that are trying to adapt themselves to the most advanced technological innovations. Table 3 presents the main characteristics of five dairy farms targeted for this study.

One important difference between the farms listed in Table 3 is their location. Farms 1 and 5 are in plains areas, not far from urban centres, and are dedicated to intensive milk production—but they follow different distribution strategies (agro-industry for Farm 1 and on-farm processing and direct selling—40% of the total abroad—to Canada and the US for Farm 5). Farms 2, 3 and 4 are in the mountains, where they practise organic farming and semi-wild breeding and sell on-farm processed food mainly to local markets.

What follows outlines the main themes that emerged during the interviews, showing that the digitalisation of agriculture is a process that calls directly into question a set of issues strictly related to different dimensions of sustainability.

Technology as a response to labour shortage

The interviewees described technology as a way to increase productivity and to optimise the use of inputs but also to try to cope with the labour shortage, which is repeatedly mentioned as one of the major problems of rural areas. Apparently, however, the possibility to concretely reduce labour needs through technology is limited to the introduction of advanced levels of automation, as in the case of milking robots, but this is not convenient below a certain scale:

> Only with the robot can you reduce the staff, but then there is a scale of heads, in the sense that you must have a greater number of animals to be able to do that. When you have a total of 50–60 animals with 20 milking animals, you need one person to manage them. But you still need one person even if you have the robot. So, to install a robot you should have at least 50–60 heads in milking. (Interview, dairy farmer 3_C)

Only Farm 1, the largest one, has introduced milking robots. The same farm also introduced a pioneering milking system with the support of the Swedish robot producer DeLaval. This agreement allowed this farmer to become a dealer for milking robots for DeLaval in Southern Italy. Milking robots are described as a solution for saving labour and also for creating new and more qualified job positions:

> When we are going to install 20 robots in the big barn with 16 milkers, we will only need four operators who do not necessarily have to be milkers [...], that is, from milkers you may need good electromechanical technicians. This also means making a contribution to the qualification of the workforce, that is, nowadays you can't find any Italian personnel willing to do the job of a milker, but there are some young people out there with a diploma in electromechanics. (Interview, dairy farmer 1_C)

According to all the interviewees, behind the high levels of regional unemployment, there is also a significant labour market mismatch that particularly affects rural areas. Here, the quality of life is compromised by a chronic lack of services, and the employment opportunities offered by local farms are rarely in line with the skills and aspirations of job seekers, especially the youngest. Farmers 2_C, 3_C and 4_C expressly stated that they were forced to reduce their production volumes due to difficulties in recruiting workers.

Migrant labour helps to mitigate worker scarcity, but this is hardly the case for medium-skilled positions that require a certain degree of experience and knowledge of the Italian language:

> I'll explain to you the problem of the foreign workforce[…] for some jobs you manage to train them, for others you simply don't […]; imagine someone who comes here and doesn't know how to get on a tractor and doesn't have a licence […]. The problem is the training […] there are also language problems […] consider that with me there have been people for 7–8 years who have the Internet, have everything, but still hardly speak the language. (Interview, dairy farmer 4_C)

Within this context, the interviewees tend to describe digital technologies as something that could attract young local workers, improving working conditions in agriculture and employment prospects offered by the sector. This potential of digitalisation to attract young local workers is connected to an overall perception that technological development is vital for sustaining agriculture.

Digital innovation as 'an option for survival'

An empirical observation here is that most digitalised farms also tend to be the most innovative in many other respects. Digital innovation has never appeared alone but always as part of a set of innovations. This includes the resort to diversification and multifunctionality:

> Digital innovation has brought many benefits, especially with regard to our agri-tourism, in the sense that […] through the social or company websites, we immediately intercept new customers, even for online sales, e-commerce. […] I'll give you a banal example: on Saturday night I upload a photo of a dish or a part of the farm and on Sunday the restaurant is full […]. From the point of view of sales, innovations help me because they allow me to sell directly without having too many intermediaries. So I can shorten the chain and raise my income (Interview, dairy farmer 4_C)

In this case, the interviewees do not refer to digital innovation as machinery oriented towards production intensification but rather as a combination of practices and tools used to improve efficiency, to develop new products and services and to reach new customers. Following this conception, more than being an option within the exclusive reach of the biggest and most financialised farms, digitalisation is presented as an opportunity for small and versatile realities. As stated by one of the interviewees:

> Very often the application of an innovation is much easier in a small company than in the medium or large one […] innovating a stable of 1000 heads is much more complicated than one of 100 heads […] It's easier to manage 10 hectares with a single set of instruments than 100, having to use data bridges, etc. From this point of view, the challenge must be taken up by small companies in order not to close; otherwise, closure is certain. (Interview, dairy farmer 1_C)

