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DISCUSSION PIECE

"Lights out" poultry production and pandemic influenza

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Abstract
Poultry production makes a substantial contribution to global food security, providing energy, protein, and essential micronutrients to humans. Modern intensive poultry farming systems are challenged by the evolution of Highly Pathogenic Avian Influenza strains. The presence of avian influenza in poultry flocks poses a significant risk of an avian origin influenza that is easily transmittable between human beings evolving. By reducing contact between humans and fowl, the use of automation in poultry production has the potential to improve biosecurity and thus reduce the risk of pandemic influenza. Many poultry facilities are already highly automated. The rapid rate of progress in robotics and AI suggests that "lights out"—fully automated—poultry production systems may soon be possible. In this paper we consider the ethical and policy issues that would be raised by lights-out poultry production. There is a strong animal and human welfare case for reducing the risk of pandemic influenza via increased use of automation. However, lights-out farming looks to be the ultimate endpoint of dynamics already present in industrial agriculture, which led to the dangers of zoonotic infection from animal agriculture in the first place. Whether nations should respond to that risk by doubling down on industrial models of animal production and embracing fully automated farms or by reconsidering the current model of animal agriculture altogether is, we suggest, both the most important, and the most difficult, question posed by the prospect of lights out farms.

Keywords Ethics · Pandemic influenza · Poultry · Robotics · Artificial intelligence · Agriculture

Modern intensive poultry farming systems are challenged by the evolution of Highly Pathogenic Avian Influenza (HPAI) strains, which in turn pose a risk of a global pandemic. The use of automation in poultry production has the potential to improve biosecurity and thus help control HPAI. The rapid rate of progress in robotics and AI in the current period suggests that now is the time to consider the ethical and policy issues that would be raised by the development of "lights out"—fully automated—poultry production systems. Although there is an emerging literature on the ethical issues raised by automation in agriculture more generally (see, for instance: Ayris and Rose 2023; Barrett and Rose 2022; Ryan 2023; Sparrow and Howard 2021; Sparrow et al. 2022), there has been little, if any, discussion to date of the ethical issues raised by the prospect of complete automation of animal production or of the biosecurity benefits of this project, which are a novel– and important– consideration in this case.

Poultry and pandemic influenza

Poultry production makes a substantial contribution to global food security, providing energy, protein, and essential micro-nutrients to humans. According to the Food and Agriculture Organization of the United Nations (2022), "World poultry meat production soared from 9 to 133 million tonnes between 1961 and 2020, and egg production shot up from 15 to 93 million tonnes". The poultry sector is expected to continue to grow as demand for meat and eggs is driven by growing populations, rising incomes and urbanisation (Motte and Tempio 2017).

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Increases in productivity in poultry farming have been achieved by an expansion of the scale of production and intensification on a per-unit basis - both in stocking density and through selection of desired genetic traits. Intensive meat-chicken farms may house several hundred thousand meat chickens at any one time. Farms producing eggs may be larger still, with some facilities in China now containing millions of layers (Yang 2021). Turkeys, ducks, and geese are also increasingly farmed in intensive production facilities (Gajendran and Veeramani 2022; Guemene, Shi, and Guy 2012; Marchewka et al. 2013).

As might be expected, the ecosystems created by large scale poultry production are providing ideal conditions for the rapid evolution of bacteria and viruses. In particular, they are sites at which Low Pathogenic Avian Influenza (LPAI) may evolve into more virulent strains of virus (Lebarbenchon et al. 2010; Wallace and Wallace 2015). HPAI outbreaks in commercial poultry production may disrupt international trade, decrease regional commerce, interrupt farm operations, and trigger extensive government and industry expenditure for control and eradication (Johnson, Seeger, and Marsh 2016). The 2014–2015 H5N2/H5N8 HPAI epidemic required $879 million dollars in public expenditures to eradicate the disease from poultry production, making it the most costly animal health incident in US history (Seeger et al. 2021). Fifteen years after its emergence, the direct economic costs of the H5N1 HPAI outbreak– including destroying more than 250 million birds– were estimated by the World Bank at more than US$10 billion (World Bank 2010). Models of HPAI population dynamics suggest that the persistence of the virus in poultry flocks is a function of farm size, and that current production systems are increasingly configured in ways that can sustain the pathogen indefinitely (Hosseini et al. 2013).

Poultry farmers have three strategies to try to control HPAI.

