A MORAL OPERATING SYSTEM OF LIVESTOCK FARMING

Bart Gremmen
Wageningen University
bart.gremmen@wur.nl

ABSTRACT: Societal views about livestock production systems in Europe are changing dramatically in a negative direction. Based on the tradition of pragmatism in applied philosophy I develop a Moral Operating System of animal production systems in cooperating a plurality of ethical views. This moral operating system of animal production systems consists of two interactive, dynamic parts: an internal professional care ethics combined with an emergent ethics in life sciences enabling change by responsible innovation, and external ethical boundary conditions based on societal values and concerns in animal ethics and environmental ethics. I focus on the emergent ethics in life sciences because it most normative ethical theories have problems in dealing with the future. In moral reasoning about innovations in the making, the relevant moral facts and the appropriate principles are more or less still unknown, as also the relevant moral consequences. Only by doing ethics in life sciences in future projects will the moral dilemmas emerge in the trajectories of responsible innovation like molecular technologies in animal sciences and precision livestock farming.

1. Introduction

The number of animals in the world has grown to an all-time high. Billions of animals play an important role in different activities as pets, in sports, as hobby and companion animals, but they are also used in clinical trials and tests, especially in agriculture (Eijsackers and Scholten 2011). To mention only a few trends in the European Union that will reduce animal numbers in the long run: a ban on wild circus animals, a ban on mink (six million animals each year), a restriction on keeping certain species as pets, and a 20% reduction in dairy cows. Besides their role in society, animals are also found in nature areas, where humans are causing the sixth global mass extinction of wild animals. A future without the need to care for large and medium sized animals seems to lie ahead.

Most societies in the Western world are changing dramatically in a negative direction in relation to societal ideas about agricultural production (Ankersmit 2010), especially about genetic modification and the use of animals (Bruijnis et al. 2015). Who still cares for livestock*?* The answer to this question may be interpreted in a more cynical way: Does this correspond with the thoughts of Francis Kint, the CEO of Vion, on the filmed animal abuse in a Belgian slaughterhouse? In a recent interview in a Dutch newspaper, he said that his first thoughts were that this was bad for the industry, and that it could have been prevented by a better layout of the slaughterhouse (Tuenter 2017). Although this is not the empathic reaction that concerned people from *outside* the production system would have expected, it is a typical reaction of a professional *inside* the production system who *cares* for a better system (Bergstra et al. 2015). In the same interview, he suggested some innovations to prevent stress, like no bends in the walkway to the slaughter site.

The take home message of this paper is that we need to develop a Moral Operating System of animal production systems bases on a plurality of ethical views. An ethics of livestock farming needs more than just animal ethics. We need an ethics of animal production *systems* consisting of two interactive, dynamic parts: an *internal* professional *care* ethics combined with an *emergent* ethics in life sciences enabling change by responsible innovation, and *external* ethical boundary conditions based on societal values and concerns in *animal* ethics and *environmental* ethics. Together, these four ethics are the Moral Operating System of a production system.

Hereafter, the focus will be on the *emergent* ethics in life sciences aimed at tackling the immoral aspects and moral dilemmas of animal production systems. An example can be found in *Boer zoekt vrouw internationaal*, a Dutch television series based on the English series *Farmer wants a wife*. In the episode of Sunday, April ninth, Alberdien decides to leave Olke, a Dutch dairy farmer, in Texas. She cannot cope with the fact that the nice, healthy young bulls that she fed in the morning will be killed, simply for economic reasons. More examples are: the thousands of pigs burning in stable fires, the mutilation of piglets, and the death of more than fifty million day-old male chicks annually. These immoral aspects and moral dilemmas arise when societal values clash with the principles of an animal production system, because of unintended consequences and risks (Alders 2011). To tackle these immoral aspects and moral dilemmas as an ethicist, it is necessary not only to be part of a life sciences trajectory of responsible innovation, but also to strengthen ethical reflection along the agricultural production chains and among the involved stakeholders. What do I mean by ethical reflection in the field of life sciences?

