Country life: agricultural technologies and the emergence of new rural subjectivities

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Abstract

Rural areas have long been spaces of technological experimentation, development and resistance. In the UK, this is especially true in the post-second world war era of productivist food regimes, characterised by moves to intensification. The technologies that have developed have variously aimed to increase yields, automate previously manual tasks, and create new forms of life. This review focuses on the relationships between agricultural technologies and rural lives. While there has been considerable media emphasis on the material modification, and creation, of new rural lives through emerging genetic technologies, the review highlights the role of technologies in co-producing new rural subjectivities. It does this through exploring relationships between agricultural technologies and gender, changing approaches to understanding and intervening in animal lives, and how automation shifts responsibility for productive work on farms. In each of these instances, even ostensibly mundane technologies can significantly affect what it is *to be* a farmer, farm advisor or farm animal. However, the review cautions against technological determinism, drawing on recent work from Science and Technology Studies to show that technologies do not simply reconfigure lives but are themselves transformed by the actors and activities with which they are connected. The review ends by suggesting avenues for future research.

Introduction

Changes in agricultural technologies rarely seem far from public debate. Recently, genetic modification again hit the headlines following the UK Government's backing of an EU vote which could lead to the planting of weedkiller-resistant maize (Poulter 2014). Around the same time, the annual UK Livestock Event demonstrated technologies that aimed to automate aspects of livestock farming – such as milking and feed provision – and which promised increased real-time monitoring of farm animals. Meanwhile, the international policy agenda of 'sustainable intensification' promotes production systems that raise yields, 'increas[e] the efficiency with which inputs are used and reduc[e] the negative environmental impacts of food production' (Foresight 2011, 35; Royal Society 2009; USAID 2011). This has prompted debate around the desirability of 'ecocentric' (involving smaller-scale, locally-situated agriculture) or 'technocentric' (utilising new biological, informational, digital, environmental and mechanical technologies to permit more intensive agriculture) strategies (Robinson 2009, 1759) for food production. These developments, among others, have been widely discussed in terms of their environmental and economic implications, as well as their impacts on farm animal health and welfare. However, their social and cultural implications have been considered less widely.

In this paper, we explore some of these implications by reviewing recent work on geographies of agricultural technologies. Rural geography has a long-standing interest in technological change, particularly through a focus on notions of technological diffusion and the role of technology in driving and symbolizing modernisation. We concentrate on more recent work, which has explored how technologies are affective, are co-produced by their users and are co-constitutive of new rural

subjectivities. Subjectivity 'grounds our understanding of who we are' (Longhurst 2003, 283). While humanist geographers conceptualise subjectivity as 'contained within the body', enabling 'subjects to be self-knowing', poststructuralism has destabilised 'notions of a coherent subject' (*ibid*), arguing that 'subjectivity is not a given but rather a process and a production' (Probyn 2003, 294). This has stimulated a range of research in rural geography, which has explored how subjectivities are co-constituted by (for instance) changing rural economies, experiences of homelessness and the introduction of new technologies. This work also extends beyond humans, according animals 'a status as subjects', moving away from 'essentialising the subjectivity of farmed animals', engaging with the 'potential for them to *become*' (Holloway 2007, 1041).

This recent wave of research on rural technologies has been heavily influenced by geography's material turn (see Anderson and Tolia-Kelly 2004), which has encouraged a focus on material objects and their role in everyday geographies. While these roles might relate to the meanings objects are given by the humans (or non-humans) around them, other research explores how they are bound up in everyday practices, sometimes being seen to 'act back' (Thrift, 2000) and are not simply surfaces on which humans project their values and desires. In such a way, ostensibly 'human' geographies are never *just* human – they are 'more-than-human' (Whatmore 2006), with human and animal bodies, as well as 'technologies' such as machines, being conceptualised in Science and Technology Studies as 'hybrids' (Latour 1993) or 'cyborgs' (Haraway 1991). In other words, by being bound together in co-constitutive relationships, objects do not have clear, bounded, essentialised identities.

