Caspian Journal of Environmental Sciences
Online ISSN: 1735-3866
Print ISSN: 1735-3033

Implementation of technology and information systems (IOT) to support sustainable livestock development: Future challenges and perspectives

Neni Widaningsih[1,2*], Budi Hartono[2], Hari Dwi Utami[2], Eni Siti Rohaeni[3]

1. Department of Animal Science, Faculty of Agriculture, Islamic University of Kalimantan Banjarmasin, South Kalimantan, Indonesia
2. Faculty of Animal Science, University of Brawijaya, Malang, East Java, Indonesia
3. Research Center for Animal Husbandry, Research Organization for Agriculture and Food, National Research and Innovation Agency, Cibinong Science Center, Indonesia

** Corresponding author's Email: nieasgar2@gmail.com*

ABSTRACT
The purpose of this study was to provide a comprehensive understanding of the implementation of technology and information systems to realize sustainable livestock development through Precision Livestock Farming (PLF) and the Internet of Things (IoT). The literature study method was used in this study to search electronic data in order to write a collection of journals, publications, books, and websites, then analyze various kinds of literature that combines, among others, coding framework, in-depth assessment, and conclusions. We used a phenomenological approach, by trying to get the widest possible data, then trying to get a deep understanding, so that it becomes a valid and convincing finding. Sources of literature information used were various data published from 2005 to 2021 using the Google search application to find information using keywords such as Precision Livestock Farming (PLF), Internet of Things (IoT), sustainable livestock, creativity, innovation, and some which were related to this study. The results of this study indicated that digital technologies such as PLF and IoT can develop sustainable agriculture and animal husbandry. Management automation in livestock business with the application of these technologies can increase the capacity of livestock production systems.

Keywords: Digital technology, Precision livestock farming (PLF), Internet of things (IoT).
Article type: Review Article.

INTRODUCTION
Livestock is one sector that is very important for the food needs of the community. Livestock products as a source of animal protein are needed by the human body. Therefore, various types of livestock (poultry, cattle, buffalo, sheep, goats, and others) are the potential to be cultivated, both as producers of meat, eggs, and milk. Poultry commodity as a provider of animal protein, especially as a producer of eggs, has a very good market share and is prospective to continue to be developed, since the unique characteristics of poultry products can be accepted by all levels of society with relatively cheap prices and are public goods so they are easy to obtain (Vernooij *et al.* 2018). The poultry industry in Indonesia is developing under the progress of the development of the global poultry industry. The poultry industry is very good at the global level in terms of price, production, consumption, as well as export opportunities, or import substitution. This is due to the large global investment support in the upstream industry, namely in the form of breeding, animal feed, and medicine, and in the downstream industry, post-harvest, cold chain systems, processing, and the modern market revolution (Indonesia 2014). The world demand for poultry meat is expected to be double in 2025 when compared to 2005. In addition, the demand for eggs will increase by around 40% (Smith *et al.* 2015). Berckmans (2017) suggested that global meat consumption is

Caspian Journal of Environmental Sciences, Vol. 21 No. 2 pp. 457-465 Received: July 05, 2022 Revised: Oct. 19, 2022 Accepted: Dec. 28, 2022
DOI: 10.22124/CJES.2023.6540

