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ARTICLES

Precision Livestock Farming and Farmers' Duties to Livestock

Ian Werkheiser[1]

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Abstract Precision livestock farming (PLF) promises to allow modern, large-scale farms to replicate, at scale, caring farmers who know their animals. PLF refers to a suite of technologies, some only speculative. The goal is to use networked devices to continuously monitor individual animals on large farms, to compare this information to expected norms, and to use algorithms to manage individual animals (e.g. via changes in climate, feeding, or reproductive decisions) automatically. Supporters say this could not only create an artificial version of the partially mythologized image of the good steward caring for his or her animals, but to also improve on it. As one paper in favor of PLF has said, "We can not only replace the farmer's 'eyes and ears' to each individual animal as in the past, but several other variables (infections, physiological variables, stress, etc.) will soon be measurable in practice" (Berckmans, in: Geers, Madec (eds) Livestock production and society, Wageningen Academic Publishers, Wageningen, pp 287–292, 2006). Yet these methods of monitoring and control raise a host of ethical issues, including alienation of laborers, further consolidation of farms, and further cover for meat consumption (a possibly independent ethical problem depending on one's views of eating meat). In this paper, I will address these ethical issues, and suggest a different, underexamined concern: namely, that though PLF may indeed improve the lives of livestock, and the sustainability of livestock operations, it is possible that it will do so at the cost of a loss of identity and relationships for farmers, as well as for the animals in their charge.

Keywords Precision livestock farming · Relational animal ethics · Livestock welfare · Values in technology · Ethical farming

✉ Ian Werkheiser
ian.werkheiser@utrgv.edu

[1] Department of Philosophy, University of Texas Rio Grande Valley, 1201 West University Drive, Edinburg, TX 78539, USA

Introduction

As agricultural production scales up, it faces a problem. While larger facilities benefit from economies of scale, farmers lose the ability to closely monitor their farm (particularly their livestock)[1] and make adjustments as needed. Practically, this is a problem because it cuts against farmers' sustainability goals. Ethically, expansion often makes animal welfare and welfare for human farm laborers more difficult to preserve. There is also a symbolic cost as the vision of a traditional farmer of whom Wendell Berry might approve, one who knows their farm and the animals on it personally and uses this information to be a good steward, recedes toward impossibility. This is a drastic, and likely unwelcome, change to a farmer's identity, and also has the possibility of changing the public's perception of farmers and farming, with possible policy implications. The harms that go along with a loss of attentive stewardship at scale is particularly likely to have significant effects in the case of livestock production, as animals move from being individuals known and recognized by farmers toward numbered but ultimately undifferentiated units.[2]

One potential answer proposed to this problem is Precision Livestock Farming (PLF) (Berckmans 2014, 2017; CEMA-AGRI.org). PLF refers to a suite of technologies, some only speculative. The goal is to use networked "smart" devices to continuously monitor individual animals on large farms, to compare this information to expected norms, and to use algorithms to manage those animals (e.g. via changes in climate, feeding, or reproductive decisions) automatically. This promises to allow modern, large-scale farms to replicate and even to improve on the benefits of caring farmers who know their animals, transferred to a much larger scale. Advocates of PLF point to the ways it might address the problem of scaling farms (ibid.), but PLF also raises a host of ethical questions. Some of these questions are shared by many advances in technology in any industry and particularly in agriculture. Some other issues, however, are less common, because they center on the ways in which PLF technologies might in fact fail to replicate the relationship between farmers and livestock in important ways.

In the section two of this paper I will discuss PLF and its promise to address many of the problems in modern livestock production, including sustainability and animal welfare issues. In section three, I will discuss ethical concerns about and potential problems with PLF that are exacerbated with this new suite of technologies, but that are not unique to it. In section four, I will discuss relationships between farmers and livestock. The preservation of these relationships is one of the promises of PLF, but, as I will argue, the nature of PLF technologies may render this impossible. I will then briefly look at what this all might mean for

[1] In this paper, I will focus on livestock farming. There are other kinds of precision farming, but the arguments for how that technology, plants, and farmers interact are different from how PLF, livestock, and farmers do.