We begin by giving a brief overview of the trajectory of research on geographies of agricultural technologies. While much of this work has examined the diffusion of innovations at regional, national and international levels, recent work on technology and rural subjectivities that we explore in subsequent sections has often focused on the microgeographies of everyday practices. In the first such section, we discuss research that explores how gendered identities are constructed and

negotiated in relation to agricultural machinery, showing that performances and experiences of gendered identities are co-constituted by agricultural machinery, but also in relation to the transition from productivist to postproductivist rural economies. In the second, we examine how genetic technologies imply new ways of rendering animal life meaningful. The work outlined there also implies new geographies of expertise, where animals are known less through proximate embodied relations, and more as genes, in turn bringing about new spatial animal groupings. The final main section examines how new technologies of automation shift responsibility for work and care away from humans and towards animals and machines. Implicit here is the emergence of new 'beastly places' (Philo and Wilbert 2000), wherein animals and technologies do not neatly slot into spaces designed by humans; the technologies are not just mechanical objects but are embedded in, and co-constitutive of, social relationships, transforming through everyday encounters. We end by outlining the key implications of this research and suggest potential avenues for future work.

Geographies of agricultural technologies

Given the role of mechanical, chemical and biological technologies in the industrialisation of agriculture and the wholesale restructuring of agricultural production and food systems (e.g. Goodman et al. 1987; Goodman and Redclift 1991; Levidow 1996; Whatmore 1994), rural geographers' interest in agricultural technological innovations is not surprising. Such developments have been studied through various frameworks. Until recently, most research focused on technological *objects*, such as farm machines, viewing these as stable and fixed, rather than as mutable and manipulable. Associated with the notion of 'innovation diffusion', this field of research emerged in rural sociology in the 1940s (see Ruttan 1996; Cochrane 1958, Rogers 1983, 1995; Ruttan and Hayami 1973; Ward 1993), focusing initially on communication of information about innovations, and how communication networks facilitated, or restricted, innovation. These agricultural innovation studies took a geographical turn, following Hägerstrand's (1952, 1953)

seminal work, resulting in more attention being paid to technology transfer's spatial dimensions, often referred to as an 'epidemiological model' whereby innovations can be recorded as spreading out across space like an infectious disease. Viewing this strand of work as successful, many argue that research should continue to explore ways of extending innovations into commercial farming (Postlewait et al. 1993). However, such work ignores the diversity of life experiences in rural spaces (see Philo 1992: 200), regarding farmers who do not adopt as problems, and conceiving ways to overcome their resistance to new technologies (Rogers 1995, Ruttan 1996).

In contrast, other authors view farmers as active participants in processes of technological development and change. Busch (1978) and Winter (1997), for instance, explore ways in which farmers' knowledge and experiences affect how particular technologies are used in particular agricultural contexts, highlighting technology transfer models' limitations. In the following three sections, we explore more recent research in rural geography that has built on these ideas, focusing less on the movement of technological objects and the 'adoption' of innovations, and more on situated encounters with technologies conceptualised as emergent and becoming, co-constituted by their 'users' who, in turn, are co-constituted by the technologies with which they engage.

Technology, gender and the body

Since the 1990s, research has explored the differential experiences of various groups and individuals in rural areas in relation to age (Leyshon and Bull 2011), sexuality (Smith and Holt 2005), homelessness (Cloke et al. 2000) and gender (Little 2002a). Our specific focus here is on how technological developments can affect the constitution, experience and expectation of gender in rural places.

Much of this research has focused on images and constructions of masculinity. For instance, , Brandth and Haugen (2005) examined associations between a changing rural economy, technology and masculinity in Norwegian forestry magazines. Depictions of masculinity shifted from 'the sturdy working man' in the 1970s, to the 'young man with efficient and powerful machinery' in the 1980s and, by 2002, 'the tourist host' (Brandth and Haugen 2005: 20). While tasks associated with tourist hosts 'like caring for and being sensitive to other people's needs' might traditionally be connected to femininity, technologies remain significant in 'supporting the impression of masculine rural competence and activity' –objects such as skis, fishing rods and pick-up trucks continue to appear in spite of the shift towards a service economy (Brandth and Haugen, 2005, 19). Notions and experiences of masculinity, therefore, can take on new forms alongside technological change. In related work, Brandth (1995, 123) has examined relationships between heavy agricultural machinery, such as tractors, and 'a traditional masculine ideology', where tractors are a 'sign of male identity'. While others (Little 2002b, 2006; Whatmore 1991) have investigated the different roles played by men and women in rural places, Brandth focuses on the role of the tools used to perform these roles, arguing that they can be 'coded as either masculine or feminine and they help mark individuals as gendered subjects' (1995, 125). In part, Brandth's work focuses on machinery as 'signs', observing that 'there are no women to be seen in tractor ads, something which reinforces the status of agricultural technology as a completely male arena' (2006, 21). Indeed, Strategaki (1988, 256) goes so far as to label large agricultural machinery, such as tractors, 'the main criterion' for differentiating between the type of works that should be carried out by women or by men.

