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Smart Farming for Farm Security: Mitigate Wild-Birds Intrusion in Agriculture Farms

Pankaj Raj Dhital
Department of Agricultural Extension and Rural Sociology
Agriculture and Forestry University, Rampur, Chitwan
Corresponding email: prdhital@afu.edu.np

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Abstract

The instances of wild bird intrusion in the standing crops cause significant losses to agricultural yields which needs for a creative and effective solutions. This study investigates a method to apply smart farming technology to this problem; for sustainable management of the issue by introducing Internet of Things (IoT) devices and automated deterrent systems, for small and medium farms, to develop a proactive and strong farm protection system. By combining these technologies, a more secure and sustainable farming environment may be created through real-time monitoring, early bird detection, and prompt response mechanisms. This is evidence of the IoTs' potential to revolutionize conventional farming methods, improve bird-human cooperation, and protect farmers' agricultural investments. The study explores potential ways to control birds' incursions into farmers' standing crop fields, particularly in Nepalese cereal-based farming systems. An approach to the issue would be to repel the approaching birds in farmland by using LED technology. The creative application of LED (Light Emitting Diode) technology serves as an inexpensive, practical method of keeping encroaching birds out of agricultural fields without endangering the animals or the farm. The results present an innovative way to deal with the difficulties posed by a variety of instances of animal-bird intrusion in agricultural lands, which contributes to the rapidly developing matter of wildlife and wild bird management. This approach can be a base for providing farmers with a practical, ethically acceptable, and ecologically sound way to reduce confrontations between humans and nature while preserving crops and birds that encourage sustainable coexistence.

Keywords: *Agricultural farmland, crop management, human-bird interaction, IoT, smart farming.*

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Introduction

Agriculture is one of the most important profession in the context of farmer's involvement and also the backbone of national economy providing livelihood for a more than two-thirds of the population. The majority of Nepal's GDP, or gross domestic product, is derived from agriculture. Although its GDP contribution declined from 36.64% in 2005–06 to 33.1% in 2014–15 and 25% in 2021, it maintained the largest economic sector (Pradhanang et al., 2015; GoN, 2021). Although 65.6% of the population is still employed in agriculture, Nepalese agriculture faces several challenges. Crop and tree farming remain the main sources of income for smallholder farmers from diverse social, cultural, and ethnic origins; occasionally, they also rear animals (Syan et al., 2019). The dominance of livestock, horticulture, and cereal farming in various parts of the nation should be taken into account for agricultural growth, as does the prevalence of integrated farming.

Challenges affecting modern agriculture include declining or stagnating food production, increasing instances of malnutrition, a reduction in arable land, contamination of the environment, a drop in the groundwater table, higher production costs, short-term farm earnings, jobs, etc. (Prakash et al., 2017). The demand for food grains is predicted to rise in a manner consistent with the 0.93 percent annual growth in Nepal's population (CBS, 2021). Since agriculture and rural areas comprise most of Nepal's economy, the country faces significant challenges in maintaining lucrative and sustainable farming practices due to the reduction of arable land (Paudel, 2016).

Reduced farm income and possible agrarian hardship are the effects of this reduction in farm area or landholdings without any substitute strategies for expanding revenue opportunities (Prakash et al., 2017). The majority of the population living in rural areas is made up of farmers. While the Nepal Agriculture Research Council (NARC) and affiliated organizations have recommended several promising crop production technologies, relatively few of these have been implemented on a commercial scale because of ineffective marketing strategies, varieties, or technologies that are not suitable for a given area, or limited access to marketing opportunities (Dhital & Joshi, 2017). Improving farmers' access to new and promising crop production technologies has been recognized as a critical step for increasing agricultural productivity.

Among many challenges faced by the farmers is the intrusion of wild animals and birds in the farmers' crop field stands high and presents a significant challenge for farmers, impacting agricultural productivity and economic stability (Bapat et al, 2017; Praveen, 2018). This avian invasion occurs in large flock and feast on crop fruits, grains and vegetables leading to a high loss in total farm production and productivity. Besides this loss in total production, the birds also cause collateral damage by crushing plants and contaminating the crops with their droppings, which further is also detrimental to human health and the produce to lose marketability. Birds such as crows, sparrows, starlings, and parrots often target standing crops during critical growth phases and consume seeds, fruits, and grains, and their activities can result in broken stems and damaged plants, further exacerbating losses. Farmers try or cope with these problems in their own strategies like reflective tapes, noise cannons, scarecrows, netting, and use of drones for deterrence (Rivadeneira et al., 2018; Mohamed, Naim & Abdullah, 2020).