They try to mitigate outbreaks by being alert to the symptoms of the disease, slaughtering infected birds, cleaning and disinfecting poultry houses, and minimising movements of birds or staff between different areas in the same farm or between farms (Food and Agriculture Organization of the United Nations 2008).

They can vaccinate birds to reduce the incidence of HPAI infection. Vaccines must be chosen carefully and updated regularly to match the strains of AI circulating in poultry and wild birds. Vaccination is expensive and an adjunct to– and not a substitute for - good biosecurity (see below) when it comes to control of outbreaks. Vaccination, especially if not universal across large geographic areas, also risks selecting for mutations in the circulating strains of avian influenza (Guyonnet and Peters 2020).

Farmers can also try to prevent HPAI, and LPAI that might evolve into HPAI, entering the facility. Influenza and other pathogens can be introduced into a flock by contact with wild birds, which form a natural reservoir of infection, or other animals, via the movement of livestock, or through contact with (human) staff or visitors. By removing points of contact between poultry flocks, wild birds and potential human vectors, farmers can enhance biosecurity and reduce the risks associated with HPAI (Food and Agriculture Organization of the United Nations 2008; Hinchliffe and Lavau 2013). Preventing contact with wild birds and their droppings requires that poultry be confined in cages or to barns.

As well as killing birds, HPAI can cause human deaths and morbidity. For instance, from January 2003 to end of March 2022, there were 863 cases of human infection with H5N1, of which 455 were fatal (World Health Organisation Western Pacific Region 2022a). Another avian influenza variant, H7N9, generated 1,568 laboratory-confirmed human infections, including 616 fatal cases between 2013, when it first emerged, and 2019 (World Health Organisation: Western Pacific Region 2022b). The H5N6 variant is known to have infected 81 people, 33 of whom then died, since it first emerged in China in 2014 (World Health Organisation: Western Pacific Region 2022b). While, as yet, these avian influenzas are not easily transmissible between human beings, the possibility that a highly transmissible variant might emerge is extremely concerning, given the high case-fatality rates of existing strains. The prevention of influenza virus introduction from wild waterfowl or human beings to domestic poultry not only prevents the occurrence of HPAI in poultry farms but is also a critical step in preventing an Avian-Influenza-Virus-origin pandemic in the human population.

Automation in poultry farming

One way of reducing contact between humans and animals is via the use of automation. Many poultry facilities are already highly automated (Cronin 2011). Eggs may be candled, sorted, and vaccinated by a robotic system and hatched in automated incubators (Tolentino et al. 2018). Temperature, ventilation, and lighting can all be controlled remotely, or even automatically, and adjusted for maximum productivity (Choukidar and Dawande 2017; Kommey et al. 2022). Food and water are provided using automated systems that deliver precise amounts of each (Choukidar and Dawande 2017). CCTV cameras allow farmers to monitor the health and behaviour of animals without entering the facility (Okinda et al. 2020). In caged bird facilities, manure may be removed by conveyor belts (NSW Government: Department of Primary Industries 2022). On layer farms, eggs may be

collected and removed from the facility on conveyor belts and counted, sorted, and packed by an automatic system (Ren et al. 2020). In meat-chicken production, animals can be weighed in situ using automated scales and the data fed back into the precision feeding system (Zuidhof et al. 2017). Systems also exist for automatically transferring birds from the hatchery to the broiler shed (Cronin 2011).

However, there remain a number of tasks essential to poultry farming that, as yet, have resisted automation and thus require that people enter the facility. Removing dead birds must be done by hand, as must cleaning and disinfecting cages. Checking the health of sentinel birds and the state of the physical infrastructure requires someone to enter the facility. In cage-free systems, some eggs will be laid outside the nesting boxes and must be collected by hand. Moving animals in and out of barns must also typically be done manually. Further innovations in robotics and automation are required before it might be possible to eliminate contact between human beings and animals in poultry farming completely (Park et al. 2022).

Towards "lights out" animal farms?

Given the rate at which robotics and AI are developing in the current period, the prospect of farms on which human beings never set foot no longer seems far-fetched. Harper Adams University has provided proof of concept of autonomous crop farming with its "hands free farm" and "hands free hectare" (Lowenberg-Deboer and Keeble 2020). Recently, Wang et al. (2021) have made the case for "unmanned farms", wherein there is no need to have human beings onsite to grow crops or raise animals. Park et al. (2022) ask their readers to imagine a future of poultry production "where the ecosystem is fully automated and managed by constantly evolving artificial intelligence".