Extending beyond representations, other research has examined machinery's role in everyday *performances* of gendered identities. Pini (2005, 5), for example, suggests that women who exclude themselves from tractor work (in her case on Australian cane farms) 'protect and reinforce the masculine subjectivities of their farmer husbands as well as their own feminine subjectivities'. Brandth (1994, 128) approaches this issue in a slightly different way, asking howwomen who *do* use

heavy agricultural machinery 'create themselves as women, when they are breaking the gendered division of labor by doing the same work as male farmers.' Here, rural lives, identities and subjectivities are increasingly bound together as male farmers are expected 'to have "identical" qualities with the machine' (Brandth 1995, 132). While Brandth emphasises how machinery and its advertising change notions of what it is to be masculine, Saugeres (2002, 143) contends that 'male farmers use agricultural technology to reproduce and reinforce patriarchal ideologies which marginalise and exclude women from farming'. Technologies, therefore, not only transform relationships and subjectivities, but also are transformed and manipulated in themselves. In relation to the former, Saugeres's study found that the increasing prevalence of tractors in farm work has marginalised the contributions of farmers' wives. While male farmers in her study saw this change as a direct result of mechanisation, Saugeres contends that it is as much through men's 'appropriation' of the work previously carried out by women (2002, 148). Pini (2005, 6-7), building on Brandth (1994), takes these ideas further, showing how identities are negotiated around the use of machinery, suggesting five strategies that women adopted for undertaking masculine roles while retaining their femininity. First, some women tried to 'hide their involvement' to prevent their husbands from being 'labelled lazy or inefficient for relying on female labour'. Second, they emphasised 'the importance of their domestic and household role' as a reminder that, even if engaged in tractor work, their priority was domestic labour. Third, they distanced themselves from other male farmers and men on their farms, and from their performances of masculinities. Fourth, they consciously presented themselves to the wider non-farming public as 'lady-like in what they said', reinforcing 'a feminine identity' that 'on-farm physical work' had compromised. In the fifth strategy, women talked about tractor work simply as part of looking after one's business. In contrast to Brandth's (1995, 132) suggestion that 'the ideal of the strong, dirty, manual [male] mechanic is giving way to a more business-like masculinity', Pini highlights that the 'adoption of a farm as business discourse' can make working with machinery acceptable as part of a feminine subjectivity

In this section we have shown how developments in agricultural technologies are active in the re-working of gendered identities. Research here has highlighted ways in which expectations about gender roles in agricultural work are partly constructed in relation to discourses surrounding technological developments. Concurrently, this body of research has shown how such expectations are negotiated in everyday performances of gender, and how the meanings attached to machinery shift through these performances. It is partly through such technological engagements that particularly 'rural' forms of femininity and masculinity emerge (Brandth 1995).

Genetic technologies, bodily modifications and the re-making of rural lives

While the previous section showed how technological developments are often intrinsically intertwined with changing gender identities, the next two sections explore areas in which technologies affect human relationships with animals. Here, we focus on emerging genetic technologies, which affect not only how animals are understood, valued and acted upon, but also how farmers understand *themselves* in relation to new ideas about what constitutes a 'good' breeder.

Debates around genetic techniques in livestock farming have often been confined to 'specialist, scientific arenas' (Morris and Holloway 2014, 150) (in contrast to highly publicised debates around GM crops). Within these arenas, genetic technologies have been promoted as progressive, with those who resist their use 'represented as problematic obstacles to the modernisation of livestock breeding' (Morris and Holloway 2014, 151). In spite of limited public debate around many of these developments, research has explored the complex ethical, legal and social issues surrounding uses and effects of particular technologies (see Twine 2007, 2010; Macnaghten 2004). Much of this work responds to, and reports on, fears of particular publics about changes to animal bodies and their produce.

