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RURAL

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RURAL TECHNOLOGY

Rural space is distinctive because of its low population density and its territorial extensiveness. Settlements are small in size and people, and economic activity are widely dispersed geographically. The resulting condition of remoteness in terms of physical distance and transport inaccessibility correlates with higher costs of delivering public services and the provision of infrastructures in rural areas. Indeed, it is a symptomatic characteristic of true rurality to live 'off the grid' in terms of access to services like electricity, telephony, mains drinking water and sewage systems that are ubiquitous and taken-for-granted in cities (Vannini and Taggart, 2014).

Rural places are typically also politically and culturally peripheral from new ideas and political power. In many places, rural residents are economically poorer and less educated than comparable people in cities. Given these conditions peripheral rural regions have traditionally been backwaters for technology and slower adopters of new digital developments (cf. Salemink et al., 2017). This chapter is focused on the rural space in a broadly Western developed economy context with empirical examples drawn from contemporary farming practice in Britain.

It is well known that telecoms and internet services available to residents and businesses in rural areas are often of poorer quality, lower capacity, less sophisticated and without choice, more unreliable than in urban areas, and yet ironically they can also be more expensive. The high cost of physical cabling to connect widely dispersed households has held back high-speed broadband (Skerratt, 2010). The difficulty and cost of siting antennas to service scattered population, which can often be in challenging terrain, have meant mobile telephony and 3G/4G provision can be patchy at best and completely unavailable in more remote places. These 'not-spots' in broadband internet connectivity and mobile phone coverage persist in parts of rural Britain, for example, despite several years of significant capital investment and government subsidies to commercial providers (Philip et al., 2017). As part of wider 'digital divide' debates the relatively poor provision of internet infrastructure and lower-level enrolment of digital technologies are seen as significant impediments to the socio-economic development of rural areas (Malecki, 2003). It is therefore somewhat paradoxical that for decades information and communication technologies (ICTs) have been championed as a possible way to overcome the disadvantages of rurality in development projects, particularly the sense of remoteness (cf. Kleine, 2013).

AGRICULTURE, INDUSTRIALISM AND THE RURAL IDYLL

In economically developed nations the majority of the population live in cities and tend to overlook and underappreciate what happens beyond the urban hinterland. In part this is because the notion of the rural as a tranquil backwater, the antonym to busy urban modernity, remains potent, even while being patently untrue. The idyllic countryside is a fantasy but with real effects in how society in general relates to rural space and, in particular, understands agriculture. It can also be argued that these deep misperceptions contribute to the absence of the rural from most mainstream reporting and contemporary scholarly analysis of digital technologies. Most academic researchers, technology journalists and major philosophers of 'the digital' – who are almost all urbanites – have a blind spot with regard to consideration of the particular 'impacts' of computerization in rural contexts. The countryside is usually completely missing in descriptions of the organizational effects of software systems, in consideration of the social implications of the internet of things, and in analysis of the possibilities of the sharing economy and so-called 'big data'.

Yet rural spaces are a heterogeneous set of productive landscapes, most of them owned and actively managed by conventional information systems and economic activities planned by software algorithms, with results stored in spreadsheets and databases. So while overlooked in scholarly analysis, it is self-evident that software increasingly makes a material difference to how the rural is brought into being. While the physical prevalence of computer hardware equipment and other visible ICT infrastructure is considerably less, in part, as the population densities of rural areas are low and the activities are spatially dispersed, the algorithmic processes of code are no less intensive or significant.

This is demonstrated by changes in agricultural systems – the most significant use of rural space and its most distinctive economic feature – and the everyday practices of farmers. To most outside observers living in cities, the superficial appearance and social perception of agriculture, for example in lowland Britain, is that of a 'green and pleasant' landscape as it lacks most of the overt signs of technological dependency: the human-made infrastructures and the hard materiality of steel and concrete associated with industrial production and consumption. People see fields of crops, familiar farm animals grazing on grass and green trees. While there are sign of orderly cultivation and elements of management, such as gates and fences, nevertheless farming space is perceived as essentially rooted in 'natural' processes (unlike cities).