Indeed, the most digitalised farms operating in the region are much bigger than the average farm. Still, all the interviewees concurred with the idea that digital innovation is 'one of the only options for survival'. Rather than as a new development frontier, digitalisation is described as a 'way to catch up with the rest' because of the 'disadvantaged starting position'. However, digital

technologies are also portrayed as an opportunity to overcome the fragility of the local agrarian structure, as they would help to reduce costs and improve efficiency without having to increase the scale and incur overproduction risks:

> If I can produce the same quantity of milk with 900 cows instead of 1000, it means that I am saving on the purchase of raw materials for feeding. That's where we need to get to. Otherwise, it is obvious that in a market where there is already overproduction, the more we produce, the more it becomes a slaughtering game. Instead, managerial efficiency within a company means that I have to maintain my production at lower costs. (Interview, dairy farmer 1_C)

Similar arguments emerged when we asked about sustainability. Interviewees mainly refer to this in financial terms, as the ability to reduce costs to survive in an increasingly competitive market.

The contested meanings of sustainability

The interviewees tend to reproduce a narrative that glorifies the ecological potential of digital tools, described as 'green technologies' that make it possible to reduce the use of fertilisers, avoid the dispersion of water resources, increase the well-being of plants and animals and so on.

This narrative presents digital technologies as practical solutions to reach economic, environmental and social sustainability all at once but does not make any mention of the concrete environmental problems related to the dairy sectors and intensive models. In one case, however, the interviewee talked about the difficulty of reconciling economic and environmental sustainability without having a clear vision of an alternative development model:

> Here, we have people with 2–3 hectares that start farming manually in the afternoon with their son or brother. They do it for passion, and this is a very sustainable agriculture from an environmental point of view but not from an economic one [. . .] On the other hand, we have a strong industrial agriculture that is not sustainable from an environmental point of view. In my opinion, you have to find a middle ground that allows you to reach social, economic and environmental sustainability. This is still an open issue, in the sense that there are praiseworthy examples and best practices, but there is still no clear direction to follow. I very much dislike intensive livestock farming, but what do we do to make non-intensive livestock farming economically sustainable? (Interview, dairy farmer 5_C)

The lack of a 'clear direction to follow' calls directly into question the ambiguity that characterises agricultural policies at the EU and regional levels. When asked about agricultural policies, all interviewees strongly complained about the absence of a clear vision, the lack of administrative skills in local government, the existence of bureaucratic delays and rules that discourage innovation and the persistence of interest groups anchored to an outdated and failing idea of rural development:

> I say that the central and regional governments must invest much more in the introduction of technological innovation within farms. That is the future; the future is not the subsidy that is given per hectare. That only serves to give a momentary breath and

> to prolong the agony. It is necessary that the resources of the next rural programming will be destined to make farms more competitive, and they will be competitive only if they can adapt to the technology that we now find around the world. (Interview, dairy farmer 1_C)

Interestingly, even when calling for a new and more integrated rural policy vision, the interviewees tend to emphasise productivity and competitiveness. This way, they reproduce, and contribute to build, a narrative in which traditional market goals are combined with an idea of rural development as 'the valorisation of the rural environment' through the 'management of the territory' (OECD, 2009). Here, digital technologies, other than being tools for increasing productivity, become management practices that contribute to create new rural spaces of production and reproduction, in which human and non-human nature is shaped by market relations, and the latter is charged with new and changing meanings.

DISCUSSION AND CONCLUSION

The two cases analysed show that the digitalisation of agriculture is far from being a deterministic process with standardised outcomes. Indeed, the incorporation of digital innovation into local farming systems is influenced by a combination of endogenous and exogenous dynamics leading to contradictory outcomes. Our empirical findings also suggest that the digitalisation of dairy farming shapes and is shaped by the intersections of local politics of sustainability, contradictions in the corporate food regime and the politicisation of the ecological and social terms of food production where established agrarian structures are incorporated into the existing food regime. At the same time, food regimes are being reshaped by how local actors understand—and respond to—digitalisation. As in the case of organic farmers in the EU (Lynggaard, 2001), our findings suggest that regional contexts matter in how digitalisation intersects with dairy farmers' responses to production and sustainability demands. Indeed, the digitalisation of dairy farming is part of a wider process of transformation of agriculture through the incorporation of advanced technologies, but it also represents a set of practices imbued with changing meanings (Lioutas & Charatsari, 2021)—although largely driven by the socio-political goal of increasing productivity and efficiency to compete in a market characterised by high price fluctuations, increasing costs and tensions between labour and technology. In line with recent critical approaches to the digitalisation of agriculture (Carolan, 2020; Dietz & Drechsel, 2021; Hackfort, 2021; Prause et al., 2021; Rotz et al., 2019), we found that the local processes of digitalisation in dairy farming in Uppsala and Calabria cannot be reduced to the technical dimensions of the implementation of digital technologies at the farm level. In what follows, we organise our discussion around key themes emerging from our comparative analysis.