Other research has explored the circulation and application of genetic technologies in livestock farming, highlighting how they are enmeshed in, or even constituted by, complex relationships between different types and spaces of knowledge (for example, specialist scientific knowledge on the one hand, and 'lay' experiential knowledge on the other [see Wynne 1996]). In such a vein, Grasseni (2005), Holloway (2005), Holloway and Morris (2008), Morris and Holloway (2009) and Holloway et al. (2009) consider ways in which particular genetic technologies can be used by livestock breeders within breeding strategies. They explore why some breeders more willingly engage with these technologies than others, and how breeders who do adopt genetic techniques combine their use of specialist information with their own experiential knowledge of animals' quality and breeding potential. Such work follows Greenhough and Roe's call (2006, 417) to investigate 'non-expert, micro-scale knowings' of biotechnology – how techniques are negotiated through everyday practices and emerge differently in different spatial settings, rather than focusing solely on their lab-based development or their wider reception.

This research has especially explored discourses and practices around animal bodies' 'boosting' through genetic techniques – techniques that are increasingly ubiquitous, being used alongside or replacing longer-standing approaches in the evaluation of animals. Discourses of good breeding and pedigree have been prevalent in livestock farming since the eighteenth century (Calvert 2013), often focusing on breeding animals for particular characteristics (producing larger yields of milk or leaner meat, for instance). Conventional (non-genetic focused) breeding has placed emphasis on the visual assessment of animals. As Holloway and Morris (2008, 1714) note, 'this is associated with being in close proximity to that animal, and with having experience of many similar animals, and hence with an experiential and sensual knowledge-practice'. Emerging genetic technologies and associated knowledge-practices offer a potentially very different, less place-based and embodied, way of imagining, representing and developing life, whether through statistical techniques such as Estimated Breeding Values (EBVs) – which indicate 'the probability that an individual will pass on

specific heritable qualities to their offspring' (Holloway et al. 2009, 395) – or genetic marker technology, where 'actual genetic material [is associated with] a heritable quality, such as meat tenderness' (ibid). Both developments have a number of implications in relation to the emergence of new rural subjectivities.

First, they suggest a shift in the constitution and geography of expertise. For Holloway and Morris (2008, 1717-1718), this involves the increasing entanglement of 'places of evaluation,' such as animal bodies, farms and show rings, with circulations of knowledge and practice associated with 'laboratories, breeding companies, breed societies, texts and so on', which are often 'distanced from specific instances and sites of evaluation'. While their research highlights the continuing importance of farm-based visual assessments for many farmers (see also Yarwood and Evans 2006), they show how expertise is increasingly distributed across individuals, institutions and space. As such, the nature of, and expectations for, farmer-as-evaluator is changing in relation to these technological developments.

Second, then, as the nature of expertise shifts with the introduction of these new technologies, so many breed societies and commercial organisations attempt to 'constitute the identities of breeders…persuading them that in order to be "progressive", "forward thinking" farmers, then they need to adopt and work with the latest genetic techniques' (p. 1713). Although farmers do not adopt these technologies unquestioningly, their engagement with them leads them to be subjectified in new ways, working 'on themselves simultaneously with their work on their animals…inscribing discourses and practices of improvement and genetic "truth" onto breeders and livestock animals alike' (Holloway and Morris 2012, 66).

Third, therefore, this work has also focused on changing ways of imagining and intervening in animal life, exploring how genetic techniques affect the very constitution of 'life' in farmed animals. Life,

through conventional visual approaches to assessing animals for breeding, is 'an entire living body, known from an external appearance which, to the expert at least, tells something about the meaty interior lying underneath the skin' (Holloway and Morris 2008, 1714). In contrast, genetic technologies allow animals to be understood on the basis of their genetic attributes – 'life as genes' (ibid). This not only represents this life in new ways, but also produces new ways of intervening in it and imagining its futures. This new approach to breeding uses genetic data as the basis for decisions about which animals to mate and how to realise 'genetic potential' (Holloway and Morris 2008, 1714). Reaching genetic potential depends not on a single animal's attributes, but on the coming together of two animals in mating (or artificial insemination), along with 'successive generations as a gradual process of boosting bodies by making them more productive, disease resistant, etc.' (ibid).