Agriculture is also widely perceived as being less technological advanced, yet it is often an intensive and industrial-scale activity. Most farming landscapes have been thoroughly technologically dependent since the start of twentieth century and progress in mechanization and the replacement of horse power by cheaper and more capable diesel engines and electrical motors. During and immediately after the Second War World, in the UK, there was a major push to increase individual farm outputs, raise crop yields per hectare, and improve overall productivity while also reducing the labour force. Government subsidies and price guarantees encouraged consolidation of farms, specialization, and intensification in production. Wholesale modernization across agricultural practice meant the enrolment of more and larger machinery, new types of buildings, improved livestock breeds, and the application of biochemical breakthroughs in the form of pesticides and herbicides.

While the push for ever more intensive industrialized agricultural production may have diminished somewhat in the UK in recent decades – in part due to concerns about food quality, animal welfare, biodiversity and sustainability – the application of ICTs and more digital technology for automation has become more evident throughout farming. Code now makes a difference to daily farming practice and more widely in the operation and governance of agro-industrial food systems – with some parts coming to *depend* on software and distributed information systems to function.

HOW CODE IS CHANGING AGRICULTURAL PRODUCTION – THREE CASE STUDIES

Industrial-scale farms are complex spatial and economic entities that are 'made (and constantly remade) through the entanglement and interaction of the social and the natural, the human and the non-human, the rural and the non-rural, and the local and the global' (Woods, 2007: 495). The entanglements that bring contemporary farms into being now include multiple instantiation of ICTs and increasing layers of 'pervasive computing', environmental sensors, automated identification systems, distributed databases, software algorithms and simulation models.

To illustrate the how digital technologies, particularly software, are making a real difference to agricultural practices and changing the farming landscape, we present three brief case studies in a British context: (i) precision-agricultural techniques in arable production; (ii) bio-digital livestock production and food traceability systems; and (iii) dairy production and robotic milking.

Precision-agricultural techniques in arable production

One area of agriculture where digital code has had most impact in terms of changing practice to enhance yields and improve profitability is in arable farming, particularly for large-scale cereal production. During the twentieth century increasing mechanization had already transformed cereal farming into an efficient industrial activity. To further raise productivity digital technology has been enrolled to overcome the lack of information about how crop yields vary within fields and where best to apply inputs like fertilizers and pesticides to have maximum impact (in the past, farmers had to apply inputs uniformly across large fields, which was ecologically inefficient and economically wasteful). Computerization of key farm machinery to record spatial position through on-board GPS and monitor crop and environmental conditions through sensors, in combination with external data (such as high resolution, multi-spectral satellite imagery and meteorological data; Yang, 2009), is facilitating the informatization of farmers' working practices in what has been termed 'precision agriculture'.

Mobile digital technologies and analytical software packages have transformed tacit and embodied knowledge of the farmer (their 'feeling' for land, one might say) into quantified automated procedures, using digital data that is captured largely autonomously and processed algorithmically to give actionable spatial knowledge (Tsouvalis et al., 2000; see also Figure 4.1). In large-scale cereal production, where a single farm might have several thousand hectares growing one crop, even relatively small gains in yields per hectare and reductions in chemical inputs, enabled by the algorithms in precision agriculture software, represent significant financial return. Derived information from precision farming on crop yields, land quality and varying soil capabilities, coupled with details on prices, subsidy payments, environmental grants, etc. are then fed into long-term forecasting models for food supplies.

The combine harvester, initially developed in the 1930s to bring together several key stages in the harvesting of cereal crops into a single mobile machine, is one of the iconic symbols of industrial-scale farming. Today they are the central mechanical component in precision agriculture and are packed with digital technology. Integrated software systems and a raft of sensors continuously monitor and control many aspects of the harvesting process; this includes being capable of running semi-autonomously with steering via laser guidance and positioning the