Contradictory outcomes of agricultural digitalisation and contested meanings of sustainability

The incorporation of digitalisation among dairy farmers in the Uppsala region, as suggested in other cases of farming in Sweden (Saunders, 2016), demonstrates that the unfolding of agricultural digitalisation is permeated by contradictions between productivist orientations and multiple political definitions of sustainability. In our cases, the political meanings of sustainability bring

together political definitions of ecological problems in dairy production and survival strategies of dairy farmers. The differences in farmers' views on digitalisation contrast with policies that tend to envision general technological solutions to both social and environmental sustainability challenges in rural Sweden. Here, the terms of milk production are defined by a range of actors trying to combine production goals with environmental sustainability goals. Hence, technology and digitalisation are politically ambivalent as shown by the farmers' limited capacity to keep pursuing new technologies while also maintaining production costs and contributing to sustainability goals. This adds to the contradiction between expectations for new labour possibilities and the real prospects of employment in a digitalised agriculture. In this regard, the tendency towards increased productivity underpinning technology incorporation at farm level becomes a key political problem for rural development and sustainability. This contradiction is clearly observed in Uppsala, where notwithstanding the already comparatively high levels of productivity of the local dairy farms, digitalisation is expected to keep increasing agricultural productivity. To an important extent, this same effort is directly enshrined in policy interventions under RDPs. The interplays between these programmes and the capacity of private and public actors to foster technological innovation for increased productivity is feeding a rural sustainability discourse strongly hinged on technological solutions.

Ultimately, environmental and social challenges connected to the technological transformations of dairy production, along with the need to cope with price fluctuations, have had important implications for how discourses on rural development and sustainability become contested. Different narratives regarding the role of digitalisation in rural development arise, when the focus is shifted from environmental sustainability towards concrete problems related to the sustainability of dairy farmers. Again, the role of digitalisation is ambivalent at the discursive level too, as the implications of digitalisation in rural development and agriculture are also associated with the labour drawbacks linked to the technologically driven agricultural development.

The case of Calabria sheds further light on the ambivalence intrinsic to technological innovation as a process that, on the one hand, can produce unemployment and depopulation, as in past processes of modernisation, while, on the other hand, can also foster new development paths and alternatives to cost-reduction strategies based on intensive (migrant) labour exploitation. In this regard, our empirical evidence suggests distinguishing automation, as a process generally oriented towards economies of scale with decreasing labour intensity, from the introduction of digital technologies allowing the optimisation of production at different scales. Certainly, most expensive automation technologies are fully integrated into digital systems, but the latter can also be developed step by step, including small farms that cannot afford overly high initial investments. Yet, digital tools require well-developed information and communication technology infrastructure that in contexts such as Calabria is still lacking in many rural areas. In this regard, a common tendency in these patterns of digitalisation, as outlined in the agrarian question literature, is represented by deep transformations in the labour process, skills and training requirements to incorporate new workers. While this can create new forms of autonomy for farmers and agricultural workers, it also engenders new dependencies on key inputs produced outside the farms.

All this has important implications regarding long-term impacts of digitalisation in local agrarian structures. On the one hand, these processes are likely to produce a further expulsion of the smallest and least competitive farms (Kritikos, 2017), consistent with the productivist approach that inspires an important piece of the regional and EU agricultural policy. On the other hand, they could also provide new solutions to increase sustainability of diversified farms and support the transition towards a 'new rural paradigm' (Lombardo et al., 2017).

For the peripheral and fragmented Calabrian agriculture, new technologies entail both risks and opportunities. Here, with a few exceptions, technological innovation cannot be read as an endogenous creative process responding to specific local needs. Indeed, it mainly consists of the incorporation of tools and the emulation of practices taken from abroad. This exposes local farms to new risks, such as digital divide and dependency on technology providers. However, digitalisation also seems to offer concrete solutions to cope with local problems such as labour shortage, to support diversification and to enable innovative sustainable development patterns. The latter are likely to find fewer obstacles in a context such as Calabria, where agriculture is overall less specialised and capital-intensive. Yet, today digitalisation is an option pursued mainly by large and dynamic farms for which technology is, above all, a way to reduce cost and increase competitiveness. In this way, discourses about sustainability overlap with a market-oriented narrative in which the concept of sustainable rural development is constantly negotiated and charged with contrasting political meanings.