Alongside the subjectification of farmers, therefore, these genetic techniques objectify livestock animals in new ways. New populations are constituted, 'associated with new processes of genetic relationality and corporeal management, and with trademarked tests for specific markers', rather than with reference to national boundaries or lines of pedigree, as might have been the case in conventional approaches to breeding (Holloway et al. 2009, 401).

Finally, these new techniques do not simply involve humans acting on animals. Holloway et al. (2014a, 134) develop Rabinow's (1999) concept of biosocial collectivities, which they define as 'social groups formed around particular geneticised truth discourses; members share, for example, a medical experience which is constituted in terms of a common genetic inheritance or abnormality'. Viewed thus, breed societies' employment of genetic techniques can act on both animals '(in terms of their corporeal characteristics) and the breeders (in terms of their judgements and decisions)' in their 'attempts to guide processes of breeding future generations of livestock' (Holloway et al. 2009, 403). The 'social group' in question here is not simply human, where those working in the agriculture sector intervene in the lives of cows. Rather, 'livestock breeding can be seen as a process of co-

producing humans and non-humans', emerging in relationships with particular technologies, sites and practices (Holloway et al. 2009, 405).

In this section, we have highlighted ways in which the emergence of new genetic technologies subjectifies humans in particular ways, while rendering livestock animals meaningful and governable through new modes of objectification. In contrast, the next section explores how emerging automation technologies on dairy farms imply the reworking of subjectivities for both farmers and cows.

Technology, automation and responsibilities for work and care

While developments in agricultural technology have long been associated with increased mechanisation of manual tasks, attention has recently shifted towards a so-called 'technological revolution' involving 'machines increasingly taking over jobs currently undertaken by people' (Driver 2013): driverless tractors (Williams 2013), robotic strawberry harvesters (Sigler 2012) and automated milking systems (AMS). Although many such technologies are not in widespread commercial use, AMS – often known as robotic milking – are increasingly common in dairy farming(Pugh 2011). Research reviewed here questions how these robotic technologies might change farmer-cow relationships, and examines the implications for the reworking of farmer and cow subjectivities.

A central difference between conventional milking systems and AMS is the (supposed) lack of need for farmers to herd up their cows 2-3 times a day and attach milking cups by hand. Cows are expected to present themselves to a milking robot, enticed by the presence of food, which identifies a cow by scanning a tag on her neck,determining whether she should be milked on the basis of how many times she has been milked that day and how much milk she has produced. If she is to be milked, the robot cleans her teats, attaches milking cups and begins milking. The robot concurrently

collects data about the cow, tracking productivity and indicators of health and welfare, such as milk conductivity (an indicator of mastitis), weight and food consumption. AMS is often presented as a necessary feature for progressive dairy farms – a brochure from one manufacturer, for instance, opens with the heading 'Preparing your business for the future' (Lely 2013, 1). As such, they might be characterised in terms of innovation diffusion and technology transfer, where robots are simply installed and adopted by farmers.

While some authors examine these developments in terms of the differences they make to farmers' routines and lifestyles (e.g. Butler et al. 2012), our focus here is on two specific issues: the promotion (and contestation) of AMS as offering 'freedom' to cows; and the associated issue of how these technologies co-constitute emergent responsibilities of care. AMS are frequently promoted by manufacturers as promising greater 'freedom' for cows, linking this to health and welfare benefits. As marketing material (Lely date unknown) stated, 'Freedom = happiness. More milk, healthier cows and a happy farmer'. While Buller and Morris (2003, 217) wrote that geographies of farm animals 'will always be largely constructed and confined by their human-serving functionality', the freedom rhetoric suggests the emergence of new bovine spatio-temporalities, co-produced by technologies and less directly by humans, and wherein cows are enabled to express their subjectivities.