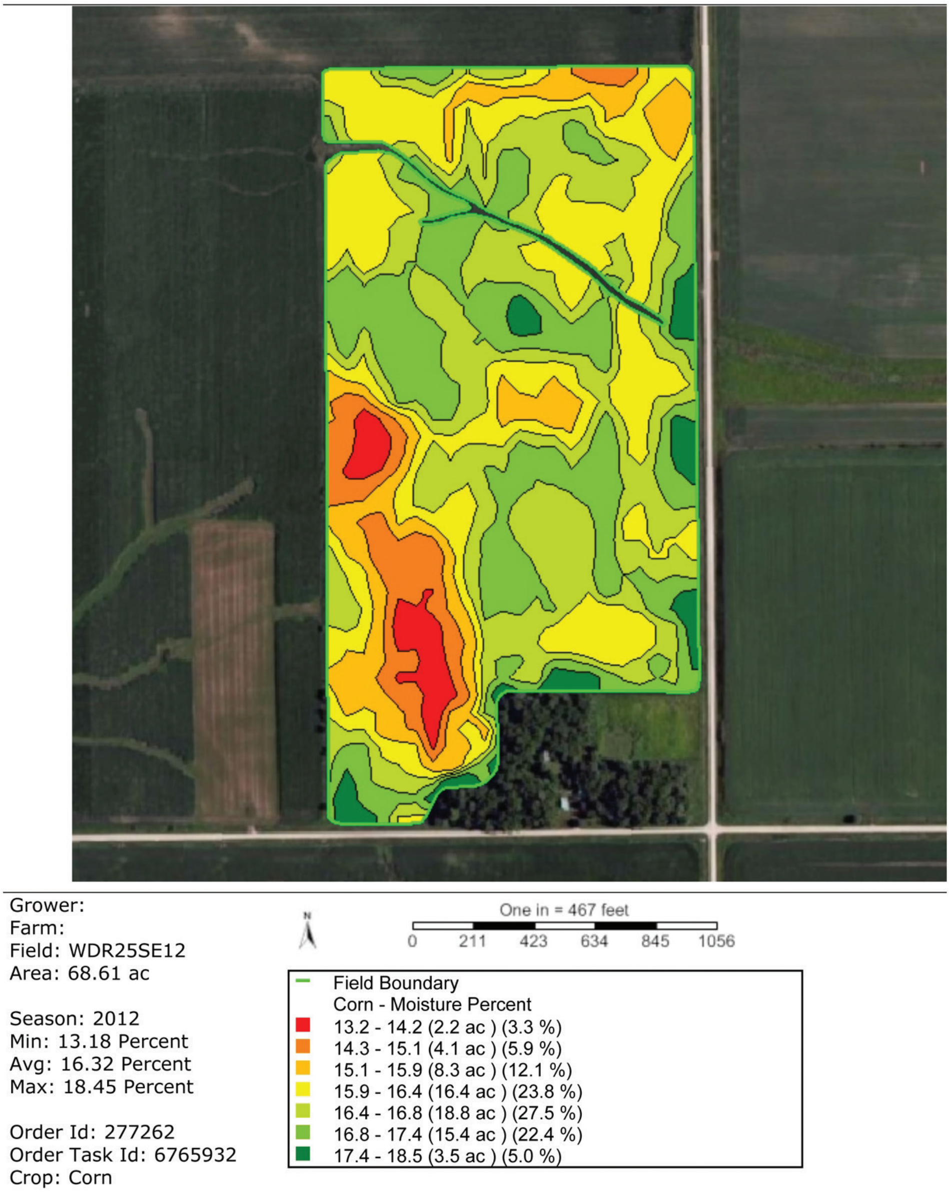

Figure 4.1 Detailed yield mapping of productivity enables input resources to be spatially targeted for best effect. Here in-field variability is visualised as a continuous surface by software algorithms from a grid of sampled data. Courtesy of Viafield/AgriCharts, a Barchart.com, Inc. company.

reel and cutting bar using cameras and image recognition algorithms. As well as handling the complex tasks around crop harvesting, they operate as mobile data collection platforms, with detailed measurements of yield volumes, quality, and moisture content being gathered continuously and georeferenced by GPS. The driver's cab, traditionally a noisy and dusty place, is now fully sealed, soundproofed and air-conditioned, and is as much a software monitoring centre as a site to physically manoeuvre the machine. Code has transduced farmers into screen-workers, spending as much time monitoring sensor outputs as looking at the crop in the field (Figure 4.2).

