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AUTOMATED BIRD SCARING SYSTEM: A REVIEW

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ABSTRACT

Birds are a considerable menace to crop farming, resulting in major economic detriment through crop damage. Conventional avian deterrence techniques, including scarecrows, reflecting substances, and chemical repellents, have demonstrated ineffectiveness over time due to habituation. This research examines diverse ways for bird detection and deterrent, classifying them into singular and multimodal approaches. Contemporary innovations, like as artificial intelligence (AI), drones, machine vision, and deep learning-based detection, have markedly enhanced the efficacy of avian management systems. The review emphasises the advantages of combining detection with adaptive deterrence strategies, including Unmanned Aerial Vehicle (UAV)-based acoustic deterrents, AI-driven repellent systems, and laser-based frightening techniques. Moreover, multimodal deterrence—integrating visual, aural, and physical barriers—demonstrates the most efficacy in mitigating avian-related damage. The paper indicates that subsequent research should prioritise the development of cost-efficient, automated, and species-specific deterrent methods that reduce habituation and improve sustainability in crop protection.

INTRODUCTION

Birds constitute a huge threat to crop farming worldwide, causing substantial economic harm to crops. The devastation produced by certain bird species can be particularly destructive, as they can entirely destroy entire crops. With at least 60 recognised species of birds that eat on and damage cereals and horticulture crops, it is tough to develop a generally efficient means of repelling them. Diverse avian species exhibit distinct eating and locomotion behaviours, complicating the formulation of a universal solution. In some locations, ducks with sharp eyesight, starlings, woodpeckers, blackbirds, pigeons, parrots, skylarks, crows, and ravens are among the bird species that attack diverse crops like celery, lettuce, wine grapes, sunflowers, and peas. (Augustina *et al.,* 2023). The economic impact of bird damage is multifaceted, involving direct yield losses, increased management costs, and reduced marketability of crops (Sausse *et al.,* 2021). Studies on crop damage during a 15-year period found thousands of occurrences, contributing to large losses in diverse crops (Kumar *et al.,* 2025). The most harmful bird species included common cranes, barnacle geese, greylag geese, bean geese, and whooper swans, with the majority of losses related to the first three species (Clausen *et al.,* 2022). A minor percentage of total crop damage was caused by other bird species. Also crop losses in cereals crops are mostly attributable to birds like White Manikin *Spermestes bicolor*, Vieillot's Black Weaver *Ploceus nigerrimus* Redheaded Quelea *Quelea erythrops*, Red-eyed Dove *Streptopelia semitorquata*, and Laughing Dove *Streptopelia senegalensis* (Odewumi, 2024).

Traditional methods of scaring birds

Various strategies have been used over time to limit bird assaults on crops and minimize damage (Micaelo *et al.,* 2023). Simple deterrents such as kites, balloons, reflective strips, mirrors, scarecrows, and trained or natural predators like falcons and owls are widely deployed. However, these tactics tend to be useless in the long run, as birds quickly adjust and disregard them. Physical repellents, like thorns, nets, artificial nests, and habitat change, give another alternative (Thakur *et al.,* 2021). Nets are the most effective physical barrier, however, they are expensive and do not ensure complete protection, as birds may still discover methods to get crops (Angkaew *et al.,* 2022). Trap cages can assist lower bird populations but are not cost-effective due to their limited influence. Habitat change, such as tree removal, revegetation, and altering water supplies, can make regions less appealing to birds. Chemical repellents, including sticky chemicals, taste-based deterrents, and synthetic pesticides, give a higher effectiveness rate but pose dangers to humans and other wildlife. Due to its toxicity, their use is limited and usually discouraged. Electronic bird repelling gadgets give a more advanced option, combining acoustic and visual cues to terrify and disorient birds (Ade-Omowaye *et al.,* 2024). These devices offer advantages such as quick installation, energy efficiency, extensive coverage, and a small design, making them more effective than traditional deterrents. (Augustina *et al.,* 2023).

Various methods of birds' deterrence and detection as reported by several researchers are presented in Table 1, while Table 2 shows researchers that worked on bird detection only. Globally, the utilisation of intelligent protection systems in agriculture is gradually expanding. Compared to older approaches, these technologies provide increasingly detailed data on agricultural conditions, bird species, pests, and other pertinent elements. Additionally, the economic benefits of adopting intelligent crop control systems play a key part in securing agricultural holdings and successfully managing pests (Rehman *et al.,* 2022). As a result, several devices have been created to dissuade birds from harming crops, such as a smart light emitter meant to scare birds away from specific agricultural zones.