It is, we believe, time to think critically about whether this project should be pursued. Already there are a number of researchers and enterprises developing– and in some cases selling– robots that are intended to take on some of the jobs in poultry production that have stubbornly resisted automation to date, including egg collection in free range farms, remote visual inspection of birds and facilities, removal of dead birds, litter and manure processing, and harvesting (For surveys, see Liu et al. 2021; Park et al. 2022; and, Ren et al. 2020). While the biosecurity case for removing the need for people to enter poultry facilities is strong, we suspect that many in the community will be appalled by the idea of animals confined in facilities run by AI and attended only by robots.

The term "unmanned farms" fails to distinguish between remotely operated farms, wherein people still play an essential role but do not set foot on the farm, and fully automated farms, wherein routine farm operations are entirely performed by robots and supervised by computers using machine learning. The biosecurity benefits of robotics can be secured by moving to remote operation of poultry facilities. Nevertheless, we have chosen to write here of "lights out" farms, to emphasise that in such facilities birds will be entirely enclosed and because the technologies that will make remote operations of farms possible will also enable completely automated ("lights out") operations, in which the ethical issues associated with remote operations are writ larger still. Fully automated industrial facilities are known as "lights out" operations because no lights are required therein owing to the fact that human beings are not present: robots can operate in the dark. In fact, fully automated poultry facilities *would* have lights, their timing controlled by computers, in order to maximise the growth rate of meat birds, or to prompt egg laying, both of which are responsive to a dark-light cycle.

Ethical considerations

The cost of slaughtering large number of birds to control outbreaks of HPAI is extremely high. Work in poultry houses is demanding and unpleasant, with high turnover rates amongst employees. The *economic* case for developing lights-out farming is correspondingly strong. Ultimately, however, the question as to whether or not to proceed to develop such farms is an ethical one. It is not our goal to resolve this ethical question here– not least because, as we argue below, the trade-offs involved, between biosecurity, animal welfare, and the transformation of the nature of farming, have implications for the welfare and ethics of every human being and therefore should be addressed via a democratic process. Rather, our purpose here is to clarify the issues involved so that other scholars– and the broader community– can better understand what's at stake and formulate their own informed perspectives on the matter.

The ethical case for "lights out" poultry production

The strongest ethical argument *for* unmanned poultry production is to reduce the risk of pandemic influenza in human beings. An avian influenza that was also easily transmittable between people would, in all likelihood, lead to tens of millions of human deaths. Even a small reduction in the risk of such a pandemic looks to be a goal that we should pursue as a matter of urgency. Influenza causes significant suffering and mortality in infected animals, as do other diseases that might be controlled via the improved biosecurity made possible in unmanned farms, so there is also a compelling

animal welfare case for removing human beings from farms. Finally, when HPAI does enter, or emerge in, facilities, control measures typically begin with the slaughter of all the infected animals as well as all the animals within an appropriate radius of any infected animal (Food and Agriculture Organization of the United Nations 2008). These culls may involve tens, if not hundreds, of thousands of birds and are highly stressful for farmers and those who must carry them out (McGreal 2022). Culls can be economically devastating for communities and for small holders caught in the depopulation zone. Again, then, there is a strong animal and human welfare case for reducing the need for such measures.

Although our focus here is on the ethical case for lights-out poultry farms because of the improvements in biosecurity that they offer, it would be remiss not to observe that animal and human welfare arguments that do not refer to the risks of the introduction of disease might also be made for lights-out farms. Insofar as interactions with human beings may be a cause of significant stress to birds, replacing humans with robots might lead to improvements in animal welfare (For a sophisticated discussion of the extent to which automation has produced improvements in animal welfare in dairy farming, see Driessen and Heutinck 2015). Cost savings owing to increased use of robotics might also make it more feasible for farmers, or regulators, to enhance or enrich the environments in which birds are kept for the sake of animal welfare by promoting the Five Freedoms (Farm Animal Welfare Council 2009; Rowe et al. 2019). Reducing contact between humans and animals might also reduce the number of instances of the casual animal cruelty that sometimes occur in industrial livestock facilities. Work in such facilities is also a paradigmatic example of the "dull, dirty, and dangerous" work that, most critics agree, should be performed by robots where possible (For a somewhat sceptical take on the extent to which automation of agricultural technology has delivered on this promise to date, see Baur and Iles 2023).