[2] Except when drawing a distinction between humans and other animals, I will mostly refer to non-human animals in this paper as "animals," or even "livestock," but this is for ease of reading and to maintain congruity with the literature, rather than a reflection of some metaphysical commitment. Though it reads better, it is worth being aware of, and acknowledging, the category error in contrasting humans and animals.

the future of livestock production. Ultimately I will argue that while PLF may indeed improve the lives of livestock, and the sustainability of livestock operations, it is possible that it will do so at the cost of a loss of identity and relationships for farmers and the animals in their charge, as both human and non-human animals are further alienated from the farm and each other by these technological developments.

Precision Livestock Farming and Its Promise

The term PLF is sometimes used interchangeably with IMS (Integrated Management Systems) applied to livestock. When they are differentiated, PLF refers to those systems that try to monitor in as fine-grained a way as possible (hence "precision"), with the ideal being constant monitoring of *each individual* animal on the farm. The more fine-grained the observations in PLF, the more efficacious it can be. Thus, there is a motivation to observe individual animals over pens or buildings or entire herds, because individual animals may need more food than average, or may be sick when others are not and need medicine. A host of other individual idiosyncrasies can be accounted for with individualized PLF. Using the terms "SmartFarming" or "Smart Animal Farming" has also been suggested, because PLF might be seen as the domain of engineers rather than farmers, leading to difficulties in dissemination and uptake (Lehr 2014). For the purposes of this paper, however, I will continue to use the most common term.

Another way to look at PLF is as the application of process engineering—the purposeful design and optimization of production processes—to dairy, egg, or other agricultural production. Process engineering, when confronted with sets of interconnected processes under independent open-loop control—in which the output is not measured and automatically fed back into the system as an input—as is found on a farm, tries to manage the process holistically by integrating the controllers and putting as many of them as possible into closed-loop control—in which the output is automatically fed back into the system (for an example of this in IMS for broiler chickens, see Frost et al. 2003). To do this effectively, process engineering emphasizes the value of data at all points along the production process to allow for feedback and useful modification. In particular, process engineers focus on those aspects of a process that are most crucial to the success of the process, as well as those aspects that have the most problems.

On a farm with livestock, the aspects of the system that are most crucial, and most prone to problems in terms of regulation, are the animals themselves. Animals are what process engineers call CIT systems—Complex, Individual, and Time Variant. As a result, in order to adequately address those systems (the animals) it is necessary to continuously monitor them over time for change along a wide variety of variables. It is also necessary to develop algorithms that can use the states of those variables at any one time-slice to reliably predict future states of those variables. Finally, it is necessary to be able to intervene in those variables in order to alter future states (Berckmans 2006; Wathes et al. 2008). For example, for a CIT system like a pig, it is important to be able to monitor variables like temperature over time, perhaps by having temperature sensors in the pen, as well as by sensors

on and in the pig, to measure surface and deep body temperature. It is also important to be able to use the pig's current temperature to predict the pig's future temperature, as well as her respiration, need for hydration, heart rate, and so on, and to be able to intervene if necessary by lowering or raising the temperature in the animal's stall to get her to a temperature that is predictive of better health and welfare. These observations, judgments, and adjustments could be made by humans, either in person or using monitoring technology. Indeed, PLF advocates often stress the possibility of access by farmers, for example by promoting an app for their phone that allows them to monitor individual animals or stalls in addition to overviews of their entire operation. However, the logic of process engineering pushes toward ever-increasing automation. An automated system can respond more quickly to temperature changes, and can handle essentially an unlimited number of animals given enough computational power. More interestingly, decision algorithms can learn over time to make predictions and connections between variables that humans might not ever see.