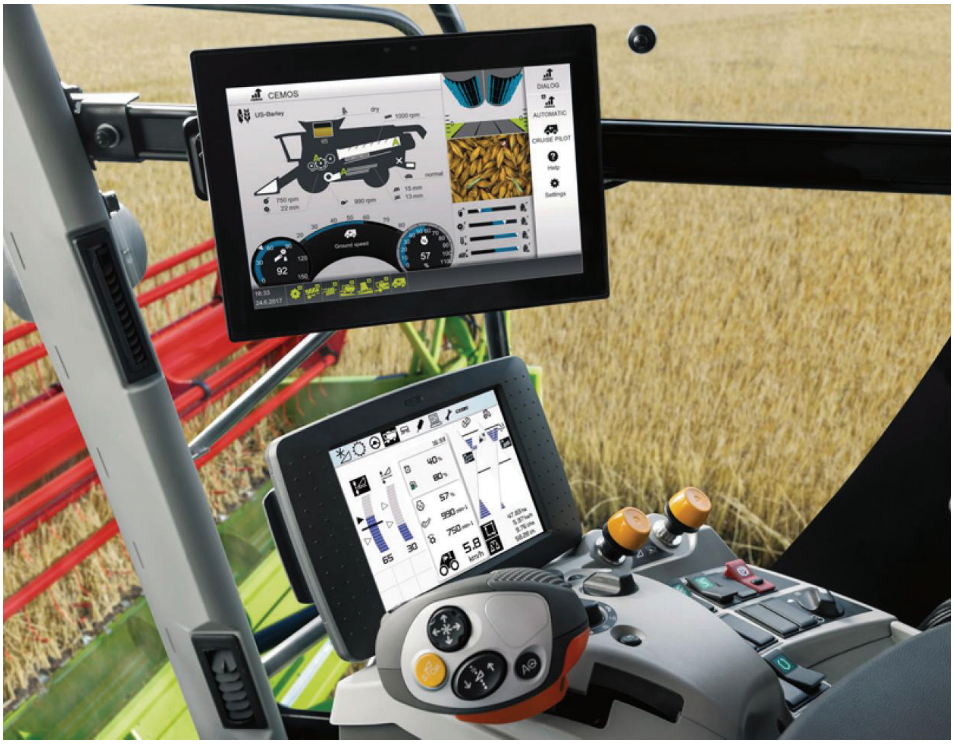

Figure 4.2 Operator control panels in a combine harvester. Courtesy of CLAAS UK. http://www.claas.co.uk/fascination-claas/media/download-center

The code underpinning precision agriculture and the algorithms in expensive machinery like combine harvesters have developed to a point where there are viable attempts at a fully automated arable production system using smart technologies, big data and self-learning algorithms (Wolfert et al., 2017). Given the scale and capital intensity in the arable sector, it is here that autonomous farm robots could feasibly replace humans completely for open-field operations. As such the future combine harvester, working all day and all night to gather in the wheat, will not need an air-conditioned cab at all because there will be no person on-board.

Bio-digital livestock production and food traceability systems

Information systems and complex software databases are now a crucial aspect of livestock farming. Agro-food manufacturers and major retail corporations have implemented systems of hazard analysis and complete life-cycle traceability for meat products, and changed their sourcing and standards of production to enable auditing and accountability (Freidberg, 2007).

The goal is 'farm-to-fork' traceability, which is only achievable in a financially and logistically efficient fashion through the enrolment of sensors and digital identification systems. These systems automatically record material flows and changes in status, which are controlled through software algorithms, with the results being stored in distributed databases that feed into different actors in the supply chain. Analysis by Buhr (2003) details multiple different track-and-trace systems relating to meat supply and demonstrates that in each case, individual animals, and subsequently post-slaughter component parts of the carcass, are abstracted and monitored through various mechanisms. This requires a lot of abstraction and identification, much of which is invisible to the various parties involved. One mode of identification is the use of mandatory ID coding of animals, such as wing tags on birds, barcode ear tags on livestock, and cattle passports (Figure 4.3), which make farm animals into easily machine-readable commodities. Database records build up around the livestock over its life, including the details of breeding, farm location(s), feeding regimes, and space-time points of interaction or transformation (such as vet check-ups, vaccinations, slaughter and the packaging, processing, and distribution of the animal as separate meat products). These audit trails can also collect the names of human operators involved to provide a chain of responsibility/liability for any failure or contamination. Much of this data outlives the animal and is folded into livestock breeding databases to deepen knowledge about the productivity of genetic lineages and then worked upon by software algorithms to predict and determine the next generation of cattle, pigs, and poultry through genetic selection and artificial breeding.

One driver of computerized traceability, which seeks to fully regulate the rearing, movement, and approved slaughter of livestock in Britain, is past failures in audit systems, which led to notable disease issues in the 1990s and 2000s including scrapie in sheep, BSE in cattle, and avian-flu risks in poultry (Barker, 2015). Some elements of these traceability databases have also been opened up to consumer-facing inquiry, enabling shoppers with the inclination to be able to 'look up' details on the source of food, which typically reveals the name of the farm and its geographical location (Figure 4.4).