The ethical case against lights out poultry production

Ethical arguments against unmanned farms are more difficult to express precisely than arguments for unmanned farms: they are also hard to distinguish from criticisms of industrialised animal farming more generally. One of our reasons for drawing our attention to the possibility of, and the case for, lights-out poultry production is precisely to encourage other scholars to take on the task of clarifying what might be said against it.

Nevertheless, it is difficult to be entirely sanguine about the prospect of animals living out their entire lifespans without contact with any creature other than their own kind. Birds in lights-out facilities would be entirely contained within, and subjugated to, an industrial process of food production: biological components of a larger machine (for an illuminating comparison, see Blanchette 2020). Animals would be highly vulnerable to equipment failures and breakdowns and or delays in repairs to sensors and/or robots. Their suffering, if they suffer, might be witnessed by no human being other than those who happen to view the camera feeds that artificial intelligences use to monitor their condition. There would be little prospect of whistle-blowers revealing any animal welfare issues that did arise (for discussion of the steps that producers take to try to prevent such whistleblowing, which in turn serve as evidence that such whistleblowing does, occasionally, occur see Pachirat 2011). There would be no contact between human beings, to whose desires the birds would be completely dedicated, and the living animals themselves: human alienation from food production would be complete. This alienation in turn might have implications for the moral character of individuals and communities. Farming, like medicine, is a practice that produces moral as well as material goods (Mayes 2018; Sandler 2009; Thompson 2010). Some critics have suggested that technologies designed to fundamentally change, or by-pass, natural processes represent hubris and arrogance that undermine historical virtues of farming, namely humility and patience (Comstock 2000; Sandler 2004).

The powerful economies of scale generated by the use of robotics and automation also have implications that are ethically salient. A robot that generates efficiencies when used in a shed with 100,000 animals may make little sense in a shed with 100 or even 10,000 animals. The cost of investment in automation may be prohibitive for smaller producers. Increased use of automation is therefore likely to drive increases in the size of animal production facilities and further consolidation of ownership in the poultry sector: perversely, in doing the former, automation increases the costs of HPAI outbreaks at the same time as it reduces the risk thereof. The larger literature on the applications of robotics and AI in agriculture suggests that these technologies have complex implications for the daily practice of those involved in agriculture, to the social meanings that accrue to farmers and farming, and to the distribution of political power amongst the various parties involved, and implicated in, agriculture (see, for instance: Carolan 2020; Driessen and Heutinck 2015; Forney and Epiney 2022; Higgins et al. 2023; Legun et al. 2022; Sparrow and Howard 2021), some of which might count against their use in poultry production. Finally, automation would expose farmers to risks of IT failures, including cyber-security risks (Sparrow et al. 2022).

In many ways, a lights-out farm looks to be the ultimate endpoint of dynamics already present in industrial

agriculture (Fitzgerald 2003; Thompson 2017), which led to the dangers of zoonotic infection from animal agriculture in the first place. Whether nations should respond to that risk by doubling down on industrial models of animal production and embracing fully automated farms or by reconsidering the current model of animal agriculture altogether is, we suspect, both the most important, and the most difficult, question posed by the prospect of lights out farms.

Policy implications

The extent of the ethical issues raised by lights-out farms and the possibility that the existence of such farms would further exacerbate public hostility to intensive animal production argues that it will be important to secure a "social license" for lights-out farms before they are developed. Fully automated poultry production is unlikely to be socially, economically, or politically viable in the longer term if the public is not convinced that its virtues outweigh its vices. More fundamentally, decisions about how our food is produced have the potential to affect all of us, given the pathogens we risk incubating and releasing in the process, and thus should not be made solely by unelected technocrats. For these reasons, we believe that governments and industry peak bodies should pursue a process of public consultation before making any decision to pursue lights-out farming. The risk that public opinion will not be adequately informed either about the risks of HPAI or the animal welfare implications of lights-out farms strongly suggest that deliberative methods, such as citizens juries, should be used to inform policy in this area.

Should a social license for lights out farming be secured, governments should quickly move to fund research into developing the technologies necessary to realise it. Every year that HPAI circulates in the environment increases the risk of pandemic influenza.