Publisher: University of Guilan,

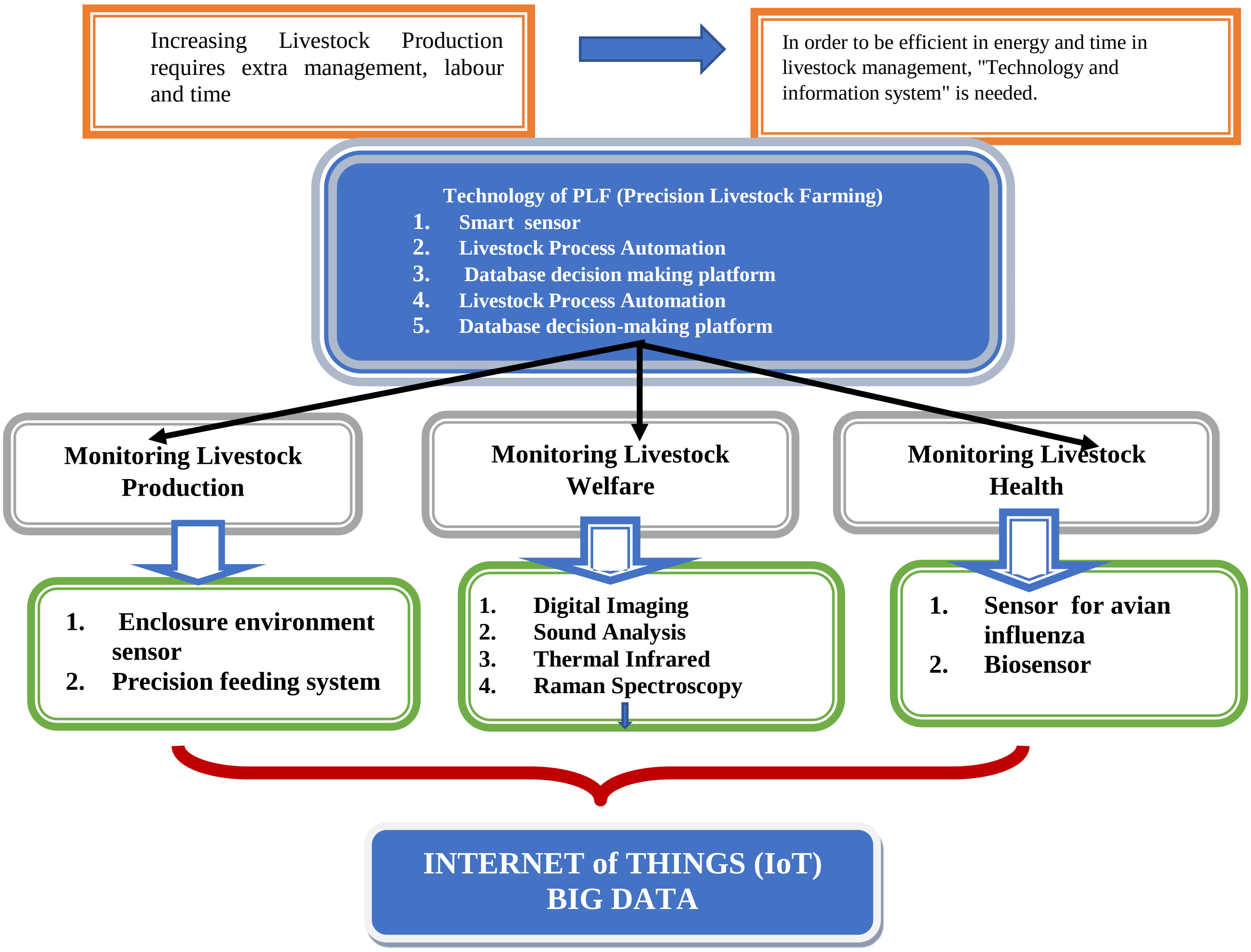
expected to increase up to 70% by 2050. The pattern of demand for meat (broiler) in the domestic market which is increasingly favoring white meat over red meat has pushed market demand for meat (broiler) to increase faster than beef, mutton, lamb, and pork. Commodities of cattle, buffalo, sheep, and goats as well as providers of animal protein can be used to support the fulfillment of the national meat self-sufficiency target, so that the existence of this livestock can directly or indirectly contribute to the realization of national meat procurement. The national demand for beef and buffalo is 361,210 tons, so the target set by the government is that the national meat production is set at 2.32 million heads or equivalent to 422,533 tons of meat. However, until the end of June 2020, the Ministry of Agriculture recorded beef and buffalo production in Indonesia only 210,707 tons or 1.16 million heads. This shows that the availability of domestic buffalo meat is not sufficient nationally, so Bulog imported 80 thousand tons of buffalo meat in 2021. This condition is an opportunity as well as a challenge for farmers in Indonesia to continue to increase their livestock productivity, so that they can contribute more to meet the national meat needs. The increasing demand for livestock products causes extra efforts to increase production through management, monitoring, and control of production. Management of large production requires a lot of labor and time and at the end, farmers will be overwhelmed to manage the large production without the help of technology. Therefore, to speed up, simplify and assist the work of farmers in efficient management, it is necessary to apply the right technology according to needs. Research findings show that digital technologies such as Precision Agriculture, Smart Farming, Precision Livestock Farming (PLF), the Internet of Things, and Artificial Intelligence in livestock farming are technologies for developing sustainable agriculture (Verdouw *et al.* 2017; Wolfert *et al.* 2017; Schepers 2019; Hrustek 2020; Jung *et al.* 2021).