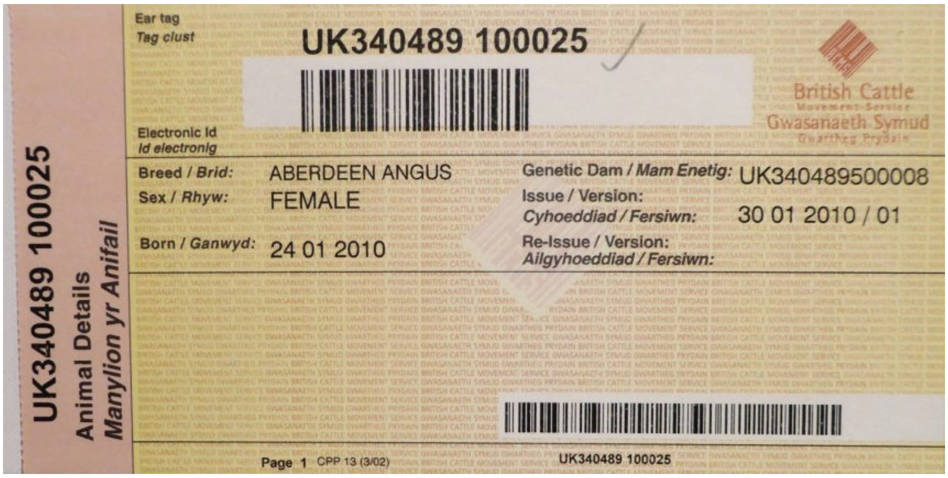

Figure 4.3 The printed manifestation of the 'passport' required to rear cattle for human meat consumption in the UK. The id codes are linked into digital records relating to the individual animal. Courtesy of Crabbs Bluntshay Farm, Bridport, UK.

In spite of extensive computerized audit systems and the sophistication of resulting traceability databases, they are not infallible and there is ample evidence that meat hygiene and quality are still being compromised by mistakes, accidents and cases of deliberate fraud (Manning, 2016). This is, in part, because of how the code operates in actuality, being active across many thousands of different farms, abattoirs, food production facilities and packing factories and distribution warehouses. There are many points where something can go wrong or where tampering can occur. For instance, illegal horse meat contamination was uncovered in many European countries in 2013 and millions of eggs entered the human food chain despite being potentially contaminated by illegal insecticides such as fipronil in 2017. Of course, food fraud and deliberate adulteration by producers for profit is a centuries old problem and it is therefore unsurprising that software systems cannot prevent such criminality.

Despite continued failures in traceability systems, there is no doubt that digital technology and the agency of software is significantly changing the short lives of animals bred for food. The cattle grazing in the field or the pigs raised intensively indoors are in a very real sense dependent on code to live – if their correct registration and logging in audit systems fails then in practical terms the animal is dead.

While it would be biologically and cognitively functional, it would become economically unviable because it could not be legally slaughtered and sold into the food chain. Farmer would be compelled to dispose of the animal as waste. So the livestock we see in fields and millions that are reared in farm sheds now comprise bio-digital animals, brought into being according to production plans on spreadsheets, selected from breed stock according to predictive outputs from genotype databases and choices made on interactive pedigree charts on computer screens (cf. Holloway et al., 2009).