Instances in Nepalese farming practice is to employ labor to deter and scare the birds during the peak production period to the date of harvest. This further causes the economic burden in the part of crop production. In some regions, the economic impact can be devastating, with farmers losing a substantial portion of their harvest, affecting their livelihood and food supply stability. The life of the wild birds are also in a risk due to the farmers' efforts in controlling the intrusion. Despite these efforts, the dynamic nature of bird behavior and their adaptability often make it difficult to completely eliminate the problem. However finding a balanced solution to protect crops from avian intrusion and preserving these wildlife remains a complex and challenging task for the

farm management in the agricultural system.

Methodology

This review article integrates insights from existing literature and field studies to explore innovative solutions for mitigating wild bird intrusions in agricultural farms. Relevant peer-reviewed articles, technical reports, and case studies were systematically reviewed to assess traditional and advanced deterrent strategies, including IoT-enabled technologies and LED-based deterrents. Key focus areas included the use of motion sensors, acoustic detection systems, and automated LED lights for proactive bird management. The reviewed studies were selected based on their relevance to Nepalese farming systems and their potential for sustainable crop protection. Findings were contextualized to address local challenges, emphasizing scalability and the integration of smart farming practices. The review also identified gaps in existing research to highlight areas for future innovation in farm security.

Results

Farmers' strategy to protect wild bird intrusion in crop field

There are no any bird deterrents that possibly assure complete protection from intruding birds but most of the prevalent methods focus on explosive noises, making the target area threatful to the approaching birds, making other crops more attractive, manipulation of the habitat, and netting, but still, the bird scaring and population reduction is found to be ineffective (Bomford & Sinclair 2002). More success is seen in cases where there are integration of multiple techniques and efforts around the calendar. Review and field reports about bird damage in 19 crops by Gebhardt et al. (2011) found that the avian intrusion and damage still remains significant where a wide variety of bird control methods, including avicides, trapping, exclusion, and chemical aversion were being used to deter the birds. When three bird deterrent systems i.e. visual, acoustic, and falconry were tested, the most effective was the visual scaring, indicating that an effective deterrent must immediately respond to the presence of birds to reduce the probability of attaching the crop field. Since there are no bird deterrents that work all the time in every situation with lasting effects, a variety of techniques that together provide the best results (Soldatini et al. 2008). Birds are a critical part of every ecosystem, offering ecosystem services that are not always acknowledged, including pest control in agricultural fields. The coexistence of birds with agriculture is not a new concept, but it has become one of the most challenging endeavors.

Crop loss due to wild bird intrusion in standing crops is a pervasive problem that affects farmers worldwide. Farmer in their own are using their own traditional to more sophisticated measure to crop field protection. We find multifaceted approach that combines physical, auditory, visual, and sometimes chemical deterrent in controlling crop loss due to wild bird intrusion (Baral et al, 2019). Commonly seen approaches found in the farmers field are like Physical Barriers – netting (covering crops with bird netting and particularly useful for high-value crops such as fruits); Fencing (Installing fences, especially those with an electric component); noise Cannons (propane cannons that emit loud noises at intervals scare birds away); recorded bird calls (Playing distress calls of specific bird species); visual deterrents like traditional scarecrows; reflective tape and objects; Predator decoys: life-like models of predators such as hawks, owls; Chemical Repellents like taste aversive that make crops taste bad to birds and reduce their interest in feeding on them (Dyck & Warbick, 2017). Some techniques of biological controls like encouraging natural predators, timing of crop planting, crop rotation and diversification also help the management to certain extents. Some of the major strategies to avian control in agricultural management are highlighted (see Table 1).

Table 1. Bird deterrents commonly used to protect fresh produce fields from nuisance birds.

Category	Specific Type
Visual	Reflective tapes, Dyes or colorants, Balloons, Kites, Predator models, Kite hawks, Flags, Lights (flashing, rotating, strobe, searchlights), Humans, Dogs, Scarecrows, Drones, Mirrors, Lasers, Reflectors,
Auditory	Screamers, Whistlers, Gunfire, Propane sound cannons, Ultrasonic sounds, Sonic net, High intensity sounds,
Tactile	Sticky substances, Spikes
Habitat modification	Lure crops, Bait stations, Removal of roost structures, food, and shelter Sacrificial crops
Exclusion	Nets, Anti-perching devices, Electric fencing, Overhead wires
Chemical	Methyl anthranilate, DRC-1339, Anthraquinone, Keyplex-350, Measurol
Reproductive	Chemo-sterilants, Contraceptives, Immune contraceptive vaccines
Lethal	Shooting, Avicide, Nest and Egg destruction,
Multi-faceted	Optical gel, Pyrotechnics, Falconry, Drones