The cost of feed is the largest production cost in the livestock business, which is 70% of the total production cost (Thirumalaisamy *et al.* 2016). The implementation of automation systems in the world of animal husbandry has been carried out by many industries, for example controlling the automation system for feeding chickens using the ATMega8535 or Arduino microcontroller combined with fuzzy and smartphone applications that can increase the efficiency and effectiveness of the work of farmers (Ridhamuttaqin 2013; Wisjhnuadji & Narendro 2017), manufacture of automatic animal feed dispenser based on the infrared sensor as feed volume detector with Atmega8535 controller. Yuda (2016) used the RTC DS1307 to manage feeding schedule with a closed system Jayatun 2016) developing solar cell energy for controlling feed opening and closing. Sidik *et al.* (2017) used an SMS gateway-based control application and Kurniawan & Huda (2018) designed a farm feeding system using a smartphone based on the HC-05 and Arduino modules. Nowadays, the development of the internet has also made the integration of web-based control. This condition can be accommodated by NodeMCU as a microcontroller integrated with a web-based Wi-Fi shield leading to significant efficiency in the employment of feed without reducing livestock weight and farmers' profits can be increased through feed savings. It is easy to monitor feedstocks, since data can be displayed in real-time via the web (Kurnia & Widiasih, 2019). Meanwhile, in minimizing and handling greenhouse gas emissions, the highest weight is found in the amount of fuel used in Fresh Fruit Bunch (FFB) shipments of 54.07% (Rosyidah *et al.* 2022). The strategy in animal husbandry should change along with the development of faster changing times. Therefore, alternative solutions must be found so that the management of large livestock productivity can be carried out easily, effectively, and efficiently. One of these strategies is to implement digital technology and information system-based through Precision Livestock Farming (PLF) and the Internet of Things (IoT). PLF acts as a support system for farmers to monitor various bioprocesses and bio responses related to livestock welfare, livestock health, and productivity (Silvera *et al.* 2017). PLF is described as an agricultural system that optimizes attention to livestock by monitoring the condition of livestock in real-time. Technological progress can no longer be counted. Advances in electronic and computer technology, one of which is a microcontroller based on the Internet of Things (IoT), which is a system that can communicate with each other through the internet network (Morgan 2014). This technology allows us to control technological devices anywhere and anytime as long as they are connected to an internet connection, so that they can control or monitor the condition of livestock cages such as ammonia gas levels, temperature, humidity, and livestock weight. The extension is an active procedure requiring contact between the extension worker and the individual to establish a behavior change process (Sulandjari *et al.* 2022).

MATERIALS AND METHODS

The writing of this paper used the library study method which is more emphasized in the review articles of research results. For the first time, we describe this study to gain an understanding of the implementation of Precision Livestock Farming (PLF) and Internet of Things (IoT) technologies to realize sustainable livestock development.

An electronic search was carried out for data in the literature database of book publications and websites (Ozdogan *et al.* 2017). Reviewing various literature by involving in-depth evaluation coding systems and making conclusions (Zewge & Dittrich 2017). We conducted this research using a phenomenological approach, which is an approach that tries to obtain the widest possible information, so that we can learn and gain understanding and become valid findings (Niknejad *et al.* 2021). Because this study uses secondary data from various sources, we have reported it in a qualitative design data study whose data sources we took from several publications between 2005 and 2021. In searching for data, we used the Google Search application on Google Scholar, such as Livestock Farming (PLF). Internet of Things (IoT), sustainable farming, creativity and innovation, agriculture in digital and so on which are related to the title of this research (Bing 2016). The framework of this study is as follow:



RESULTS AND DISCUSSION

1. Implementation of precision livestock farming (PLF) to increase livestock production

Livestock management systems generally consist of 3 separate functions, namely sensing and monitoring analysis, decision-making, and intervention (Astill *et al.* 2020). PLF systems can improve livestock production systems including optimization of the cage environment for precise feeding systems. Sensor technology can also detect and diagnose diseases in livestock quickly. Livestock can be monitored and managed with the PLF system in real-time. Livestock production can be increased through PLF technology in two ways:

a. Enclosure environmental monitoring system

Livestock production can be increased, one way by monitoring or controlling the environmental conditions of the cage in the form of temperature, air velocity, ventilation rate, humidity, and concentrations of carbon dioxide and ammonia gases. PLF technology can be used to monitor and control the enclosure environment, for example, humidity regulation through changes in ventilation rates mediated by relative humidity sensors. The level of relative humidity can affect the health of livestock. It is also highly correlated with the concentration of ammonia and carbon dioxide in the cage. When the levels of these gases increase, a decline in production and health will occur (David *et al.* 2015). The multi-sensor system is proven to be able to effectively assess the ventilation function in the cage, tracking temperature, air velocity, and pressure differences in the cage (Bustamante *et al.* 2012). Even though sensor technology can effectively monitor environmental conditions in cattle pens, this sensor technology also has limitations that lie in the sensor nodes. Several sensor nodes are used for example to measure carbon dioxide in a special room. Individual sensors show a linear response to increasing the concentration of carbon dioxide, However, the appearance of these individuals is different which leads to differences in absolute carbon dioxide levels (Calvet *et al.* 2014). The sensor placement in the environment of the cage that, e.g., on the wall or in a high position does not always reflect the actual environmental conditions of the cattle pen space. It is important to calibrate the sensor every time it is used to monitor environmental conditions in the cage. This shows that the drilling system hurts the environment, especially in the climatic conditions of soil, plants, and fossil fuels which continue to decrease (Rosyidah *et al.* 2022). Another technology that can be used to monitor the environmental conditions of the cage is a robot that is designed as a small autonomously driven vehicle, runs on rails around the cage to monitor around the cage. The robot contains sensors that can evaluate the livestock pen environment in real time (McDougal, 2018). Robots like this allow the enclosure environment to be monitored remotely, reducing the need for labor to enter the cattle pen and increasing biosecurity.

b. Precision feeding systems

Feed has a very important role in the success of the livestock business. The PLF system can assist farmers in efficient feeding (proper feed conversion), producing maximum growth, or maintaining optimal body weight. New technologies can optimize feeding especially poultry feed. Broiler breeders usually consistently weigh the birds one by one and feed them according to the average weight of the birds. This is certainly not efficient, so we need a system that can weigh individual birds at once. The system is using ratification frequency identification. This precision feeding system results in efficient feed conversion (Hadinia *et al.* 2018).

2. Implementation of precision livestock farming (PLF) to improve livestock welfare

The development of genetic engineering has resulted in increased livestock productivity. However, this increase is not always balanced with livestock welfare, causing stress to livestock. Livestock needs comfort/welfare in life before being used by humans. Livestock welfare can be seen from changes in livestock behavior. Monitoring the behavior of livestock that shows welfare is not an easy thing. A technology is needed to monitor the welfare of the livestock. The ability to understand the welfare status of large numbers of livestock can be realized by the application of new technologies. Many non-invasive technologies enable the assessment of livestock welfare including:

a. Digital imaging

Digital Imaging can be used to determine livestock welfare by capturing movement patterns of livestock in pens or pastures for large livestock, such as gait, livestock weight, livestock density, diet, and livestock response to environmental conditions (Silvera *et al.* 2017) using eYeNamic™ i.e., surveillance camera and software system, which displays the camera above the cattle pen, the ability to assess gait scores of cattle, showing it as a scientific solution to assess inequality in beef cattle (Colles *et al.* 2016), chickens infected with *Campylobacter* (a bacterium) can be detected within 7 to 10 days after hatching. This is even though it usually does not cause clinical symptoms in chickens. *Campylobacter* is a common cause of foodborne illness in humans therefore, rapid detection may allow action to be taken to prevent further infection in other birds. There are members of the community who are relatively able to meet their financing needs, however, a few of the communities have not met their needs (Sungkawaningrum *et al.* 2022).

c. Voice analysis (Vocalization analysis)

The sound of livestock can be used as an indicator to know about the health and welfare of livestock. Fontana *et al.* (2015) were able to determine the peak frequency of broilers (600 Hz) which was randomly selected by recording the sound of the broiler for 38 days and this peak decreased as the broiler grew bigger (Manteuffel *et* *al.* 2004). Broilers will make a sound with a high frequency when there is distress. One of the technical obstacles in vocalization analysis is that the conditions in the cage should be calm, but not noisy.

d. Infrared thermal imaging

Infrared Thermal Imaging is a technique that can be used to assess livestock welfare with minimal invasiveness. It can determine the surface temperature of objects and create an image map with colors that represent the current temperature differences (Nääs *et al.* 2020). Heat stress can be detrimental to livestock health and body temperature is an indication of physiological abnormalities that can lead to increased mortality. Infrared Thermal Imaging can be used to detect livestock temperature after changes in diet, cage environment, and stress levels. Livestock monitoring with infrared technology also has the potential to help automate certain livestock procedures.