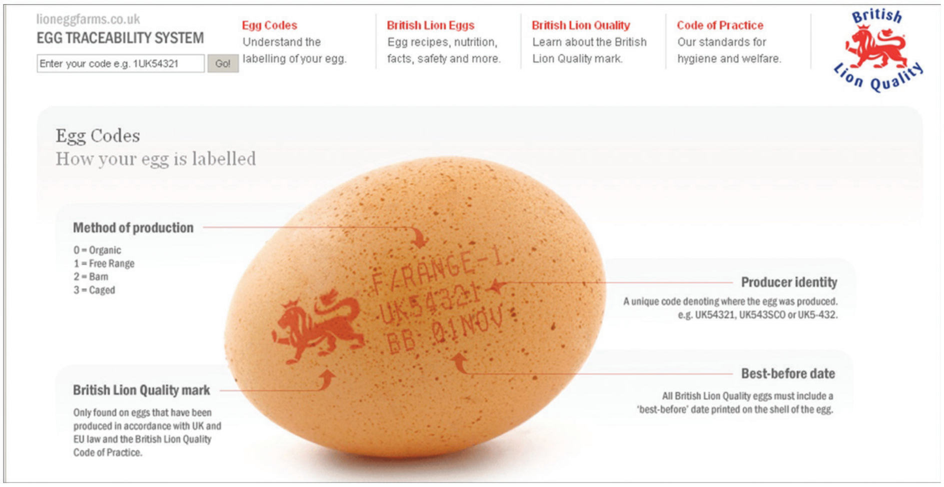

Figure 4.4 The web interface that allows consumers to enter the production ID code, laser-etched on the shell, to find out some details on the origin of their eggs. It is unclear how widely queried such public links to traceability databases are, or the degree to which the information provided helps reassure customers.

Dairy production and robotic milking

Daily farm practices relating to livestock rearing and the management of unpredictable animals and their changing welfare needs have been much harder to remake with automation compared to cereal production. However, there are significant efforts under way in the agro-industry to take code and apply it much more directly to animal husbandry, particularly through altering practices around milk production.

While significant mechanization of farm milking parlours has occurred over the last century to raise productivity and ensure greater hygiene of the milk, it remained a labour-intensive practice. This has changed with the advent of automatic milking systems (AMS), and companies selling the systems make significant claims that they offer the farmer greater control as well as labour savings (Holloway, 2007). In material form AMS are large robotic machines that literally envelop the cow and can conduct the whole milking process without human intervention or direct oversight (Figure 4.5). Their operation is dependent on code, particularly in positioning the electro-mechanical component smoothly upon the body of the cow, using inputs from its sensors. Code must also continuously monitor and respond appropriately to unpredictable events (such as 'kick-offs' when an animal's foot detaches the suction cups from its udders). Software algorithms controlling the machine are able to recognize the cow as an individual in the database, utilizing the sensed ID number in the radio collar tag, registering her current visit and

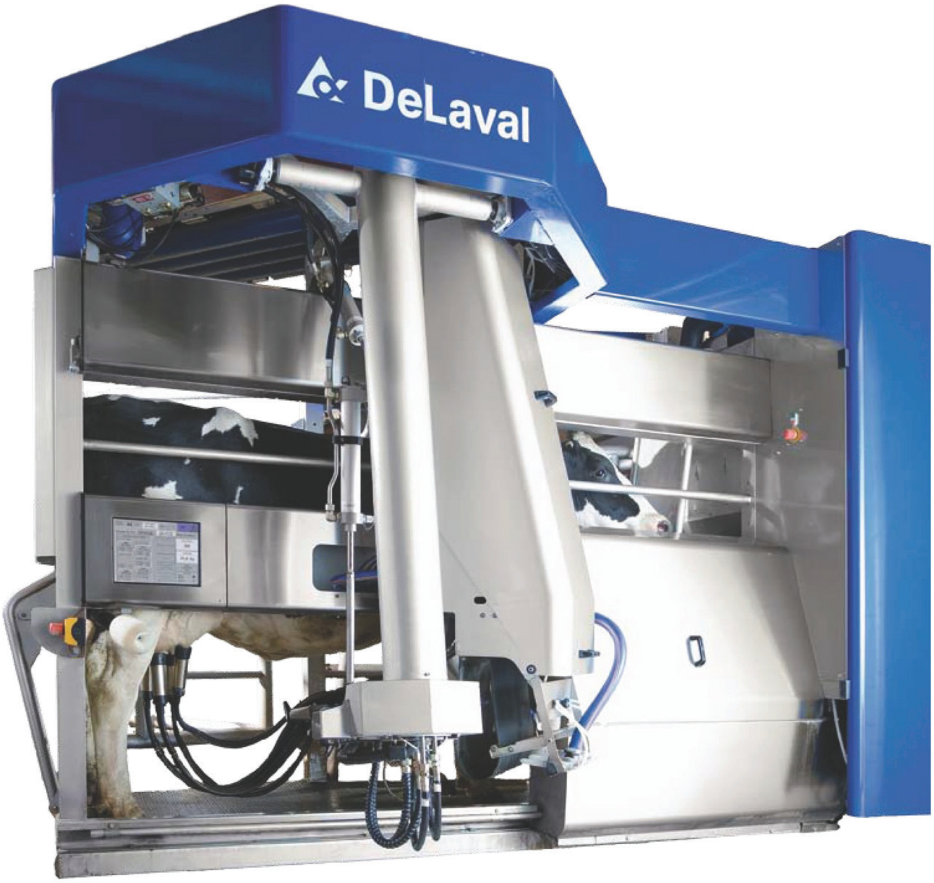

Figure 4.5 A typical automatic milking system. The cow is barely visible inside, although most animals are easily trained to accept the machine and the robotic processes. Courtesy of DeLaval A/S.