Source: Dyck & Warbick, 2017; Baral et al, 2019; Lindell, 2020; Pruteanu et al., 2023)

Smart deterrents can be a valuable tool in the fight against bird intrusion in crop fields. When used correctly and in conjunction with other deterrent methods, they can significantly reduce crop losses due to birds (Rehman et al, 2022). However, as with any pest control measure, it's important to tailor the approach to the specific circumstances and continually adapt to the behavior of the target bird species (Rehman et al., 2022).

Smart LED options in management of avian intrusion

The current demand for sustainable management of agricultural management issues is driving the introduction of smart farming and Internet of Things (IoT) devices on small and medium farms. This concept is equally applicable and important in management of the avian invasion in the crop fields. Internet of Things (IoT) promotes the use and interconnecting network of systems and devices; that collect, share, and analyze data to enhance agricultural management (Raj et al., 2021; Tzounis et al., 2017). These devices in agriculture include sensors, cameras, drones, automated tools and devices. IoT for smart farm security aims to create smarter, more sustainable management option for protection the crop field and control avian intrusion while minimizing environmental impact (Perwej et al., 2019; Ayaz et al., 2017)

The approach focuses on the creation of an automated "ledger light" system that uses carefully positioned LED lights to make the field regions visually undesirable to the birds. This system is controlled by motion camera sensors or sound detection. The particular light spectrum and patterns that are repulsive to the specific wild birds are then produced by the ledger light. This novel approach not only tackles the problem of preventing birds from damaging crops, but it also advances sustainable farming methods. Together with a concept of smart, tech-friendly IoT use in the Nepalese farming system, these ideas offer a promising alternative for farmers seeking compassionate and non-intrusive ways to decrease human-wildlife conflicts in agricultural environments. The use of cameras, sensors, and LED (Light Emitting Diode) automated deterrent systems, which collectively contribute to creating a proactive and robust farm protection system (Sayem et al., 2023; Ubina & Cheng, 2022). Cameras enable continuous monitoring of the farm, quickly identification of the intruding birds and respond to potential threats or unauthorized intrusions. An effective approach to using sensors for identifying when a bird is approaching a predefined field involves deploying a combination of motion detection and ultrasonic sensors, coupled with an LED light emitting source as an appropriate response top the motion or sound detection.

Detection of birds in crop fields

The first step in the development of an effective deterrent system for avian intrusion in crop fields is the accurate detection of birds. Recent advancements in mobility and sound sensors have significantly enhanced our ability to detect birds approaching crop fields, providing a solid foundation for developing responsive deterrent systems. Both radar system and infrared sensors

are applicable for mobility detection in this step. Ground-based radar systems can detect the movement of birds over large areas (Hüppop et al., 2019; Bonter, Gauthreaux Jr & Donovan, 2009). These systems are capable of tracking the speed, direction, and altitude of flying birds, providing real-time data that can be used to trigger deterrents. Infrared sensors can detect the heat signatures of birds, making it possible to identify their presence even in low light or nighttime conditions. These sensors can often be used in combination with other detection methods to enhance accuracy.

Acoustic Sensors and microphones on the other hand can be used as an alternative detection system. These sensors detect the sounds made by birds, such as calls and wing flapping (Boulmaiz et al., 2020; Blumstein et al., 2011). By analyzing these sounds, the system can identify the species and number of birds, allowing for tailored deterrent responses. Advanced acoustic sensors can also be used to filter out background noise to improve detection accuracy. Arrays of microphones can be placed around the crop field which can further triangulate the position of birds based on their sounds. This method provides precise localization, enabling further action.

LED based smart deterrent system

Once the detection of the intruding bird is accomplished, the next step is to automatically trigger the deterrent system. This can be achieved by using LED ledger lights that focus in the direction of the detected birds. These lights can effectively irritate and repel the birds, helping to protect the crops The LED ledger lights emit high-intensity, focused beams that are irritating to birds (Seamans, & Gosser, 2016). The lights may also use specific wavelengths and patterns known to be particularly disruptive to avian vision. Strobe or flashing patterns can be used to enhance the deterrent effect, as continuous light may not be as effective over time. These lights are strategically placed around the crop field and should be installed with the capability to rotate and focus their beams in the required direction to ensure effective coverage to focus on the detected birds.