(Shinder *et al.* (2009) used infrared technology to measure the eggshell temperature of developing embryos, enabling the determination of the average embryo temperature. The results of this study exposed eggs, incubated at a temperature of 15 °C on the 18th or 19th day of incubation, which can increase the thermoregulation ability of hatching chicks, while reducing the incidence of ascites. Therefore, Infrared Thermal Imaging can enable manufacturers to accurately determine embryo development temperatures which may be important for future management strategies.

e. Raman Spectroscopy

A prominent welfare issue in the laying industry is the culling of one-day-old male chicks. Non-contact Raman spectroscopy is a technique that has been proven capable of assessing the sex of chicken embryos. This was done by analyzing the spectroscopic Raman profile of circulating embryonic blood from eggs that had just been incubated for 3.5 days (Galli *et al.* 2016). This technique of sexing developing embryos does not require a biological sample from the egg to be taken for analysis, but it does require removing and replacing a portion of the eggshell. This embryo sexing method allows male embryos to be removed before hatching. In addition, automated developments in-ovo sexing techniques can reduce the costs and labor associated with the current practice of sexing day-old embryos manually by skilled workers.

3. Livestock farming (PLF) to improve livestock health

Diseases in livestock will result in losses in the livestock business, therefore early detection of disease is very necessary. Farmers usually detect sick cattle by manually monitoring, and seeing changes in livestock behavior. However, this is not effective when the number of livestock is very large. Breeders will not be able to accurately detect individual diseases. Therefore, technology is needed to facilitate and speed up the detection of disease in chickens early, so that, losses caused by the disease can be immediately overcome, since the right and rapid detection and diagnosis can lead to rapid treatment which has the potential to reduce the spread of the disease to other livestock. Many technologies are used to detect disease, including:

a. Sensors for influenza virus

Influenza virus infection is a major concern for poultry farms. Rapid detection of influenza viruses is very important for the poultry industry, since early detection allows preventive measures to be taken more quickly, before the infection spreads within the farm or to other farms. In the past, traditional treatment for poultry infected with the influenza virus consisted of collecting samples from chickens after clinical symptoms appeared, followed by viral culture techniques or by PCR-based techniques (Okada *et al.* 2014). By measuring movement patterns using an accelerometer versus only measuring body temperature can provide a faster and more accurate detection of H5N1 virus infection in chickens. Accelerometers represent a relatively inexpensive sensor technology, as they are often incorporated into many smart devices.

b. Biosensor

Biosensors use receptors that use fixed molecules, including proteins, nucleic acids, or other materials, which are capable of detecting the presence of an entity (pathogen, protein, nucleic acid, etc.) in the sample and can transduce it into visual or electrical signals (Luka *et al.* 2015). Many biosensors are currently being developed that can determine, and directly detect influenza viruses, however, detection can be limited to a single subtype. This type of biosensor relies on the detection of specific molecular entities present in the virus. Chen & Neethirajan (2015) developed a test that can detect the hemagglutinin (HA) protein from the influenza virus. This sensor test uses a dual-probe system in which both probes should bind to the HA protein. The sensor is capable of detecting the HA proteins of the H_1 and H_5 viruses, the latter representing viruses that can cause pandemics in humans.

4. Internet of Things (IoT) /Big Data

As new sensors and technologies are introduced into farm operations, vast amounts of data are generated. Collecting, interpreting, and applying all this data will be a challenge for farm operations. This data should be stored and processed electronically to be understood and used by manufacturers. As data is generated by newly incorporated technologies, data collection, storage, and access systems should be established to maximize the usefulness of these technologies. IoT is a description of the infrastructure in which a wide variety of devices are connected to the internet, which is causing massive changes to the way people live and work (Morgan 2014). The IoT infrastructure consists of several components including hardware to collect data from the environment, connectivity to transmit data, software to store, analyze and process data, and interfaces. So that, users can interact with the IoT platform and can be accessed anytime and anywhere as long as they are connected to the internet, hence more practical, effective and efficient.