Finally, given the potential implications– both positive and negative– of lights-out farming for animal welfare, it would be prudent for governments to revisit animal welfare regulations for the poultry sector should the technology for lights-out farming be introduced. Again, it will be vital to bring public opinion along in this process.

Conclusion

Food production systems affect and implicate all of us — as, most likely, would any pandemic that emerged from HPAI. Ultimately, then, the shape of these systems should be determined democratically, by the entire community and not solely by experts and industry stakeholders (Degeling and Johnson 2015). For this reason, we have not tried here to reach any all-things-considered conclusion about the ethics of fully automated poultry production. Nevertheless, we hope that the account we have provided of the ethical questions posed by the prospect of lights-out farming can usefully inform public debate about the future of poultry farming and the risk of pandemic influenza.

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Declarations

Competing interests Authors declare that they have no competing interests.

References

Ayris, Kirsten, and David C. Rose. 2023. Social and ethical considerations for agricultural robotics. In *Advances in agri-food robotics*, ed. E. Van Henten and Y Edan. Cambridge, UK: Burleigh Dodds Science Publishing. https://library.oapen.org/handle/20.500.12657/61554.

Barrett, Hannah, and David C. Rose. 2022. Perceptions of the fourth agricultural revolution: What's in, what's out, and what consequences are anticipated? *Sociologia Ruralis* 62(2): 162–189

Baur, Patrick, and Alastair Iles. 2023. Replacing humans with machines: A historical look at technology politics in California agriculture. *Agriculture and Human Values* 40: 113–140. https://doi.org/10.1007/s10460-022-10341-2

Blanchette, Alex. 2020. *Porkopolis: American animality, standardized life, & the factory farm*. Durham and London: Duke University Press.

Carolan, Michael. 2020. Automated agrifood futures: Robotics, labor and the distributive politics of digital agriculture. *The Journal of Peasant Studies* 47(1): 184–207.

Choukidar, Geetanjali A., and N. A. Dawande. 2017. Smart poultry farm automation and monitoring system. *2017 International Conference on Computing, Communication, Control and Automation (ICCUBEA)*. https://doi.org/10.1109/ICCUBEA.2017.8463953

Comstock, Gary L. 2000. *Vexing nature? On the ethical case against agricultural biotechnology*. New York: Springer Science & Business Media.

Cronin, Greg. 2011. Robotics in the poultry industry. PoultryHub Australia. https://www.poultryhub.org/all-about-poultry/husbandry-management/robotics-in-the-poultry-industry (accessed 28 October 2022).

Degeling, Chris, and Jane Johnson. 2015. Citizens, consumers and animals: What role do experts assign to public values in establishing animal welfare standards? Journal of Agricultural and Environmental Ethics 28: 961–976

Driessen, Clemens, and Leonie F.M. Heutinck. 2015. Cows desiring to be milked? Milking robots and the co-evolution of ethics and technology on Dutch dairy farms. *Agriculture and Human Values* 32: 3–20.

Farm Animal Welfare Council. 2009. *Farm animal welfare in Great Britain: Past, present and future* . London: Farm Animal Welfare Council.

Fitzgerald, Deborah. 2003. *Every farm a factory: The industrial ideal in American agriculture*. New Haven: Yale University Press.

Food and Agriculture Organization of the United Nations. 2022. Gateway to poultry production and products: Production. https://www.fao.org/poultry-production-products/production/en/ (accessed 27 October 2022).

Food and Agriculture Organization of the United Nations. 2008. *Biosecurity for highly pathogenic avian influenza: Issues and options*. Rome: Food and Agriculture Organization of the United Nations.

Forney, Jeremie, and Ludivine Epiney. 2022. Governing farmers through data? Digitization and the question of autonomy in agri-environmental governance. *Journal of Rural Studies* 95: 173–182.

Gajendran, K., and P. Veeramani. 2022. Intensive duck rearing. In *Duck production and management strategies*, eds. A. Jalaludeen, R. Richard Churchil, and Elisabeth Baéza. Singapore: Springer. https://doi.org/10.1007/978-981-16-6100-6_7.

Guemene, Daniel, Z. Dan Shi, and Gerard Guy. 2012. Production systems for waterfowl. In *Alternative systems for poultry: Health, welfare and productivity*, eds. Victoria Sandilands, and Paul M. Hocking. 128–153. Abington: Carfax Publishing Company, CABI.