Various theoretical frameworks have been adopted in approaching this issue, each viewing the subjectification and subjectivities of cows differently, though retaining a common starting point of questioning AMS's emancipatory nature. Stuart et al. (2013) identify four areas of 'alienation' in conventional dairy farming: from the product, from productive activity, from species being, and from fellow animals. They argue that, contrary to manufacturers' claims, AMS only offer limited advantages in these areas;any 'work performed in a profit-maximising animal agriculture system will inevitably cause alienation, exhaustion, and suffering' (p. 217). While their interviews with AMS farmers suggested that 'cows are calmer and less stressed by human presence' (p. 216) and that 'the

milking process demands less from the cow and is much less stressful' (p. 214), these features do not negate the negatives of, for instance, calves being separated from their mothers, coercing cows to be milked through provision of food and water, or limiting their involvement in the food system to the production of milk (p. 217).

Porcher and Schmitt (2012) similarly view cows as subjugated by the dairy production system, framing them as 'workers operating in the shadows, an ultraflexible underproletariat, exploitable and destructible at will' (p. 42). Conceptualising cows as workers, however, highlights their activity and agency, opening questions about the opportunities they have to choose how they perform tasks, and how they relate to each other, to people and to farm technologies. Porcher and Schmitt (2012, 43) thus argue that cows take 'decisions and initiatives; they facilitate or complicate the farmer's work'. Cows should not, therefore, be viewed simply as units of production, or as machinic; research might usefully question how cows 'invest their intelligence and their affects in [farm] work' (p. 55). Porcher and Schmitt (2012, 43) explore whether it can be said that cows 'collaborate' in a farmer's work, and what form this collaboration might take. Through observational work on an AMS dairy farm, they concluded that dairy cows 'work' through: investing 'their intelligence and affects in the activity of work'; collaboration between cows; the emergence of a 'collective intelligence' through work; and in adapting 'to the constraints of work' (p. 56) The cows carry out this work by developing group and individual understandings of how to engage with each other, and with each other in relation to the robot (*ibid*). For these authors, the cows in an AMS not only carry out work for farmers, but through this also carry out work *on themselves* (see also Holloway 2007), actively developing their subjectivities as they find new ways of engaging with each other, with farmers and with the robot.

Holloway et al. (2014a, 2014b) extend this perspective, questioning not only how cows are affected by their participation in AMS, but also how the robotic technologies themselves might be viewed as

'co-constituted' by the cows. Understanding these 'technologies' as more than just machines, they see users as contributing to the emergence of the technology rather than being regarded as passive recipients of an already-finished piece of equipment (see Oudshoorn and Pinch 2003). As such, they are interested not only in the everyday negotiation of agricultural technologies, but also in its continual transformation and re-making through associated knowledge practices. This moves the focus beyond the technological object itself to instead examine how it is bound up in social relationships. This is partly a question of how cows are subjectified in the design and installation of robots – how farmers and manufacturers, for instance, design the robots and barn spaces around particular expectations of what the cows can or should do. Following Law and Mol (2008), a 'cow' can be seen as subject to a series of overlapping 'enactments', whereby it is not only a physical body but also a computer model, a factor of economics, a member of a wider group of 'cattle' and a living being with which farm workers may develop close relationships.

Holloway et al. (2014a, 134), however, show that cows are enacted on an everyday basis 'within the framing of a particular technology and its "demands"'. For instance, cows' relative quietness in robotic (as opposed to conventional) milking barns led some farmers to describe their cows as 'happy'. In contrast, cows that did not present themselves to be milked as frequently as a farmer desired were referred to as 'lazy'. Here, cows are not simply cows, but individuals expressing their subjectivities in a range of ways, in relation to each other, the farm workers and technologies. This does not simply refer to labels applied to cows by farmers, but further encapsulates the different ways in which cows *use* the milking technologies. As such, Bear et al. (forthcoming) highlight some ways in which cows re-make barn spaces and robotic technologies – entering the machine in search of discarded food, for instance, in the process disturbing the careful measurements provided by the robot. The robots, in other words, are not simply a complete technology diffused from a manufacturing centre, but constantly transform through everyday relationships with farmers and cows. In turn, cows' interactions with the robot in part result from their position in a herd, with

more dominant cows for example gaining more regular access to the robots during the day, and less dominant cows entering more frequently at night. Nonetheless, rather than viewing such expressions of subjectivity as confirming the 'freedom' rhetoric of manufacturers, Holloway et al. (2014a, 138) show that cows' ability to make choices 'is countered by the re-capturing of bodies, performance and subjectivity'. It could be said, then, that 'freedom' comes with the cost of 'responsibility', and 'when cows are made responsible for attending the robot for milking, those who do not face sanctions' (Holloway et al., 2014b, 192). AMS, therefore, requires cows to care for themselves, but 'AMS collect, analyse, and represent more data on cows' behaviours and productivity than is normally available', allowing farmers to intervene in new ways in the lives of individual cows (Holloway et al. 2014b, 196).