Temperature is an obvious example, but we can perhaps more easily see the variety of potential benefits of PLF if we look at feeding. Pomar et al. (2009, 2011) point out that individual pigs differ greatly in terms of feed requirements depending on their age, but also depending on individual idiosyncrasies. The common solution to this problem is to feed pigs at or near the requirement level of the pigs who need to eat the most. This leads to unhealthy pigs, environmental damage from increased methane and nitrogen production in the pigs' waste, a loss of profit to the farmer due to the purchase of unnecessary feed as well as the loss of potential weight from those few pigs who needed more than was provided, and a lower quality of meat at slaughter for the consumer (also further lowering the profits of the farmer). While this might suggest that farmers ought to feed their pigs at an average amount instead, this is unlikely to be adopted by farmers (unless it can be shown that the savings more than make up for the loss in weight gain, and by enough of a margin to overcome biases toward increasing production rather than efficiency). Even if pigs were fed an average amount, this would still be too much food for some, and not enough for others—an example of the common situation in which outliers create welfare problems. On the other hand, if pigs were fed with PLF technologies at the precise amount each one needs, those welfare problems could perhaps be avoided (ibid).

Engineers are working on developing new metrics in this field, thanks in no small part to interest and support for PLF from industry and the EU, as well as technological improvements resulting in more precise and accurate automated controls for making the required measurements and adjustments. Other proposed measures include biosensors to detect pathogens in the air or the stool, microphones to pick up vocalizations, electrodes to detect skin conductivity and heart rate, automatic scales combined with volumeters to measure lean-fat ratios, pedometers to predict estrus, cameras to detect position in stalls, olfactory receptors to detect illness, and so on. This list is by no means exhaustive. Along with advances in sensors and controls, there is also rapid development in predictive models, as computer engineers combine learning algorithms with bigger data sets.[3] In order for

[3] For some examples of PLF in practice, see Berckmans (2014) and Vranken and Berckmans (2017).

PLF to work, there also needs to be targets for the system to work toward and maintain, as well as trajectories for reaching them. Setting these targets and trajectories appropriately requires close communication between engineers, farmers, and animal health and welfare experts. Values such as economic efficiency and profitability, the various kinds of animal welfare, environmental effects, quality criteria for the product, and so on all must be put into terms of measurable metrics, and targets must be assigned (Wathes et al. 2008).

Practically, these technologies facilitate sustainability goals, such as minimizing environmental impact, minimizing wasted inputs and thereby maximizing economic efficiency, maximizing food safety, and perhaps most importantly maximizing animal welfare. As I mentioned above, the EU has been very supportive of PLF research, which is seen as a way to meet the increasing global demand for animal-derived products, as well as to overcome the difficulty of economically sustaining farms in many parts of the EU, which are under pressure due to factors like high labor cost and the need to meet increasing environmental quality standards. In this way, PLF promises to allow livestock farming to continue in the EU as an economically and legally viable proposition. Without some intervention like PLF, there is a risk of substantive food production moving entirely out of Europe, and European farms being relegated to sentimental relics. That PLF promises to preserve farming while recreating an artificial version of the semi-mythic image of the good steward caring for their animals makes it understandably attractive to many in the EU who value farming and farmers.

Moreover, beyond replicating the traditional steward farmer, the rhetoric around PLF promises to *improve* on this model. This could be done via closer monitoring than farmers can provide to even a few animals, as well as integration of the data via decision algorithms that improve on the guesswork of traditional stockpersons. As one paper in favor of PLF says, "We can not only replace the farmer's 'eyes and ears' to each individual animal as in the past, but several other variables (infections, physiological variables, stress, etc.) will soon be measurable in practice" (Berckmans 2006). Another points out: "Traditionally, livestock management decisions have been based almost entirely on the judgement and experience of the stockperson who has to estimate or guess the likely effects of any control action, taking into account the complexities of the processes involved. This leads to dilemmas" (Frost et al. 2003). After listing the unexpected connections between management decisions a farmer or stockperson might miss, the paper goes on to say that "These connections need to be strengthened and formalised through the development of integrated management systems, designed to control simultaneously more than one, and ideally all, interrelated processes involved in livestock production" (ibid.). A special report by the UK Farm Animal Welfare Committee states: "Precision farming, such as telemetry boluses to measure rumen pH, can detect nutritional acidosis at a subclinical level not apparent to the stockman" (FAWC 2016).