2. Doing Agricultural Ethics

Ethics may be studied from several disciplinary backgrounds: law, theology, psychology, philosophy, and social science. In this paper ethics is studied from a philosophical background (Petersen and Ryberg 2007) and is defined as the critical, systematic reflection on implicit and explicit moral assumptions about what we do. Many of the societal and scientific challenges in relation to agricultural domains involve value conflicts. Scientific understandings and technological solutions are often contested. In a pluralistic society, philosophy can offer proactive and constructive ways to deal with such value conflicts. The mission of philosophers is to strengthen reflection on, and deliberation about, these problems and about scientific and societal responses, and thus to contribute to responsible policies and practices. This is done by engaging in dialogue with societal groups, policymakers, professionals, and scientific disciplines, enriching their reflection with philosophical questions and perspectives. The nature of values such as animal welfare and environmental integrity needs to be clarified, and possibilities for responsible innovation in plant and animal production systems need to be explored.

The tradition of pragmatism in applied philosophy (Keulartz 2002) is the philosophical background of this paper. This term is not to be taken in a strict sense (i.e. 'pragmatism' as a very specific philosophical denomination connected with the work of James, Dewey, and others), but rather in a more general and broader sense (Thompson 1998). This pragmatic approach starts from case material and concrete actual developments, and aims at interdisciplinarity, dialogue, and collaboration (Gremmen 2002 and 2007). Philosophical concepts are used as flexible tools that can be adapted to specific contexts. This empirical way of doing philosophy is applied to ethics in the life sciences. Whereas academic debates often revolve around the question of whether these sciences are benign or a threat (Singer 1975; Sandoe and Christiansen 2008), ethics *in* life sciences is done as an embedded ethicist, discussing life sciences from within (Gremmen 2007). This means that *the societal impact* is strengthened by a bottom-up approach. Starting with interviews and stakeholder surveys (see Blom and Gremmen 2012), the ethical arguments in the results are analysed, tested, and deepened. Afterwards, the stakeholders and relevant others are informed to strengthen a constructive ethical dialogue and offer them a framework to make responsible decisions. Also, this research is often part of consortia aiming to provide companies, policymakers, NGOs with information and tools to solve their problems. Is there a suitable ethical approach available?

3. Ethics of animals: animal ethics and environmental ethics

Clashes of different ethical approaches may be observed in societal debates about animals (Thompson 1998), and will be illustrated by the case of Johannes, a humpback whale. On 12 December 2012, Johannes beached on the shoreline of De Razende Bol, a small uninhabited island between the island of Texel and the city of Den Helder in The Netherlands. The whale was stuck on the beach and could not return to the water on its own. Not so long ago, humans living nearby would have killed the animal immediately, and its remains would have been used for all kinds of purposes. In our modern times, we try to save such animals' lives. Over the course of just a few days, Johannes became a national symbol for helping a wild animal in need. Political parties, civil servants, scientists, and members of societal organizations were engaged not only in debates, but also in rescue and euthanasia attempts. All these attempts failed, and the whale eventually died. In the ensuing debate, ecologists and nature conservationists still argued against killing dying wild animals in distress, whereas the majority of the other participants in the debate argued for a humane death for these animals.

At first sight, it seems that humans do not need to be involved at all when wild animals die: wild animals are wild precisely because they *take care of* themselves in areas where they are outside human control. In such situations, wild animals die for several different reasons: hunger, thirst, disease, predators, and also as a consequence of old age. Humans are often unaware of the fact that, out of their sight, animals could be dying. However, sometimes people are confronted with dying wild animals, like the beached humpback whale in 2012. What is our moral reference for killing wild animals? It seems that, in order to answer these questions, we can rely on animal ethics: the moral framework for the killing of domesticated animals. According to the law in many European Union countries, based on this theory, humans are obliged to help an animal in distress. From this ethical perspective, the first duty of humans is to save or help individual wild animals in situations where humans are present. When all help fails, our second duty is, if possible, to kill these animals in a humane way. The example of the humpback whale seems to fit into this scheme because it was an individual animal surrounded by humans. However, from the perspective of *environmental* ethics, wild animals are part of ecosystems. Therefore, the focus is on groups and species rather than on individual animals. In general, this ethical framework advocates respect for the wildness of animals. In the case of dying wild animals, like the humpback whale, the *environmental* ethics ethical framework advises a hands-off strategy. This seems to lead to a stalemate between two rival ethical frameworks, thus leaving nature management caught between two sets of norms governing animals and nature.