Control and power system

The preliminary data from the sensors during avian detection are combined to improve the reliability and accuracy of bird detection. Data fusion algorithms process and integrate inputs from various sensors to provide a comprehensive picture of bird activity in and around the crop field. This real-time monitoring and analysis of sensor data are used to control the ledger lights activation for a Responsive Deterrent System. The system is then developed with automated activation, i.e. once birds are detected, the system can automatically activate the ledger lights with the effect of deterring the detected birds. LED lights can be designed to be energy-efficient, with solar panels and battery storage as potential power sources, ensuring continuous operation when there is a lack of power supply in the field. Farmers can monitor and control the LED deterrent system remotely via a mobile app or web interface. This allows for real-time adjustments and immediate responses to any issues that arise. Notifications can be set up to alert farmers when birds are detected and when deterrent measures are activated.

Advantage of LED based farm security system

It creates a visual disturbance that is highly effective in repelling birds without causing harm, ensuring that crops are protected. The system will be non-intrusive and does not cause noise pollution, making it suitable for use in areas close to human habitation (Hossain et al., 2020). Utilizing energy-efficient LED technology and renewable energy sources such as solar power enhances the sustainability of the system. The system can be scaled to fit different field sizes and can be adapted to various types of crops and bird species (Bevins et al., 2014).

Discussion and conclusion

Discussion

The sustainability in farming is an area of special interest in the current time. The study from Adams et al., specifically stressed in no any harmful effects to intruding birds because of the light based deterrent system. Cassidy (2015) also

found impactful role of laser light system to deter the avian intrusion in crop field. He stressed that the birds are more responsive to the different wavelength of the light system and are less effected but according to Clarke (2004) this light based deterrent system is more applicable in the day period rather than the dark nights. According to Saha (2024) and Baranwal and Pateriya (2016), the current trend is in application of smart farming and IoT in farm management and farm security. This is more effective and more practical in both small and large farms. The study of Bapat et al. (2017); Rama, Jeya and Tharshiniya (2021) was supported by the study of Dhaliwal, Nahid and Abbas (2018), who found that studying data in a network and analyzing the pattern and volume of data leads to the emergence of a solid Intrusion Detection System (IDS), that keeps the network healthy and a safe place to share confidential information. In a review of the economics of use of the modern IoT and smart farming techniques in the developing nations, Jaiswal et al. (2019) have found this application is fully economic and more practical in long term in case of small to large farms in the developing nation. Thus it can be stressfully concluded that a sustainable effort to reduce the crop loss of the farmers and at the same time an effort to conserve the wild birds can be obtained by the use of smart techniques of avian deterrent system developed by using the IoT which is also supported by the findings of Mapari (2022) which they have studied with the ioT application in the deterrent of avian intrusion through smart scarecrow system. This integration of the sensor data from the detection system to the deterrent system makes an effective application of the farm security from the wild birds' intrusion in the crop fields.

Conclusion

There is a need to reduce the crop loss due to avian intrusion in the field especially when it is near to harvest. The life of the wild birds are also in a risk due to the farmers efforts in controlling the intrusion. The development of an automated LED ledger light deterrent system, triggered by a sophisticated bird detection system, represents a significant advancement in protecting crops from avian intrusion. By leveraging high-intensity, focused LED lights that irritate and repel birds, farmers can ensure effective crop protection while minimizing environmental impact and operational costs. This innovative approach offers a sustainable and efficient solution to the longstanding problem of bird damage in agriculture. This balanced solution helps to deal with complex and challenging tasks for the farm management in agricultural system by protecting crops from avian intrusion and preserving these wildlife remains.

References

Adams, C. A., Fernández-Juricic, E., Bayne, E. M., & St. Clair, C. C. (2021). Effects of artificial light on bird movement and distribution: a systematic map. Environmental Evidence, 10, 1-28.

Ayaz, M., Ammad-Uddin, M., Sharif, Z., Mansour, A., & Aggoune, E. H. M. (2019). Internet-of

-Things (IoT)-based smart agriculture: Toward making the fields talk. IEEE access, 7, 129551-129583.

Bapat, V., Kale, P., Shinde, V., Deshpande, N., & Shaligram, A. (2017). WSN application for crop protection to divert animal intrusions in the agricultural land. Computers and electronics in agriculture, 133, 88-96.