The digital contours of the new agrarian questions

The comparative analysis of Uppsala and Calabria suggests that to an important degree, differentiation regarding the intensity of digitalisation of dairy farming and the motivations to increase digitalisation are given by environmental frameworks regulating dairy farming and the labour relations in both regions. At the same time, our empirical findings concerning how Swedish technology and digital solutions for dairy farming are incorporated and disseminated in Southern Italy can be understood as a pattern of uneven and combined agricultural development where private actors realise key rural policy goals established at the national and EU levels. Here, the case of the Calabrian farmer who is also a retailer for the Swedish company DeLaval shows that there is an important connection between development for increased productivity and digitalisation of dairy farming in Sweden and how digitalisation unfolds in dairy farming in Calabria. However, dairy production is also characterised by the political role of dairy farmers' cooperatives in the definition of market conditions for dairy products, which show multiple actors participating in the political process through which intensive digitalisation in agriculture adds an important new dynamic in the reconfiguration of the corporate-environmental food regime (McMichael, 2020). In this regard, our cases show that political dynamics underpinning the digitalisation of agriculture, along with its normative conceptualisation as a path for the sustainability of capitalist agriculture, are of central relevance when addressing Kautsky's question about how capital 'is seizing hold of agriculture, revolutionising it, making old forms of production and property untenable and creating the necessity for new ones'. As our empirical analysis suggests, digitalisation of dairy farming cannot be understood without placing it into the wider context of the capitalist development of agriculture and considering the more specific local dynamics—and contradictions—of the corporate food regime. The cases of Uppsala and Calabria show that the transformation of dairy farming through automation and digitalisation is uneven and combined, being deeply connected to how politics of sustainability and rural development are embedded in specific agrarian settings.

As Kautsky observed, under capitalism, there is a tendency to continuously deepen the process of industrialisation of agriculture. In our cases, digitalisation can be seen as a contemporary manifestation of that tendency, which, in line with Kautsky's analysis, is entangled with contradictions between the use of labour in agriculture, the social position of agriculture in national economies inserted in global markets and the dependence of agriculture on ecological factors. In

relation to Kautsky's analysis of counter tendencies in the overall process of capitalist development of agriculture, our cases also show that the uneven material incorporation of digitalisation into farming entails new problems for farmers and potential conflicts. In this regard, the cases of farmers who are critical towards the increasing penetration of technology into farming and the loss of autonomy linked to digitalisation, potentially provides fertile ground for the emergence of counter tendencies to the phenomena here analysed.

Finally, our analysis indicates that changes in the meanings of agricultural development fostered by digitalisation are associated with contradictions of rural development under capitalism and that the political terms of rural development are defined as responses to struggles in the markets. Thus, uneven and combined development of dairy farming intersects with how rural sustainability is politically defined. In our cases, rural sustainability can be understood as a socio-political construction permeated by tensions emerging from policy goals feeding specific rural discourses and the political responses from farmers and farmers' associations.

What is clear is that discourses on sustainable rural development through agricultural digitalisation are far from being a simple reproduction of green economy rhetoric, as their emphasis on new cost-effective and eco-friendly technologies is part of a much broader picture involving processes that directly shape and are shaped by politics of sustainability. As highlighted by Watts (2021) and Hussain and Tribe (1983), among others, the analysis of tendencies and counter tendencies of the capitalist transformation of agriculture is crucial in Kautsky's theorising of the agrarian question. Based on our work, we believe that today the explanation of the relationships between counter tendencies towards capitalist-driven digitalisation of agriculture, and their interplays with the politics of sustainability, are an especially relevant area for future empirical and comparative research.

This call for further comparative research is expressly focused on the impact of agricultural digitalisation from a wider political ecology perspective. Indeed, a limitation of this study is that it does not consider how ongoing digital transformations of agriculture and rural spaces are related to questions concerning the impact of digitalisation on the local ecosystems. As recent research shows, emerging trends in the development of farm vehicles are leading to solutions that are unsustainable from the perspective of soil ecological function, with this calling for 'more stringent design of farm machinery that considers intrinsic subsoil mechanical limits' (Keller & Or, 2022). A political ecology analysis of technology and digitalisation in agriculture and dairy farming will also have to more deeply assess interactions between biophysical conditions for sustainability, in the sense of the capacity of local ecosystems to sustain agriculture.

Our hope is that, despite the limits to the generalisability of our findings, our study can contribute to both the academic and public debates on the political dimensions of agricultural digitalisation. Indeed, though the latter represents one of the main drivers of the recent trajectories of capitalist development, it is also a contested arena where meanings of sustainability—as well as the socioeconomic and ecological ends of agriculture—are politically defined.

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ENDNOTES

[1] For critical reviews and assessments on FRA see: Araghi (2003), Goodman and Watts (1994) and Wilkinson and Goodman (2018).

[2] We used regional data from Eurostat at NUTS2 level, where Uppsala is included within East Middle Sweden.

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APPENDIX

Analysed Documents

ARLA (2021) *Future26: Arla Foods launches new strategy in defining moment for dairy*.

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