If we see some ethological distance in the dualism between 'wild' and 'tame', all kinds of intermediary shades appear. Also, the number of situations in which humans have to decide to kill wild animals increases considerably. The humpback whale is an example of an individual wild animal in distress. We may consider this situation as bad luck and exceptional. But what about lost or abandoned baby seals on the shores of the Netherlands, Germany, and Denmark? When we locate these animals, do we help them by bringing them to a shelter? Do we have to kill them on the spot or leave them alone to die? Other examples are weak or dying animals in nature parks like the Oostvaardersplassen in The Netherlands and exotic animals that are destroying the biodiversity of an area. In earlier research I argued that the relation between *animal* ethics and *environmental* ethics in these cases is not a dichotomy, but a continuum. Because *animal* ethics is about individual animals in hands-on situations, and *environmental* ethics is about groups of animals and species in hands-off situations, groups of animals in agricultural hands-on situations do not belong to either ethics. What is a suitable ethics of animals in agricultural production systems?

4. Ethics in agriculture: care ethics and ethics of life sciences

Recently, *care* ethics has been developed as an ethical approach (Loewy and Springer 2004). Hans Harbers (2009) argues at length that *care* ethics is the most promising integrative framework for ethics of animal production systems. *Care* ethics focuses on values that are important for the maintenance and flourishing of (care) relationships, such as commitment, dependency, responsibility, and care (Devettre 2009). An important aim of caring is to create shared values for all stakeholders involved in the production chain. In agricultural systems, people care for plants and animals in the two senses of the word 'care': 'care for' and 'care about' (being concerned). Good farming is a matter of endless care, in various shapes and sizes (Scholten et al. 2013). Good care requires the involvement of all stakeholders in the production chain, but also of citizens, consumers, civil society, and government (Harbers 2009). As a consequence, care is always accompanied by societal concerns. This can be illustrated by the Wakker Dier campaign. Six obituaries of organic cows appeared on 3 April 2017 in the Dutch newspaper *Trouw*. Miep 140, Rikkie 65, and Witkop 36, cows from the organic dynamic dairy farm, Schermereylandt, were slaughtered to comply with the European Union's manure regulation. Although care is firmly embedded in economic activity, this does not automatically imply the primacy of the economy (Harbers 2009). Caring also means the responsibility to take care of the situation in farming by contributing to innovative processes, and thereby contributing to society. This entails clarity about responsibilities as an essential element for an excellent organization of a caring farming system (Goede et al. 2013)

In a number of innovation areas, such as genomics, synthetic biology, and animal welfare, ethicists are asked to help to solve moral problems in the early stages of innovation (e.g. Singer 1986). Can ethicists help to solve moral problems in the early stages of innovation? In the past, ethics often seemed to lag behind technical progress, and, according to Grunwald (2010), as a response ethics joined the move towards 'upstream engagement' in the field of Science and Technology Studies. As early as 1980, David Collingridge wrote a book on the social control of technology with the objective of avoiding the harmful social consequences of a new technology (Collingridge 1980). This may be done by changing technology in its infancy by imposing on it all kinds of controls and restrictions. Two conditions are necessary to avoid the undesired consequences of a new technology: "It must be known that a technology has, or will have, harmful effects, and it must be possible to change the technology in some way to avoid the effects." (Collingridge 1980, 18) One or both of the conditions are often lacking, and attempts to control technology seldom succeed: the 'dilemma of control'. The first horn of the dilemma is that the harmful social consequences of the fully developed technology cannot be predicted with sufficient confidence to justify the imposition of control. The second horn of the dilemma is that, by the time a technology is sufficiently well developed and diffused for its unwanted social consequences to become apparent, it is no longer easily controlled. Control may still be possible, but it will have become very difficult, expensive, and slow. What happens is that society and the rest of its technology gradually adapt to the new technology, so that, when it is fully developed, any major change in this new technology requires changes in many other technologies and social and economic institutions, making its control very disruptive and expensive (Collingridge 1980, 19).