dispensing a calculated amount of concentrated cattle feed into the hopper to keep her contented during the ensuing milking. Her flow of milk is continuously monitored for quality, and the overall yield per milking is logged as part of the ongoing record of productivity. In other words, to be milked the cow itself becomes a very real code/space (Kitchin and Dodge, 2011). In doing so, the cow's space-times of activity are also altered as she gains a new degree of autonomy. The cow is no longer considered part of a herd, but an individual that is able to milk on-demand, being able to choose when to walk into the robotic unit, rather than driven *en masse* into the milking parlour at fixed times. In doing so, the individual logging of the cow's activity enables algorithms to flag atypical patterns that might indicate a health problem with that cow and alert the farmer to investigate.

AMS represent a substantial capital investment for individual dairy farming businesses. The marketing rhetoric from the manufacturers of AMS focuses in large part on the beneficial changes for labour practices of the farmer, promising to free them from a twice daily manual chore and allow them to devote more time to other aspects of the farm. Furthermore, the manufacturers also claim that AMS potentially improve animal welfare, providing a less stressful milking environment for the cow. However, it is unclear how reliably these AMS work in real contexts on different farms and to what degree dairy farmers must maintain a 'hands-on' role for mechanical breakdowns or faults in the complex software. It is also not clear to what degree farmers are comfortable in handing over so much control of their animals to code and simply monitoring activity through statistics on screens and updates sent to smartphones.

FUTURE FARMS AND SMART RURAL SPACES

The human population has nearly doubled from 4 billion to over 7 billion during the last forty years, and agricultural productivity, on a global scale, has kept abreast of these population changes in large part through the enrolment of more technology to intensify activity and raise yields (Godfray et al., 2010). Will farming be able to keep pace with population in the next decades as the number of people on the planet is projected to pass 9 billion before 2050 (Tomlinson, 2013)?

It seems likely software will take over more aspects of governance of rural space and play an ever larger role in primary food production. Aspects of 'smart' agriculture are coming (Wolfert et al., 2017), and there are serious schemes for developing fully automated farms that operate 24/7 without human intervention. Is this trend inevitable? It might not be a desirable trajectory to some, but it might be necessary particularly in respect of the overwhelming pressure to feed the millions living in the global megacities and the major threats to agricultural land from climate change. There have been calls for 'sustainable intensification' in agriculture

(Godfray et al., 2010) with the aim of maximizing global productivity and reducing the carbon footprint of farming. It is my contention that taking accounting of diverse ecological landscapes of production and the varying environmental and social justice outcomes will only be achievable by the greater use of smart techniques, digital sensors and data science; in many respects arable agriculture is better suited to fully autonomous vehicles and mobile robots compared to driverless taxis on crowded city streets.

However, the use of digital and smart technologies also brings a risk to the fundamental ecological sustainability of agriculture, and critics like Michael Pollan point out that enrolment of this technology is premised on trying to keep 'business as usual', which is a high-energy, hugely wasteful and grossly inequitable food system. It is also evident that much smart farming rhetoric is laden with techno-science hype and naïve utopian belief in technical fixes. For critics of intensive industrialized agriculture, there is an alternative farming future, and arguably the only viable and sustainable solution to feeding the world requires socio-political change in terms of fair distribution, waste reduction, ending subsidy regimes, and providing better support for organic systems and localized supply chains. This would be combined with a radical rethink of Westernised dietary behaviour (from excessive meat consumption to vegetable-based diets) and checking human population growth. Of course, one might question whether, in this alternative future, there would be much less need for digital technology or perhaps a reimagining of the use of software in progressive ways in order to help the wider food system rather than to boost the profits of a few self-interested parties. In this alternative future, digital geographers might examine how software is used to better connect local producers and to help share out resources, reduce food waste, and reconnect urban consumers to rural producers.

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