5. Future challenges and perspectives

5.1. Challenge

PLF and IoT technology still cannot be implemented properly, and widely, since there are still many obstacles and challenges that should be faced and solutions be found. So that, using these technologies can be optimally and widely implemented. The technology is usually adopted by the modern livestock industry on a large scale. However, for local/traditional breeders the adoption rate is still relatively small and almost none of them implement modern technology, since there are still many obstacles and limitations that local/traditional farmers have, including limited capital/cost. Technology in general is expensive, so not everyone can afford to adopt it. Other challenges in implementing PLF and IoT technology on livestock are as follows:

1. Despite the success of several expert experimental results, there are several questions and challenges surrounding the adoption of precision feeding systems into commercial production, including the cost and adaptability of these systems as well as the ability to work in large numbers. This of course should be studied further with the existence of new studies.
2. Implementation of IoT infrastructure in the livestock industry will require processes and procedures for data governance, data protection, and legal compliance to be established in order to ensure data quality and integrity.
3. More complex multi-device communications will face challenges that include heterogeneous device pools, individual device limitations (power supply, processing power, storage), and inconsistent access to the network

5.2. Future perspective

The merging of PLF and IoT technologies has far-reaching implications in the livestock sector and will be part of smart farming in the future. IoT-based PLF technology can monitor livestock production, welfare, and health anytime, anywhere. So, it is more practical, effective, and efficient as long as it is connected to the internet. The implementation of PLF and IoT technologies in livestock production systems consists of various smart devices connected to the internet that enable enhanced device communication, leading to some farm operations being automated, making humans just monitor the farm and act on processes that require much more levels. The main advantage that IoT provides for farms is the ability to communicate between sensors and equipment used on farms. An important feature of PLF is the automation of procedures. In the IoT network, various device communications can occur, such as device-device, human-device, and human-human communications. Simple communication can lead to the automation of many procedures, e.g., low feed levels can signal an automatic order for feed suppliers, or high humidity and ammonia gas levels detected by environmental sensors can send signals to increase ventilation rates.

The combination of these technologies can easily and quickly make decisions based on data.

Digital technology and information systems are very important to be implemented in all business sectors of life, including the agricultural livestock sector in rural areas, since they can improve food security. This has been proven by the number of countries that present technology is owned by a sophisticated industry. Therefore, the implementation of digital technology and information systems requires cooperation from all parties, the government, the private sector, as well as individuals, and the wider community, in addition to the involved generations

CONCLUSION

PLF and IoT technologies enable providing solutions to help meet projected global livestock product demand. Management automation in livestock business with the application of technology can increase the capacity of livestock production systems. The implementation of PLF technology can increase livestock productivity through monitoring the production, welfare, and health of livestock. Production monitoring through PLF can be done in two ways, including monitoring the cage environment and the precession feed system. The livestock welfare monitoring can be done in four ways, including digital imaging, vocalization analysis, infrared thermal imaging, and Raman spectroscopy, while livestock health monitoring can be done with sensors and biosensors. The data generated from PLF technology is stored in the IoT network, so that you can quickly make decisions anywhere and anytime.

REFERENCES

Astill, J, Dara, RA, Fraser, EDG, Roberts, B & Sharif, S 2020, Smart poultry management: Smart sensors, big data, and the internet of things. *Computers and Electronics in Agriculture*, 170: 105291.

Berckmans, D 2017, General introduction to precision livestock farming. *Animal Frontiers*, 7: 6–11.

Bing, F 2016, The research of IOT of agriculture based on three layers architecture. 2nd International Conference on Cloud Computing and Internet of Things (CCIOT), 162–165.

Bustamante, E, Guijarro, E, García Diego, FJ, Balasch, S, Hospitaler, A & Torres, AG 2012, Multisensor system for isotemporal measurements to assess indoor climatic conditions in poultry farms. *Sensors*, 12: 5752-5774.

Calvet, S, Campelo, JC, Estellés, F, Perles, A, Mercado, R & Serrano, JJ 2014, Suitability evaluation of multipoint simultaneous CO2 sampling wireless sensors for livestock buildings. *Sensors*, 14: 10479-10496.