An important assumption of the Collingridge dilemma is the consequentialist/utilitarian perspective in ethics. The normative starting point of the dilemma is the need to avoid the harmful social consequences of a technology, but the message of the dilemma is that a consequentialist/utilitarian perspective is impossible. In the early phases of a new technology, ethical deliberations become speculative because we lack the required knowledge (Grunwald 2010). In the later phases of a new technology, ethical deliberations often come too late, namely, when all of the relevant decisions have already been made, when it is too late to avoid harmful consequences of the technology. Collingridge's own normative response to the dilemma is to maintain the 'freedom to control technology', because the essence of controlling technology is to retain "… the ability to change a technology, even when it is fully developed and diffused, so that any unwanted social consequences it may prove to have can be eliminated or meliorated." (Collingridge 1980, 20/21) He suggests developing organizational structures and scientific tools to deal with the resistance to such control (ibid, 19). Experts, decision makers, and end-users all are entangled in controlling the new technology.

However, Collingridge did not foresee that some experts were going to use a version of his control dilemma as a normative tool in their attempts to exclude prospective users from the innovation process. Experts sometimes stress that they are willing to include users in the early stages of the new technology (Gremmen 2007), when there is still a lot of room to take the voice of prospective users into account in the design of the product, but the experts can offer little concrete information that would allow prospective users to imagine how they could integrate the end-product in their everyday life. This version of the Collingridge dilemma depicts the end-users in the emergence of new technologies as the end-point of a linear process. However, the world of the users and the world of technological innovation are by no means separate entities that only merge when a final product is delivered to the users; they are already entangled from the start. Technology assessment, and, later, constructive technology assessment, recognized the importance of involving users in the innovation process to encourage integration of new technologies in users' everyday lives (Rip et al. 1995; Oudshoorn and Pinch 2003). The case has been made that technologists need to study responses to science in order to learn from them (Levitt 2003) and to discover missing propositions in their own reasoning (Locke 2002). Everyday-life concerns that inform people's responses to emergent technologies may be at odds with scientific and technological standards but can and should be understood on their own terms. In this way, experts could benefit from the active involvement of prospective users (Veen 2010).

It is difficult for ethicists to assist innovators, because most normative ethical theories have problems in dealing with the future. Not only do the results of an innovation trajectory have unknown consequences, but, more importantly, we do not know the results of innovation at the start of the innovation trajectory (Wathes et al. 2008). This means that, in moral reasoning about innovations in the making, the relevant moral facts and the appropriate principles are more or less still unknown, as also the relevant moral consequences. For that reason, the third part of the Moral Operating System of animal production systems is described as emergent. Only by doing ethics in life sciences will the moral dilemmas emerge in the trajectory of responsible innovation. Future projects will describe and analyse the main characteristics of an emergent ethics of animal production systems. Examples of these characteristics are moral lock-in, the slippery slope, instrumentalization, and commodification. These are discussed in the following two research themes, molecular technologies in animal sciences and precision livestock farming.

5. Molecular technologies in animal sciences

In plants and animals, the basic genetics is more or less the same, but the application of some methods and technologies differ (Barnes and Dupre 2008). For example, mutation breeding – increasing the mutation frequency through chemicals or radiation – is a common and legal method for plants, but it is not possible in animals, for both ethical and economic reasons (Shu et al. 2011). Marker assisted selection and genetic modification (GM) have been used in plant breeding (Gremmen 2005) for many years, but genetic modification has not yet been applied in livestock on a large scale (Gremmen 2009). The only approval given for a GM animal for food production is Canada's approval of AquAdvantage salmon eggs, with a focus on growth enhancement (Goubau 2011). Other examples of GM animals are pigs (i.e. increased growth rates and higher utilization of phosphate in their feed), dairy cows (enhanced resistance to mastitis and improved udder health, and improved milk quality), goats and sheep (improved wool production and disease resistance), and chickens (resistance to diseases and feed efficiency) (Thompson 2007).