Guyonnet, Vincent, and Andew R. Peters. 2020. Are current avian influenza vaccines a solution for smallholder poultry farmers? *Gates Open Research Aug* 264: 122. https://doi.org/10.12688/gatesopenres.13171.1.

Higgins, Vaughan, Dani?l van der Velden, Noemie Bechtet, Melanie Bryant, Jane Battersby, Melissa Belle, and Laurens Klerkx. 2023. Deliberative assembling: Tinkering and farmer agency in precision agriculture implementation. *Journal of Rural Studies* 100: 103023.

Hinchliffe, Steve, and Stephanie Lavau. 2013. Differentiated circuits: The ecologies of knowing and securing life. *Environment and Planning D: Society and Space* 31: 259–274.

Hosseini, Parviez Rana, Trevon Fuller, Ryan Harrigan, Delong Zhao, Carmen Sofia Arriola, Armandoe Gonzalez, Matthew Joshua Miller et al. 2013. Metapopulation dynamics enable persistence of influenza A, including A/H5N1, in poultry. *PloS One* 8(12): e80091.

Johnson, Kamina K., Riley M. Seeger, and Thomas L. Marsh. 2016. Local economies and highly pathogenic avian influenza. *Choices* 31(2): 1–9.

Kommey, Benjamin, Daniel Akudbilla, Godfred Doe, and Clifford Owusu Amponsah. 2022. A low-cost smart egg-incubator. *Sustainable Engineering and Innovation* 4(1): 22–33.

Lebarbenchon, Camille, Chris J. Feare, François Renaud, Frédéric Thomas, and Michel Gauthier-Clerc. 2010. Persistence of highly pathogenic avian influenza viruses in natural ecosystems. *Emerging Infectious Diseases* 16(7): 1057-62.

Legun, Katharine, Karly Ann Burch, and Laurens Klerkx. 2022. Can a robot be an expert? The social meaning of skill and its expression through the prospect of autonomous AgTech. *Agriculture and Human Values* 40: 501–517.

Liu, Hung-Wei, Chia-Hung Chen, Yao-Chuan Tsai, Kuang-Wen Hsieh, and Hao-Ting Lin. 2021. Identifying images of dead chickens with a chicken removal system integrated with a deep learning algorithm. *Sensors* 21: 3579. https://doi.org/10.3390/s21113579

Lowenberg-Deboer, James, and Simon Keeble. 2020. Crop robotics are changing farming. *Land Journal (May/Jun)*: 8–9.

Marchewka, J., T. T. N. Watanabe, V. Ferrante, and I. Estevez. 2013. Review of the social and environmental factors affecting the behavior and welfare of turkeys (Meleagris gallopavo). *Poultry Science* 92(6): 1467–1473.

Mayes, Christopher. 2018. *Unsettling food politics: Agriculture, dispossession and sovereignty in Australia*. London, United Kingdom: Roman & Littlefield International.

McGreal, Chris. 2022. US egg factory roasts alive 5.3m chickens in avian flu cull – then fires almost every worker. *The Guardian (Online)*, 28 Apr 2022. (accessed 27 October 2022). https://www.theguardian.com/science/2022/apr/28/egg-factory-avian-flu-chickens-culled-workers-fired-iowa

Mottet, Anne, and Giuseppe Tempio. 2017. Global poultry production: Current state and future outlook and challenges.*World's Poultry Science Journal* 73(2): 245–256.

NSW Government: Department of Primary Industries. 2022. Egg production systems in Australia. https://www.dpi.nsw.gov.au/animals-and-livestock/poultry-and-birds/poultry-planning-and-keeping/poultry-keeping-environment/egg-production-systems (accessed 28 September 2022).

Okinda, Cedric, Innocent Nyalala, Tchalla Korohou, Celestine Okinda, Jintao Wang, Tracy Achieng, Patrick Wamalwa, Tai Mang, and Mingxia Shen. 2020. A review on computer vision systems in monitoring of poultry: A welfare perspective. *Artificial Intelligence in Agriculture* 4: 184–208. https://doi.org/10.1016/j.aiia.2020.09.002

Pachirat, Timothy. 2011. *Every twelve seconds: Industrialized slaughter and the politics of sight*. New Haven and London: Yale University Press.