Baral, S. S., Swarnkar, R., Kothiya, A. V., Monpara, A. M., & Chavda, S. K. (2019). Bird repeller–a review. Int. J. Curr. Microbiol. Appl. Sci, 8, 1035-1039.

Baranwal, T., & Pateriya, P. K. (2016, January). Development of IoT based smart security and monitoring devices for agriculture. In 2016 6th International Conference-Cloud System and Big Data Engineering (Confluence) (pp. 597-602). IEEE.

Bevins, S. N., Pedersen, K., Lutman, M. W., Baroch, J. A., Schmit, B. S., Kohler, D., ... & DeLiberto, T. J. (2014). Large-scale avian influenza surveillance in wild birds throughout the United States. PLoS One, 9(8), e104360.

Blumstein, D. T., Mennill, D. J., Clemins, P., Girod, L., Yao, K., Patricelli, G., ... & Kirschel,

A. N. (2011). Acoustic monitoring in terrestrial environments using microphone arrays: applications, technological considerations and prospectus. Journal of Applied Ecology, 48(3), 758-767

Bomford M, Sinclair R. (2002) Australian research on bird pests: impact, management and future directions. Emu 102: 29–45. https://doi.org/10.1071/MU01028.

Bonter, D. N., Gauthreaux Jr, S. A., & Donovan, T. M. (2009). Characteristics of important stopover locations for migrating birds: remote sensing with radar in the Great Lakes Basin. Conservation Biology, 23(2), 440-448.

Boulmaiz, A., Doghmane, N., Harize, S., Kouadria, N., & Messadeg, D. (2020). The use of WSN (wireless sensor network) in the surveillance of endangered bird species. In Advances in ubiquitous computing (pp. 261-306). Academic Press

Cassidy, F. L. (2015). The potential of lasers as deterrents to protect birds in the Alberta oil sands and other areas of human-bird conflict. I could not find link. See below.

Cassidy, F. L. (2015). The Potential of Lasers as Deterrents to Protect Birds in the Alberta Oil Sands and Other Areas of Human-Bird Conflict. ERA. https://era.library.ualberta.ca/items/eb4bd848-32ed-456c-ae8c-6624178148e5.

CBS (2021). Population Census 2021. Central Bureau of Statistics, Government of Nepal, Kathmandu, Nepal. https://censusnepal.cbs.gov.np/results/files/result-folder/National%20Report_English.pdf

Clarke, T. L. (2004). An autonomous bird deterrent system. Queensland: University of Southern Queensland. https://sear.unisq.edu.au/64/

Dhaliwal, S., Nahid, A.-A., & Abbas, R. (2018). Effective Intrusion Detection System Using XGBoost. Information, 9 (7), 149. Shift this source in your references section

Dhital, P. R., & Joshi, N. R. (2016). Factors affecting adoption of recommended cauliflower production technology in Nepal. Turkish Journal of Agriculture-Food Science and Technology, 4(5), 378-383. https://doi.org/10.24925/turjaf.v4i5.378-383.637

Dyck, J., & Warbick, J. (2017). Bird control in horticultural crops. Ministry of Agriculture, Food and Rural Affairs, 17-029.

Gebhardt, K., Anderson, A. M., Kirkpatrick, K. N., & Shwiff, S. A. (2011). A review and synthesis of bird and rodent damage estimates to select California crops. Crop Protection, 30, 1109–1116. https://doi.org/10.1016/j.cropro.2011.05.015

GoN (2021). Economic Survey report: Fiscal year 2020/21. National Planning Commission. Government of Nepal. https://npc.gov.np/en/category/agriculture_forestry

Hossain, R., Biswas, H., Banna, M. H. A., & Degadwala, S. (2020). Design and implementation of smart security system for farm protection from intruders. Int. J. Sci. Res. Comput. Sci. Eng. Inf. Technol., 250-263.DOI: 102550382/91717838/s200_riyad

Hüppop, O., Ciach, M., Diehl, R., Reynolds, D. R., Stepanian, P. M., & Menz, M. H. (2019). Perspectives and challenges for the use of radar in biological conservation. Ecography, 42(5), 912-930.

Jaiswal, S. P., Bhadoria, V. S., Agrawal, A., & Ahuja, H. (2019). Internet of Things (IoT) for smart agriculture and farming in developing nations. International Journal of Scientific & Technology Research, 8(12), 1049-1056.

Lindell, C. A. (2020). Supporting farmer adoption of sustainable bird management strategies. Human–Wildlife Interactions, 14(3), 14?