There are different kinds of ethical arguments about controversial life sciences technologies (Rollin 1995). On the critical side, some people have objections to a particular technology as such. In the case of genetic modification for example, this argument amounts to the claim that it is unnatural and therefore morally problematic (Siipi 2004; Haperen et al. 2012). Many critics might not be so much opposed to GM technology as such, but more to its different applications (Rollin 2006). From a consequentialist stance, this means that even people who do not have an objection in principle to the technology can still be critical of its use in agriculture in general, and in food production in particular (Sandoe and Christiansen 2008). Current applications of agricultural biotechnology have also been criticized from the viewpoint of justice, in particular with respect to the distribution of economic benefits from its use (Thompson 2007). Some critics emphasize the risks and uncertainties with this new technology, and argue either that there are risks to human health or the environment, or that there might be such risks, and that for this reason some version of the precautionary principle should be applied (Gremmen 2006). Ethics may clarify and test such arguments and explicate normative and epistemic assumptions. In livestock farming, genetic modification may contribute to all kinds of efficiency benefits but, at the same time, may be used to circumvent certain ethical problems (Hanssen and Gremmen 2013). Our case study on the ethics of genetically modified chickens illustrates this (Bruinis et al. 2016).

In response to the increasing demand for safe and cheap food in sufficient quantities, the intensification and mechanization of poultry farming began in the mid-twentieth century. The number of chickens kept by any one farmer has increased considerably since then. Efficiency and specialization were enabled by developments in feeding, breeding, housing of the animals, and increased knowledge of veterinary medicine. Genetic selection enabled egg production by layer-type chickens and chicken meat production using specialized meat-type chickens. Therefore, male chicks from layer-type chickens became less attractive for meat production. With the available sexing techniques, which made it possible to distinguish males from females immediately after hatching, it became common practice to kill these male day-old chicks.

In the European Union, over 400 million male chickens are killed annually immediately after hatching. Societal opposition to this practice has prompted the development of innovations. Several alternatives to the killing of day-old chicks have been proposed (Leenstra et al. 2010); this leads to the question of whether these alternatives are morally superior. We have developed a framework to evaluate the technical and socio-ethical aspects of alternative directions of more responsible innovations to solve this issue, selected on social desirability and technical potential compared to the current situation (Leenstra et al. 2010). One alternative direction aims to use genetic modification in the breeding of laying hens in such a way that the hatching eggs containing males can easily be identified with spectroscopy, a non-invasive technique compared to the technique of taking a sample from the egg to find the difference between male and female eggs. The GM alternative takes advantage of the genetics of birds to ensure GM-free laying hens, and also that their eggs are GM free.

This clear case of a morally inferior practice has potentially morally better alternatives. Besides the GM alternative, there are several others: raising the male chicks, dual use of chickens, taking a sample from the egg, etcetera. Each alternative has its advantages and disadvantages with respect to technical and socio-ethical aspects, and each has a specific importance for various stakeholders. Solving one issue raised by the current situation throws up new issues. For example, by acknowledging arguments against the killing of such young animals and starting to rear the males, issues arise around the impact on the environment and the marketing of the chicks. The issue of killing day-old chicks and its alternatives thus seems to be an example of choosing the least of several possible evils and can be explained by a special type of moral lock-in.

Since the mid-1980s, technological lock-in has become an important subject of growing academic enquiry in the field of innovation studies, especially by economists working within an evolutionary tradition (David 1985; Arthur 1989). The general idea of lock-in is that technologies and technological systems follow specific paths that are difficult and costly to escape (Perkins 2003). Even if potentially superior alternatives are available, these technologies and technological systems often survive for a very long time. The famous examples in the literature are the triumph of the QWERTY keyboard layout over the Dvorak Simplified Keyboard layout (David 1985) and the race between VHS and Betamax as a video cassette recorder standard (Arthur 1990). In the literature, lock-in is explained by the increasing returns of an initial lead in the competition between technologies (David 1985; Arthur 1989). "This arises because early adoption can generate a snowballing effect whereby the preferred technology benefits from greater improvement than its competitors, stimulating further adoption, improvement, and eventual leadership "(Perkins 2003, 23).