It is also possible that, in terms of animal welfare, less contact with humans would be an improvement for some farm animals. Animals that are not accustomed to regular contact with humans can react with fear to human presence. This has led some to argue that farm animals see these interactions as they do interactions with

predators (e.g. Suarez and Gallup 1982). This might argue in favor of acclimatizing farm animals to human-animal interactions at a young age, as happens on small-scale farms, because acclimated animals can benefit from interactions with humans with whom they are familiar, and can be acclimated generally to human contact, even leading them to seek it out (Waiblinger et al. 2004). But when this is rendered impossible due to the size of the farm, occasional and abrasive interactions with humans can produce fear in the animals. This is a welfare harm, as well as a harm to production for many animals, and potential harm to stockpersons from injuries (Munksgaard et al. 2001). All of this can be minimized via PLF.

Some Ethical Issues in Precision Livestock Farming

These methods of monitoring and control hold promise, but they also raise ethical issues. One such issue is the further consolidation of farms, as only those concerns with the capital to invest in PLF can benefit from the "technology treadmill" of ever-improving PLF technologies (see, e.g., Thompson 1988; Nowak 1997; McCune 1998; Röling 2009). This is a common problem in modern industrial agriculture, and has sometimes been mitigated by using tax subsidies to allow farms with less capital to make improvements, but that solution brings up its own ethical and practical issues.

Another ethical concern for PLF is the problem of prioritizing values. Earlier, I mentioned that multiple values have to be incorporated into the targets and trajectories for PLF. Of course, those values can often come into conflict with one another. Profit and environmental qualities are at least at times a zero-sum game, and there is debatably a conflict between environmental protection and animal ethics.[4] Even different conceptions of animal welfare can sometimes not be mutually maximized, such as when we must weigh bodily health against species-typical behavior.[5] How these values are reconciled when possible, or prioritized over each other when not mutually realizable, is a longstanding problem in ethics.[6]

A third potential issue is the loss of jobs on farms and the "de-skilling" of those jobs that remain.[7] PLF requires fewer employees, and those jobs will no longer require many of the skills current ones do, as livestock monitoring and care are increasingly automated. The loss of jobs in animal production is a complex issue. The loss of any kind of job to technological developments and the increasing simplification of the remaining jobs can be seen as an inevitable tragedy, or an avoidable harm, or a neutral reconfiguration of the economy, or an on-balance good, depending on one's views on economics, technological development, and so on. Farm labor and a connection to food production in particular are often seen as important (e.g. Thompson 2010, 2017), and so it might be especially bad to lose those jobs, for both the individual and society. That said, there are also possible

[4] For a sample of this debate see Sagoff (1984); but compare Varner (1998).

[5] For a discussion of the different conceptions of animal welfare, see Thompson (2015, 137–142).

[6] For discussions of this problem particularly looking at PLF, see Wathes et al. (2008) and Lehr (2014).

[7] For an early discussion of this extensive discourse, see Heffernan (1972).

mitigating factors and considerations that might change the calculus. One such potential mitigating factor is that job loss could be balanced with the possibility of those fewer, less traditional jobs also being less physically demanding, as well as the addition of at least a few technical jobs on farms to install, program, and maintain PLF equipment.

Another consideration to keep in mind is the possibility that the lost jobs were ones that harmed animals, and they are replaced by a system that (potentially) harms the animals less. If this is the case, we might look at this as an on-balance moral good; we might even think that we should not see the loss of jobs which involve harming others as a moral bad at all. While I am sympathetic to this view, it would only be the case if jobs working with farm animals were necessarily harmful to those animals (over and above the eventual slaughter of the animal, since that is still the animal's lot under a PLF system). If we think that farmers and stockpersons interacting with livestock can be beneficial to the lives of those animals, even if in current operations they frequently are not, then losing those jobs *rather than transforming them* could still be a regrettable loss.