Chen, L & Neethirajan, S 2015, A homogenous fluorescence quenching based assay for specific and sensitive detection of influenza virus A hemagglutinin antigen. *Sensors*, 15: 8852-8865.

Colles, FM, Cain, RJ, Nickson, T, Smith, AL, Roberts, SJ, Maiden, MCJ, Lunn, D & Dawkins, MS 2016, Monitoring chicken flock behaviour provides early warning of infection by human pathogen Campylobacter. Proceedings of the Royal Society B: Biological Sciences, 283: 20152323.

David, B, Mejdell, C, Michel, V, Lund, V & Oppermann Moe, R 2015, Air quality in alternative housing systems may have an impact on laying hen welfare. Part II—Ammonia. *Animals*, 5: 886-896.

Fontana, I, Tullo, E, Butterworth, A & Guarino, M 2015, An innovative approach to predict the growth in intensive poultry farming. *Computers and Electronics in Agriculture*, 119: 178-183.

Galli, R, Preusse, G, Uckermann, O, Bartels, T, Krautwald Junghanns, ME, Koch, E & Steiner, G 2016, In-ovo sexing of domestic chicken eggs by Raman spectroscopy. *Analytical Chemistry*, 88: 8657–8663.

Hadinia, SH, Carneiro, PRO, Ouellette, CA & Zuidhof, MJ 2018, Energy partitioning by broiler breeder pullets in skip-a-day and precision feeding systems. *Poultry Science*, 97: 4279–4289.

Hrustek, L 2020, Sustainability driven by agriculture through digital transformation. *Sustainability*, 12: 8596.

Indonesia, KPR 2014, Food outlook analysis 2015-2019. Summary Report, Center for Domestic Trade Policy. Ministry of Trade's Trade Policy Review and Development Agency, Indonesia.

Jayatun, A 2016, Automatic chicken feed system with renewable energy. ReTII, Indonesia.

Jung, J, Maeda, M, Chang, A, Bhandari, M, Ashapure, A & Landivar Bowles, J 2021, The potential of remote sensing and artificial intelligence as tools to improve the resilience of agriculture production systems. *Current Opinion in Biotechnology*, 70: 15-22.

Kurnia, D & Widiasih, V 2019, Implementation of Nodemcu in web-based automated and precision chicken feeding system prototypes. *Technology Journal*, 11: 169–178.

Kurniawan, C & Huda, M 2018, Design of a farm feeding system with a smartphone for Arduino Uno microcontroller-based layers, Indonesia.

Luka, G, Ahmadi, A, Najjaran, H, Alocilja, E, DeRosa, M, Wolthers, K, Malki, A, Aziz, H, Althani, A & Hoorfar, M 2015, Microfluidics integrated biosensors: A leading technology towards lab-on-a-chip and sensing applications. *Sensors*, 15: 30011-30031.

Manteuffel, G, Puppe, B & Schön, PC 2004, Vocalization of farm animals as a measure of welfare. *Applied Animal Behaviour Science*, 88: 163-182.

McDougal, T 2018, Poultry World - French poultry robot up and running. https://www.poultryworld.net/Meat/Articles/2018/1/Frenchpoultry-robot-up-and-running-231202E/

Morgan, J 2014, A simple explanation of the internet of things'. Retrieved November 20, 2015.

Nääs, IA Garcia, RG & Caldara, FR 2020, Infrared thermal image for assessing animal health and welfare. *Journal of Animal Behaviour and Biometeorology,* 2: 66-72.

Niknejad, N, Ismail, W, Bahari, M, Hendradi, R & Salleh, AZ 2021, Mapping the research trends on blockchain technology in food and agriculture industry: A bibliometric analysis. *Environmental Technology & Innovation*, 21: 101272.

Okada, H, Suzuki, K, Kenji, T & Itoh, T 2014, Applicability of wireless activity sensor network to avian influenza monitoring system in poultry farms. *Journal of Sensor Technology*. Vol. 4, No. 1, DOI: 10.4236/jst.2014.41003

Ozdogan, B, Gacar, A & Aktas, H 2017, Digital agriculture practices in the context of agriculture 4.0. *Journal of Economics Finance and Accounting*, 4: 186-193.