There are many ways in which locked-in technologies may be inferior to their alternatives. I focus on *moral* lock-in: the way a production system can be locked-in to technology standards that are potentially morally inferior. In some cases, there is consensus on the potential for moral improvement that could be achieved through the development of alternative technologies. The question then becomes: What is holding back the development of these morally better technologies? Many debates about the transition to these new technologies focus only on the costs involved (Carrillo-Hermosilla 2013). Our hypothesis is that a kind of moral lock-in may explain the survival of morally inferior technologies. I consider Responsible Innovation, a concept for balancing economic, socio-cultural, and environmental aspects in innovation processes (EC 2011), as an approach to morally 'unlock' alternative innovations. By involving stakeholders in the innovation process and by considering ethical and societal aspects during this process, the socio-ethical acceptability and the societal desirability of innovative products will increase significantly (Schomberg 2013; Blok and Lemmens 2015).

Recent genetic engineering techniques, like CRISPR/Cas9, have come into use in plant breeding in a short time (Zhang et al. 2014). These so-called genome editing techniques are cheaper, faster, more accurate, and more widely applicable than older techniques because of their ability to cut and alter the DNA of any species at almost any genomic site with ease and precision (Jasanoff et al. 2015). They have been developed to overcome the problem of randomness that results from mutation breeding and to be able to determine the site of mutation or insertion of genes. Applications of animal gene editing techniques are many, varied, and rapidly evolving, including applications that promise benefits in welfare, in disease resistance, and in feed efficiency. Although the gene editing technology promises significant benefit, this promise will not be realized unless the technology is firmly and fully embedded in society. The existing ethical frameworks on biotechnology (Holland and Johnson 1998; Rollin 1995) have to be adapted and broadened to these new scientific methods and technologies. This will help scientists, stakeholders, and policymakers to understand, evaluate, and monitor the integration of the technical, social, and ethical aspects of the modern GM toolbox.

In a new research project we are refining and applying the responsible innovation approach to the technique of animal gene editing to guide the development of the technology and help ensure that applications are embedded in society. Animal scientists, social scientists, and ethicists will work together to anticipate possible impacts and implications, open up inclusive dialogue with stakeholders and wider publics, develop reflexive scientific and corporate cultures, and ensure that the science that develops is responsive to these processes. We have set out an integrated programme of research, applying the use of animal gene editing across three waves of research application: (a) editing to improve animal welfare (starting with the one-edited gene enabling dehorning in cattle); (b) editing for disease resistance (involving more complex traits); and (c) editing for feed efficiency (involving really complex traits). In this project, we will develop a responsible innovation approach to animal gene editing that will guide the responsible development of the technology and support responsible decision making at the level of breeding companies and governments.

6. Precision livestock farming

Precision livestock farming, the second research theme, is the application of smart farming technologies and a relatively new phenomenon in the agricultural sector (Reichardt et al. 2009). In smart farming, computers, sensoring devices, GPS systems, but also robots and even animals, communicate with one another and function autonomously in an integrated farm management system. In this way, farmers can reduce farm inputs (fertilizers and pesticides) and increase yields, while reducing emissions to the environment (Bos and Munnichs 2016). In precision livestock farming, the internet of things is extended to farm animals. PLF can be defined as the management of livestock production using the principles and technology of process engineering. PLF treats livestock production as a set of interlinked processes, which act together in a complex network.(Wathes et al, 2008) The introduction of this type of integrated farm management system enables farmers to control the production process by monitoring and controlling animal growth, behaviour, and health, the production of milk and eggs, the physical environment of livestock buildings, and greenhouse gas emissions and other pollution to the environment. Furthermore, the exchange of information about health and milk quality enables supply chain actors to optimize coordination and efficiency throughout the supply chain.

An example of PLF can be found in the dairy sector, where PLF has emerged with the concept of automatic or robotic milking (De Koning and Rodenburg 2004). Rising labour costs in the mid-1970s in Europe was one of the main reasons for increasing automation in the milking sector (Sauer and Zilberman 2012). An automatic milking system is equipped with electronic cow identification, cleaning, and milking devices and computer-controlled sensors to detect, for example, abnormalities in milk. The system also provides remote notification to the farmer if intervention is required (De Koning 2011). The largest number of dairy farms using automatic milking systems is found in the Netherlands, with almost 2,000 farms. Automatic milking relies heavily on the cow's motivation to visit the automatic milking system. The main motive for this is the supply of concentrates dispensed in a feed manager in the milking box during the milking process (De Koning 2011).