A final potential ethical issue in PLF worth discussing, and related to the concern expressed above, is the cover it provides for the consumption of animal-derived products, as large-scale industrial livestock production is once again given the romantic veneer of close attention to animal welfare. PLF, after all, includes monitoring animals as they go through slaughter, butchering, and packaging in addition to animals alive on farms producing milk, used for services on the farm, and so on. Whether improvements to animal welfare before slaughter or during exploitation (which might further encourage animal consumption) is an unalloyed ethical problem, or an unalloyed benefit, or a mixed tradeoff, of course depends on one's views on the consumption of animal-derived products as well as one's opinion on the strategies of abolition or amelioration.[8]

These concerns are serious, but as is indicated by the dates of some of the citations in the above paragraphs, they are fairly standard problems for many technological innovations around large-scale livestock production, albeit ones that are exacerbated by PLF technologies. In the next section, I will look at relationships involved in farming with animals. In addition to its other benefits, PLF promises to preserve these in something like their traditional form while allowing farms to change to meet modern realities. Unfortunately, this may not be the case.

Relationship Issues in Precision Livestock Farming

As was mentioned above, some people fear that the term PLF will be a hurdle to adoption by farmers, which has led to the suggestion of "Smartfarming" and similar terms instead, so that they will see PLF as something related to farming and something farmers can and should participate in, rather than as an arena for engineers working independently. In this section, however, I will look at the

[8] For different perspectives on this question, see Cole (2011), Haynes (2012) and Thompson (2015, 130–158).

possibility that this resistance is not merely a misapprehension by farmers based on an unfortunate name, but rather that they might be right to think that PLF is a technocratic approach to farming, one that undercuts "farmer" as an identity and their relationships with the livestock on their farms.

First let us look at the possible threat PLF poses to the relationship between farmers and livestock, and the obligations and responsibilities inherent to that relationship. One way to look at this is to think about famers' particular duty to listen and attend to the livestock on their farms *themselves*, and the degree to which PLF might or might not serve as a viable stand-in. Palmer has argued (e.g. 2007, 2010) that we have special obligations to domesticated animals. This is true for animals placed into relationships of dependence on and vulnerability to us, and it is especially true for those animals (such as many species of livestock) that have been created through breeding to require our care. Responsibilities arising from dependence and vulnerability on the one hand and those arising from us bringing creatures of this type into existence are two different forms of responsibility, but they are complementary, at least in cases of domestic animals.[9] As Palmer says, it can both be true that "humans have special duties to animals on the grounds that animals possess morally significant interests and that they are vulnerable to humans, both individually and collectively" (2007, 198) and that "The deliberate creation of a dependent morally considerable being brings obligations to provide for that being" (ibid). When farmers purchase or breed animals, particularly ones that could not survive on their own, they are responsible for them and have certain duties of care that they must discharge.[10] This may sound improbable, but it is not unlike many people's intuitions about a parent's duties to their children: children are vulnerable to and dependent on their parents, their parents (often) deliberately created those vulnerable and dependent children, and have taken responsibility for them. Those parents have special duties to their children, perhaps as a result. As Burgess-Jackson says:

> It is the *fact* of vulnerability, therefore, conjoined with causal responsibility for that condition, that generates moral responsibility. It is not, I hasten to add, that parents contract with their children to respond to their children's needs, for infants and children are incapable of contracting. Nor is it that the parent is related to the child genetically, for we would (and do) say the same about the responsibility of those who adopt children as about those who conceive and bear their own. Simply put: If you believe that a parent is responsible for his or her children, then, by parity of reasoning, you should believe that humans are responsible for the animals they bring into their lives. (Burgess-Jackson 1998, 170).

This analogy with parenting has something of a history in philosophical literature (see, e.g. Burgess-Jackson 1998; Francis and Norman 1978; Goodin 1985, 11; Palmer 2007, 198; 2010, 109). It has been used by some of these scholars to argue

[9] The case of our responsibilities toward wild animals is more vexed, and beyond the scope of this paper. For a look at it within this framework, see Palmer (2007, 2010)).