Ridhamuttaqin, A 2013, Design of fuzzy logic control based automatic chicken feeding system model. *Electrician*, 7: 125-137.

Rosyidah, M, Andiyan, A, Listyorini, H, Prayitno, PH, Yuswardi, Y & Yuhanah, Y 2022, LCA methodology for detecting environmental impacts on natural gas drilling process. *IOP Conference Series: Earth and Environmental Science*, 1041: 12035. https://doi.org/10.1088/1755-1315/1041/1/012035

Rosyidah, M, Khoirunnisa, N, Rofiatin, U, Asnah, A, Andiyan, A & Sari, D 2022, Measurement of key performance indicator Green Supply Chain Management (GSCM) in palm industry with green SCOR model. Materials Today: Proceedings.

Schepers, J, Shanahan, J & Liuchiari, A 2019, Precision agriculture for sustainability. Biological Resource Management Connecting Science and Policy, DOI: 10.1007/978-3-662-04033-1_10

Shinder, D, Rusal, M, Giloh, M & Yahav, S 2009, Effect of repetitive acute cold exposures during the last phase of broiler embryogenesis on cold resistance through the life span. *Poultry Science*, 88: 636-646.

Sidik, MA, Negara, TP & Zuraiyah, TA 2017, Sms Gateway Based Fish Feeding Tool Automation Model. *Journal of Feeding Tool Based on Sms Gateway.*

Silvera, AM, Knowles, TG, Butterworth, A, Berckmans, D, Vranken, E & Blokhuis, HJ 2017, Lameness assessment with automatic monitoring of activity in commercial broiler flocks. *Poultry Science*, 96: 2013-2017.

Smith, D, Lyle, S, Berry, A, Manning, N, Zaki, M & Neely, A 2015, Internet of animal health things opportunities and challenges data and analytics. *Internet of Animal Health Things*.

Sulandjari, K, Putra, A, Sulaminingsih, S, Adi Cakranegara, P, Yusroni, N & Andiyan, A 2022, Agricultural extension in the context of the Covid-19 pandemic: Issues and challenges in the field. *Caspian Journal of Environmental Sciences,* 20: 137-143. https://doi.org/10.22124/cjes.2022.5408

Sungkawaningrum, F, Hartono, S, Holle, MH, Gustiawan, W, Siskawati, E, Hasanah, N & Andiyan, A 2022, Determinants of Community Decisions To Lend Money To Loaners. *International Journal of Professional Business Review*, 7: e0510–e0510.

Thirumalaisamy, G, Muralidharan, J, Senthilkumar, S, Hema Sayee, R & Priyadharsini, M 2016, Cost-effective feeding of poultry. *International Journal of Science, Environment and Technology,* 5: 3997-4005.

Verdouw, C, Wolfert, S, Beers, G, Sundmaeker, H & Chatzikostas, G 2017, IOF 2020: Fostering business and software ecosystems for large-scale uptake of IoT in food and farming. The International Tri-Conference for Precision Agriculture.

Vernooij, A, Masaki, MN & Meijer Willems, D 2018, Regionalisation in poultry development in Eastern Africa (No. 1121). Wageningen Livestock Research. https://library.wur.nl/WebQuery/wurpubs/541134.

Wisjhnuadji, TW & Narendro, A 2017, Automatic chicken feed dispenser based on atmega microcontroller. 8535. *Semnasteknomedia Online*, 5: 2–7.

Wolfert, S, Ge, L, Verdouw, C & Bogaardt, MJ 2017, Big data in smart farming–a review. *Agricultural Systems*, 153: 69-80.

Yuda, AK 2016, Automatic Chicken Feeding and Drinking Equipment in Closed System Chicken Cage Based on RTC DS1307. Final Project, Faculty of Electrical Engineering, Padang State Polytechnic, Padang, Indonesia.

Zewge, A & Dittrich, Y 2017, Systematic mapping study of information technology for development in agriculture (the case of developing countries). *The Electronic Journal of Information Systems in Developing Countries*, 82: 1-25.

Bibliographic information of this paper for citing:

Widaningsih, N, Hartono, B, Utami, H, D, Rohaeni, E, S 2023, Implementation of technology and information systems (IOT) to support sustainable livestock development: Future challenges and perspectives. Caspian Journal of Environmental Sciences, 21: 457-465.