A more comprehensive application of PLF, so-called precision dairy farming, focuses on the transition from a group-oriented perspective to a perspective where intensive consideration is given to individual cows, and where particular goals, such as tapping individual potential, diagnosing diseases early, and using minimum medication, are pursued (Sauer and Zilberman 2012). Hence, advanced automatic milking systems are equipped with various sensors ranging from sensors that control the milking process to sensors that analyse the milk quality in several ways, such as milk composition, cell counts, blood detection, conductivity, progesterone, and so on. Because of increased information density, all these sensors require smart data-handling solutions to help the livestock manager to make the right decisions (De Koning 2011).

Although smart farming technologies provide economic, social, and environmental opportunities for the agricultural sector, they also raise ethical issues associated with the increased corporatization and industrialization of the agricultural sector. PLF facilitates the slippery slope of further intensification of livestock farming and the emergence of mega stalls with various socio-ethical consequences (Bos and Gremmen 2013). Another ethical issue is the possible alienation of animals, farmers, and citizens because of the robotization and digitalization of farm management systems. Finally, farmers have to share all kinds of information about their farm management with processors and retailers who can take (economic) advantage of this information. In this respect, PLF may lead to the concentration of economic power in the process industry, with retailers as linchpins in matching supply and demand within the supply chain (Bos and Munnichs 2016). Therefore, we may expect society to be reluctant to accept smart farming technologies because of the ongoing industrialization of the agricultural sector. This will lead to a call for a human and natural scale of agricultural practices, notwithstanding the potential of smart farming technologies to feed the increasing world population and to mitigate climate change, for instance.

This reluctance to accept the industrialization of farming practices can be understood as a resistance against the conceptualization of the natural environment as a commodity for human needs, in which nature's own strategies and principles of operation are neglected – natural animal growth and behaviour for instance – and, instead, nature is challenged to supply efficiently agri-food products as commodities in an instrumental economic exchange among chain actors. A consequent call for farming practices that are better embedded in the natural environment, like multi-functional agriculture, organic farming, and so forth, can already be recognized in current Western societies, even if these practices are disadvantageous for feeding the world and mitigating climate change. Because of the potential advantage of smart farming technologies, we raise the question of how to conceptualize smart farming technologies that are no longer characterized by the instrumentalization and commodification of nature, but instead are embedded in, and in accordance with, the natural environment.

7. Conclusion

Although the absolute global number of animals in the near future is expected to decline, the global number of animals in livestock farming systems is still rising. The past few years, the resistance in Europe against the immoral aspects of these systems is also growing. These immoral aspects arise when societal values clash with the principles of an animal production system, because of unintended consequences and risks. The strategy of organisations aiming to protect animals in society is to battle against animal abuse or even to promote the end of all livestock farming systems. From an animal ethics point of view it certainly is worthwhile to fight against all forms of abuse in livestock production systems. However, next to an animal ethical approach based on incidents, we need a more long term strategy, integrating a plurality of ethical perspectives. The Moral Operating System of livestock production systems proposed is based on four ethical perspectives. It is an ethics of animal production *systems* consisting of two interactive, dynamic parts: an *internal* professional *care* ethics combined with an *emergent* ethics in life sciences enabling change by responsible innovation, and *external* boundary conditions based on societal values and concerns in *animal* ethics and *environmental* ethics,. Together, these four ethics are the Moral Operating System of a production system.

I focused on the emergent ethics in life sciences because it most normative ethical theories have problems in dealing with the future. We do not only know the results of innovation at the start of the innovation trajectory, but also do not know the consequences of the results of an innovation trajectory. In moral reasoning about innovations in the making, the relevant moral facts and the appropriate principles are more or less still unknown, as also the relevant moral consequences. Only by doing ethics in life sciences in future projects will the moral dilemmas emerge in the trajectories of responsible innovation like molecular technologies in animal sciences and precision livestock farming.

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