[10] Note that this is true regardless of whether one thinks those animals should have been brought into existence in the first place.

for differentiated, individual responsibilities particular humans have to particular non-humans, though this it is usually used when discussing companion animals. The only reason I can see for not applying it to stockpersons is that they generally do not have much of a "companion" relationship with their livestock (though it is still the case that they acquire them or bring them into the world and assume responsibility for them, with some duties attaching as a result). However, the point I am suggesting is that traditional, small-scale farmers are better able to perform their responsibility to provide attentive care to the relatively few animals on their farm.[11] That these farmers are more likely to approximate a companion relationship with the animals in their charge (naming them, differentiating them based on personality, etc.) is to be expected. They may well not perform those responsibilities of course; animal abuse can certainly exist on small-scale, traditional farms, just as abuse can exist in families with a few children or only a few companion animals. As in those latter cases, however, it seems clear that greatly increasing the number of dependent beings does not eliminate the potential for abuse, and raises a new hazard of farmers abrogating their *individual* responsibilities.

The analogy with parenting is also suggestive, because we tend to see at least some of those parenting duties as individual to the parent, and not ones that can be discharged through outsourcing to others, nor to technology. A parent who is not attentive to their child's needs and preferences, but instead has them met by others or by some series of highly complicated combination of algorithms, sensors, and environmental controls, seems to be open to the charge of being not a very good parent, and perhaps an irresponsible one. This is in part, of course, because children have needs beyond mere physical ones, including the need for individual attention. It is also in part because we would probably be quite skeptical that this series of controls would be as good as an attentive parent in seeing to the child's particular physical needs. It is also, however, in part because we see them as not exhibiting the right kind of caring attitude.

Even if one were to ignore the available data about non-physical needs in non-human animals, which has been available since at least Harlow and Zimmerman (1959), the second and third concerns are still relevant. If this analogy can hold, then it might also be the case that some of the duties and responsibilities of a farmer include being personally attentive to their animals in a way that cannot be fully outsourced to employees or to technology. As Burgess- Jackson says, "*individual* humans, by acting in certain ways, incur responsibilities to *individual* animals" (1998, 164). If this is right, then it provides a reason to think that livestock operations scaled past the ability of anyone to attend to the animals themselves raises ethical concerns, and is perhaps irresponsible. It might even be the case that PLF is *worse* in this respect than conventional large operations. It is possible (though certainly not common) to have enough stockpersons to work reliably on a subset of the total livestock population, so that they come to know those animals

[11] Note that this responsibility on the part of farmers could be justified by animals possessing particular rights, or it could be justified by non-rights-based welfare considerations such as some inherent value of the animals, an inherent disvalue of pain, etc. It could also be partly justified by various virtues we want farmers to have, such as careful stewardship. One advantage of this framework, in fact, is its flexibility or over-determination of justification.

with whom they interact regularly. If one accepts the parenting analogy and if one thinks that a nanny would be preferable to biofeedback programs as a parenting strategy, it could also be the case that human laborers are better able to discharge a farmer's duties to his or her animals than PLF.[12]

Note that in this framework, the farmer fails to uphold his or her duties even if PLF does an equal or perhaps even a superior job of attending to the animals. If farmers have the duty to pay attention *themselves* to the livestock in their charge, and to care for them, and if PLF is defined as "A discipline where farmers, engineers, biologists and economists work together to achieve the best possible results" (Lehr 2014), then the question arises as to whether the farmers are collaborating in a way that still allows them to discharge their duties of personal responsibility (as a parent who gets advice from doctors or teachers may be), or whether they are failing to fulfill their responsibility (as a parent who leaves his child excessively in the care of others or abrogates all decisions may be). That said, there are also reasons to suspect (*contra* the claims of superior sensitivity made by some PLF advocates) that some of the communication signals farmers and stockpersons rely on might not be incorporated into PLF, resulting in worse welfare outcomes for livestock, in at least some respects.