Conclusions

In this paper, we have outlined three specific areas in which technologies impact on, and become intertwined with, rural lives, identities and subjectivities. Through this, we have sought to encourage critical scrutiny both on technologies' roles in agriculture, and on the very constitution of these 'technologies'. In this conclusion, we summarise key themes from this work and consider wider implications for future research on the geographies of agricultural technologies.

First, the review has highlighted that machines are never *just* machines. They are imbued with a variety of meanings, whether via their marketing, through discussions around them, or through their everyday use. As such, agricultural machinery is embroiled in social relationships that vary across time and space. Significantly, though, technology does not simply *hold* meaning; as we have demonstrated, technology is also *performed*. Second, therefore, we have highlighted how agricultural lives and technologies could be conceptualised as co-constitutive of one another. Co-constitution takes a variety of forms involving, for instance, farmers re-working their identities in

relation to the roles machines are given on their farms, the bodies of animals being represented in new ways as genetic technologies develop, concurrently changing relationships between breeding societies and farmers, or through the shifting responsibilities for productive work on dairy farms. By focusing on how technologies are employed, negotiated and performed 'on the ground', we have shown them to be combinations of technological artefacts and the knowledges and skills associated with them. Third, our interest in the co-constitution of rural technologies and lives has not been limited to human life. The research on genetics and automation in particular shows how humans, animals and technologies become inseparably intertwined (see also Holloway, Bear, Morris and Wilkinson 2014). The implications of this research extends beyond (ostensibly) easily quantifiable measures of 'animal welfare' and instead leads to complex questions around how relationships between individuals and groups of humans and animals emerge and might develop in relation to technologies in different times and places. Overall, therefore, we have outlined how rural geographers' focus has extended beyond the diffusion of technological objects designed to perform specific tasks towards studying how technologies work on, and are re-worked by, humans and animals, resulting in changing power relationships in the everyday performance of agriculture.

With policies on future food security increasingly focusing on technocentric approaches to production in, these topics have considerable currency, and the need to study their implications is all the more pressing. Nonetheless, much of the research on geographies of agricultural technologies continues to focus on innovation diffusion, and on attitudes to changing technologies, rather than on how these technologies play out on the ground, and how they co-constitute a range of rural lives and spaces. Although the topics covered here are significant in themselves, we argue that further research is needed to encompass a greater range of agricultural technologies. For instance, the limited existing work on relationships between gender and agricultural technologies has tended to focus on machinery such as tractors, but there is little beyond this (though see Bryant and Pini [2006] on the role of gender in the constitution of agricultural biotechnology). How, then, are

gendered identities re-worked through changing approaches to the monitoring and assessment of animal bodies that are implied by genetic techniques, and how might automation affect gender roles in everyday agricultural life? Second, while research on genetic technologies shows how they are not simply means of assessing animal bodies, actively re-working those bodies and the farmers who engage with them, future work might further explore how the animals themselves co-constitute the genetic techniques (see also Morris and Holloway 2014, 159). Third, then, we call for further methodological experimentation in research on agricultural technologies, attending more centrally to their everyday performance. In this, we follow recent work that has argued for a new set of 'more-than-human' methodologies (e.g. Lorimer 2010; Buller 2014), decentering humans in the study of heterogeneously populated places. While much of this work focuses on moments or periods of interaction between humans, animals and/or technologies, new technologies of automation act to remove human presence from farms, leading to new spatio-temporalities of agricultural life (see Bear et al. forthcoming). Future work would usefully explore the ways in which lives, machines and techniques continue to be re-worked away from direct human presence. The importance of these issues extends considerably beyond agriculture and any neatly-bounded 'rurality'. Nonetheless, rural geographers are well-placed to address them, continuing to develop their historical interests in changing agricultural technologies, contributing to their conceptualisation and studying their emergent role in the co-constitution of rural life.

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