Mapari, R., Bhangale, K., Deshmukh, L., Gode, P., & Gaikwad, A. (2022). Agriculture protection from animals using smart scarecrow system. In Soft Computing for Security Applications: Proceedings of ICSCS 2021 (pp. 539-551). Springer Singapore.

Mohamed, W. M. W., Naim, M. N. M., & Abdullah, A. (2020, April). The efficacy of visual and auditory bird scaring techniques using drone at paddy fields. IOP Conference Series: Materials

Science and Engineering, 834(1), 012072. https://doi.org/10.1088/1757-899X/834/1/012072

Paudel, M. N. (2016). Prospects and limitations of agriculture industrialization in Nepal. Agronomy Journal of Nepal, 4, 38–63. https://doi.org/http://dx.doi.org/ 10.3126/ajn.v4i0.15515

Perwej, Y., Haq, K., Parwej, F., Mumdouh, M., & Hassan, M. (2019). The internet of things (IoT) and its application domains. International Journal of Computer Applications, 975(8887), 182.

Pradhanang, U. B., Pradhanang, S. M., Sthapit, A., Krakauer, N. Y., Jha, A., & Lakhankar, T. (2015). National livestock policy of Nepal: Needs and opportunities. Agriculture, 5(1), 103–131. https://doi.org/10.3390/agriculture5010103.

Prakash, N., Roy, S. S., Ansari, M. A., & Sharma, S. K. (2017). A comprehensive manual on integrated farming system: An approach towards livelihood security and natural resource, (February). https://doi.org/10.13140/RG.2.2.24570.49609

Praveen, M. (2018). Iot-based wild animal intrusion detection system. International Journal on Recent and Innovation Trends in Computing and Communication, 6(7), 06-08.

Pruteanu, A., Vanghele, N., Cujbescu, D., Nitu, M., & Gageanu, (2023) Review of effectiveness of visual and auditory bird scaring techniques in agriculture. Engineering for Rural Development.

Raj, M., Gupta, S., Chamola, V., Elhence, A., Garg, T., Atiquzzaman, M., & Niyato, D. (2021). A survey on the role of Internet of Things for adopting and promoting Agriculture 4.0. Journal of Network and Computer Applications, 187, 103107.Rama, P., Jeya, T., & Tharshiniya, T. (2021). Smart Formland For Crop Prevention And Animal Intrusion Detection. Turkish Online Journal of Qualitative Inquiry, 12(6). 6400-6410

Rehman, A., Saba, T., Kashif, M., Fati, S. M., Bahaj, S. A., & Chaudhry, H. (2022). A revisit of internet of things technologies for monitoring and control strategies in smart agriculture. Agronomy, 12(1), 127.

Rivadeneira, P., Kross, S., Navarro-Gonzalez, N., & Jay-Russell, M. (2018). A review of bird deterrents used in agriculture. Proceedings of the Vertebrate Pest Conference, 28(28).

Saha, H. N., Roy, R., Chakraborty, M., & Sarkar, C. (2021). Development of IoT-based smart security and monitoring devices for agriculture. Agricultural informatics: automation using the IoT and machine learning, 147-169.

Sayem, N. S., Chowdhury, S., Haque, A. O., Ali, M. R., Alam, M. S., Ahamed, S., & Saha, C. K. (2023). Iot-based smart protection system to address agro-farm security challenges in Bangladesh. Smart Agricultural Technology, 6, 100358.

Seamans, T. W., & Gosser, A. L. (2016). Bird dispersal techniques. Wildlife Damage Management Technical Series. U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife Research Center. https://www.aphis.usda.gov/sites/default/files/Bird-Dispersal-Techniques-WDM-Technical-Series.pdf

Soldatini, C., Albores-Barajas, Y. V., Torricelli, P., & Mainardi, D. (2008). Testing the efficacy of deterring systems in two gull species. Applied Animal Behaviour Science, 110(3-4), 330-340.

Syan, A. S., Kumar, V., Sandhu, V., & Hundal, B. S. (2019). Empirical analysis of farmers' intention to adopt sustainable agricultural practices. Asia-Pacific Journal of Management Research and Innovation, 15(1–2), 39–52. https://doi.org/10.1177 /2319510X19848857

Tzounis, A., Katsoulas, N., Bartzanas, T., & Kittas, C. (2017). Internet of Things in agriculture, recent advances and future challenges. Biosystems engineering, 164, 31-48.

Ubina, N. A., & Cheng, S. C. (2022). A review of unmanned system technologies with its application to aquaculture farm monitoring and management. Drones, 6(1), 12.