The technologies of PLF are engineered with built-in assumptions both about what information is relevant to animals' wellbeing, as well as about what relevant information animals can provide to farmers.[13] Some of these assumptions may get embedded in those technologies by engineers unfamiliar with livestock management operating independently, but it is also quite possible that some of these assumptions are embedded (either intentionally or unintentionally) after close consultation with farmers. It is also quite possible that as PLF develops there will be more incorporation of farmers' needs and values. None of this removes the concern that what can matter to animals and what signals animals can send about them may be underestimated. Stockpersons themselves may well be unaware of some of the signals they receive from the animals in their charge, and so may well misreport what information they use to engineers. It is particularly likely that the scientific context of consulting with engineers about technology development will make it less likely that farmers and other stockpersons will be aware of, or report, communicative aspects of their relationships with animals or what they perceive those animals to care about. In part, this may be because such reports seem subjective and emotional, and the interviewee may find these embarrassing to tell

[12] One may well wonder at this point—do farmers almost invariably fail in their duties in this analogy because they send their charges off to be slaughtered? Relatedly, do farmers almost invariably fail in their duties in this analogy because they conceive of these animals as "livestock"? Presumably we would think that parents or pet owners were wildly derelict in their responsibilities if they needlessly sent their charges off to be killed and thought of them in these terms. I am quite sympathetic to this line of argument, though there are those such as Portman (2017) who explores farmer responsibility toward animals in the presence of their possession and incorporation. A full exploration of whether these responsibilities require veganism or vegetarianism is beyond the scope of this paper; instead, if the farmer/parent or farmer/pet owner analogy holds, one should say that farmers *at least* have responsibilities of care to their animals while those animals are alive.

[13] For a discussion with a different emphasis, but which shares the worry here of a potential distortion of animal welfare via PLF, see Wathes et al. (2008).

the engineer.[14] It also may be because some of this sensitivity to animal communication could be a form of tacit knowledge that is sustained and passed down through working with more experienced stockpersons without being explicitly articulated or consciously believed. If this is the case, it is unlikely that this tacit knowledge would be articulated and incorporated into technocratic solutions to livestock problems.[15] All this can potentially lead to innovations that miss avenues for animals to communicate their individual needs and personalities, thereby limiting the ways in which those animals can influence the system to be more in-line with their preferences and welfare.[16]

To pick a slightly hypothetical example, assuming that small changes to the facial muscles of cows can be a way for them to indicate stress, it is quite possible that this will be ignored as a way for cows to communicate. Such an assumption could be made by engineers who are not sufficiently intimately familiar with cows, but it is also possible that farmers in consultation with engineers and scientists would be reluctant to discuss how cows "looking sad" is something to which they pay attention.

On the other hand, advocates might argue that it could be possible for PLF technologies to increase animals' ability to improve their own welfare if they embed assumptions of a high level of animal autonomy and communicative capacity. For example, CEMA, the European association representing the agricultural machinery industry in Europe, advocates PLF on their website. There, they say that among other benefits (including of course increased productivity, but also the ability for farmers to receive updates about their herd via SMS), PLF's "Automated solutions operate without the limitations and constraints of human labour and thus provide more freedom for animals for self-determined, species-appropriate behaviour" (CEMA-AGRI.org). Though CEMA does not elaborate the point or provide a specific example, it offers promising potential. Stuart et al. (2013) argue that one form of alternative dairy production employing high technology to replace the judgment of farmers decreases (but does not eliminate) alienation of the cows from their labor. The technology in question is robotic milking facilities, where cows can choose to be milked whenever they wish, and are rewarded with a treat. The authors suggest that this technology allows the cows to have more autonomy and participation in the decisions affecting their lives. This technology is like PLF in some ways, as it replaces the need for human attention and judgment, but it also

[14] See Jensen (2004) for a discussion of the phenomenon of denying our communication with other animals and our intuitive opinions about their mental states.

[15] For some background on tacit knowledge and the difficulty of maintaining it through technocratic innovation, (see, e.g., Bresnen et al. 2003; Gertler 2003; Polanyi 1966).

[16] One way to understand the harm of not listening to animals, over and above the ways in which it may directly reduce their welfare, would be to see it as a kind of "epistemic violence" in silencing them. If silencing is defined as refusing to take up the testimony of others by reliably ignoring them as a source of testimony, it is surely the case that, as Dotson (2011) points out, this ignorance is sometimes justified, as when a three-year-old is not allowed to vote. Sometimes our ignoring non-human animals as speakers is justified in this way. However, the analysis of whether ignoring is pernicious requires context-sensitive understandings of power relationships and harms (ibid.). When we do not listen to animals expressing dissatisfaction or pain because it would be inconvenient to respond to it, it is difficult to see this as anything other than epistemic violence.

differs from PLF, as it does not attempt to recreate that attention and judgment. However, it does illustrate the possibility that technological developments *like* PLF could be an improvement to animals' participation in choices about their lives over modern, industrial farming approaches that treat animals as average group member with averaged needs, and perhaps even over small-scale, traditional farming.