Park, Michael, Douglas Britton, Wayne Daley, Gary McMurray, Milad Navaei, Alex Samoylov, Colin Usher, and Jie Xu. 2022. Artificial intelligence, sensors, robots, and transportation systems drive an innovative future for poultry broiler and breeder management. *Animal Frontiers* 12(2): 40–48.

Ren, Guoqiang, Tao Lin, Yibin Ying, Girish Chowdhary, and K. C. Ting. 2020. Agricultural robotics research applicable to poultry production: A review. *Computers and Electronics in Agriculture* 169: 105216.

Rowe, Elizabeth, Marian Stamp Dawkins, and Sabine G. Gebhardt-Henrich. 2019. A systematic review of precision livestock farming in the poultry sector: is technology focused on improving bird welfare? *Animals* 9: 614. https://doi.org/10.3390/ani9090614.

Ryan, Mark. 2023. The social and ethical impacts of artificial intelligence in agriculture: Mapping the agricultural AI literature. *AI & Society* 38(6): 2473–2485.

Sandler, Ronald L. 2004. An aretaic objection to agricultural biotechnology. *Journal of Agricultural and Environmental Ethics* 17(3): 301–317. https://doi.org/10.1023/B:JAGE.0000033078.05859.08.

Sandler, Ronald L. 2009. *Character and environment: A virtue-oriented approach to environmental ethics*. New York: Columbia University.

Seeger, Riley M., Amy D. Hagerman, Kamina K. Johnson, Dustin L. Pendell, and Thomas L. Marsh. 2021. When poultry take a sick leave: Response costs for the 2014–2015 highly pathogenic avian influenza epidemic in the USA. *Food Policy* 102: 102068.

Sparrow, Robert, and Mark Howard. 2021. Robots in Agriculture: Prospects, impacts, ethics, and policy. *Precision Agriculture* 22(3): 818–833.

Sparrow, Robert, Mark Howard, and Chris Degeling. 2022. Managing the risks of artificial intelligence in agriculture. *NJAS: Impact in Agricultural and Life Sciences*. Published online: 24 Feb 2022. https://doi.org/10.1080/27685241.2021.2008777

Thompson, Paul B. 2010. *The agrarian vision: Sustainability and environmental ethics*. Lexington, Ky.: University Press of Kentucky.

Thompson, Paul B. 2017. *Spirit of the soil: Agriculture and environmental ethics*. 2nd ed. New York: Routledge.

Tolentino, Lean Karlo S., Emmanuel Justine G. Enrico, Ralph Lawrence M. Listanco, Mark Anthony M. Ramirez, Ted Lorenz U. Renon, and Mark Rikko B. Samson. 2018. Development of fertile egg detection and incubation system using image processing and automatic candling. *Proceedings of TENCON 2018*. Doi: 10:1109/TENCON.2018.8650320.

Wallace, Rob, and Robert G. Wallace. 2015. Blowback: New formal perspectives on agriculturally driven pathogen evolution and spread. *Epidemiology and Infection* 143(10): 2068–2080.

Wang, Tan, Xianbao Xu, Cong Wang, Zhen Li, and Daoliang Li. 2021. From smart farming towards unmanned farms: Anew mode of agricultural production. *Agriculture* 11(145). https://doi.org/10.3390/agriculture11020145

World Health Organisation: Western Pacific Region. 2022b. Avian influenza weekly update number 864, 30 September 2022. https://www.who.int/docs/default-source/wpro---documents/emergency/surveillance/avian-influenza/ai_20220930.pdf?Status=Master&sfvrsn=22ea0816_18 (accessed 18 October, 2022).

World Bank. 2010. *Economic impact of avian flu. Health, nutrition and population in East Asia and Pacific*. http://go.worldbank.org/DTHZZF6XS0 2010 (accessed 18 October, 2022).

World Health Organisation: Western Pacific Region. 2022a. Avian influenza weekly update number 838, 1 April 2022. https://www.who.int/docs/default-source/wpro---documents/emergency/surveillance/avian-influenza/ai-20220401.pdf (accessed 18 October, 2022).

Yang, Ning. 2021. Egg production in China: Current status and outlook. *Frontiers of Agricultural Science and Engineering* 8(1): 25–34.

Zuidhof, M. J., M. V. Fedorak, C. A. Ouellette, and I. I. Wenger. 2017. Precision feeding: Innovative management of broiler breeder feed intake and flock uniformity. *Poultry Science* 96: 2254–2263, https://doi.org/10.3382/ps/pex013

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