The degree to which PLF can be an improvement in animals' participation and autonomy, or the degree to which it will further silence them, would depend heavily on the values and assumptions built into the technology in the first place. In this way, it resembles technological developments in the (human) workplace, which can either increase or decrease worker autonomy. The literature in this area could be a useful resource for researchers working on PLF, but only if this concern is recognized. To do this, we would have to overcome our tendency to deny and silence the voices of animals, ignoring the ways in which they could tell us things and take a role in determining their own lives. This is a high hurdle to overcome. One tool in doing so might lie in that romanticized image of the farmer as attentive steward who knows his or her animals as individuals. Reinforcing the ways that the semi-mythic farmer works *with* animals, *listens* to them, and builds a farm around the idiosyncratic needs of *particular* animals (for example, perhaps this could be discussed in a narrative at the beginning of a consultation between farmers and engineers about PLF technology) could make space for farmers to think of, and share, the many ways their animals let them know what they want and what they do not want. This could help engineers find ways to promote this communication rather than hinder it. PLF is in its early days, particularly in the US, and so there is still much that remains to be seen about its application. But as with any new kind of technology, those values and assumptions that are not discussed and considered critically will be built in unreflectively, and may well miss something important. When technology is applied at a massive scale as it can be in industrial agriculture, these lacunae can impact millions of lives. Unfortunately, even if PLF is set up to increase sensitivity to animals' needs and preferences, that still does not guarantee that it will achieve the goal of preserving, scaling, or improving relationships between human and non-human animals in livestock operations, and fulfilling the duties that attend those relationships.

Conclusion

If the concerns in the above sections of this paper are borne out in the further development of PLF, it could still be the case that the technology should be pursued regardless. If PLF can minimize environmental impacts of farms, improve their economic sustainability, improve the welfare (by at least some metrics) of livestock and laborers, minimize the spread of diseases that might jump to humans, and so on, then there might be strong on-balance reasons to develop and implement it. However, in that case one of the most common arguments for PLF—that it helps farmers be better farmers in the traditional sense even on very large operations—would be wrong. As I said in the Introduction, in conventional large-scale livestock operations, animals move from being individuals known and recognized by farmers

toward numbered but ultimately undifferentiated units. This is a failure by farmers to perform the responsibilities they themselves have to the animals in their care; responsibilities that traditional farmers perform through particular relationships with individual animals. Unfortunately, in PLF operations, an animal is still likely to change from an individual recognized by humans, but this time to a collection of data points and a CIT system: in other words, to numbered units that are differentiated, but not individualized.[17] Something similar can be said of farmers. To the extent that having a personal, attentive relationship with the animals on your farm is not merely laudatory but actually constitutive of being a farmer, scaled-up PLF could erode their identity as well. Thus the goal of using PLF to preserve farmers could ironically lead to the final nail in the coffin of that job and identity.

On the other hand, PLF is a suite of many different technological innovations. Some of them, if used on a small farm with a few animals, could aid the farmer and other laborers there to better attend to their responsibilities and duties of attentive care to the animals in their charge. To go back to the parenting analogy, it is unlikely that parents using a baby monitor to help them keep tabs on their sleeping children, in addition to their regular parenting duties, are being less responsible parents. Thus, it seems we are left with a version of the problem at the beginning of this paper: it is unclear how we can reconcile intensive, large-scale livestock operations with what we see to be good farming practices, with or without PLF technologies.

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[17] They presumably still keep their individual identity as recognized by their conspecifics, though in considering that question, it is worth thinking about the loss of individuality those animals experience when in much larger groups than they would maintain if left to their own devices.

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