Table 1: Bird detection and deterrent system

Study	Deterrent method	Detection method
Mohammed *et al.* (2020)	Visual and Auditory Bird Scaring Techniques deployed on Drone	
Macroň *et al.* (2021)	Actuator (Loud speaker or laser)	Artificial intelligence, Convolutional Neural Network (CNN)
Brown and Brown (2021)	Laser scarecrow	
Aboltins *et al.* (2021)	Auditory technique. Frequency modulated sounds generated by Direct digital synthesis signals	
Lee *et al.* (2021)	Reinforcement learning for auditory deterrent	
Uzma *et al.,* (2021)	Solar powered audible repellant	
Snow *et al.* (2021)	Inflatable scarecrow, physical barriers, chemical repellant	
Murthi *et al.* (2021)	Audio deterrent method	Motion detector to detect bird presence
Pecaso (2021)	Visual deterrent system	
Bhusal *et al.* (2022)	auditory deterrent deployed on UAV	Machine vision system
Dokey *et al.,* (2022)	Smart Scarecrow	Passive Infrared Resistor (PIR) for detection
Agossou *et al.* (2022)	Auditory, visual (scarecrow), reflective material	
Storms *et al.* (2022)	Robot Falcon as artificial predator	
Ajayi and Akanmu (2022)	Inflatable scarecrow as visual deterrent	PIR sensors
Micaelo *et al.* (2023)	Scarecrow, reflective tubes, predator models, chemical, auditory and visual barriers	
Augustina *et al.* (2023)	Visual, auditory and physical barriers	
Mhandu *et al.* (2023)	Scarecrow that produces sound	PIR sensors
Yauri *et al.* (2023)	Audio deterrent method	PIR sensor for detection
Werber *et al.* (2023)	Auditory and visual signals	
Chen *et al.* (2024)	Laser mechanism for deterrent	Deep learning for detection
Mano and Sandhiya (2024)	Audio and visual deterrent method	A sensor that detects bird presence
Varriano *et al.* (2025)	Micro-drone with Light Detection and Ranging (LIDAR) technology	LIDAR sensor

Table 2: Bird Detection System only

Study	Detection method
Raj *et al.* (2020)	CNN Visual Geometry Group Network (VGGNet)
Ummah *et al.* (2022)	Visual AI model You Only Look Once (YOLO) V4
Venkatachalam *et al.* (2023)	Transfer learning approach with MobileNet V2
Biswas and Tiwari (2024)	Computer vision and Deep learning
Mallick and Mohanta (2024)	Drone with Sprinkler mechanism
Said *et al.* (2024)	Using deep learning through Spatial Temporal -CNN (ST-CNN)

Modes of Detection

A key component of efficient bird management is bird detection, which enables prompt actions to regulate urban bird populations, reduce aviation dangers, and stop crop damage. Radar tracking, acoustic monitoring, and vision-based recognition are a few of the different detection techniques used to recognise and react to bird behaviour (Ummah *et al.,* 2022).

The crucial problem of bird strikes which happen when birds crash with aircraft during different flying phases was reported by Ummah *et al.* (2022). Numerous deadly incidents have been caused by bird strikes, which present serious safety hazards. Bird activity around airports has not significantly decreased despite the use of current bird control techniques like physical surveillance and aural deterrents. In order to improve safety and facilitate prompt actions, the study aims to develop a visual artificial intelligence (AI) model for identifying birds at airports. The YOLOv4 object identification algorithm was used to develop a bird detection system. A collection of 1,400 photos of birds was gathered from Google Images, shared into Training (80%) and testing (20%) dataset. To increase detection quality under different environmental situations, the photos were subjected to a number of filtering procedures, including image dehazing, edge enhancement, and greyscale conversion. An optimized hyper-parameters were used to train the YOLOv4 model. 4,100 iterations were used in the training process, with an emphasis on accuracy and loss minimisation. 71.89% was the mean Average Precision (mAP) attained. The system was created to allow for webcam-based real-time bird detection. When birds were spotted, it had capabilities that could notify operators both visually and audibly. In order to help airport operations with spatial awareness, the model was created to compute the x-y coordinates of birds that were spotted. To assess performance in various scenarios (bright, dark, foggy), the YOLOv4 model's efficacy was contrasted with conventional motion detection techniques. The findings showed that in a variety of situations, the YOLOv4-based bird detection system performed better than conventional motion detection techniques. In a variety of situations, the system showed excellent accuracy in identifying birds, reaching a maximum accuracy of 100% in close-range fog and retaining 30–90% accuracy in other situations. False Positives (FP): 133, False Negatives (FN): 56, True Positives

(TP): 216, Precision: 0.62, Recall: 0.79, F1-Score: 0.70, and Mean Average Precision (mAP): 71.89% are among the training results obtained. In terms of detection reliability, the YOLOv4 model consistently outperformed motion detection, especially under difficult circumstances like fog or low light.

Using a single-mode detection framework, Raj *et al.* (2020) showed that a CNN model built on a VGGNet-inspired architecture can successfully and accurately classify 60 bird species from photos. The study tackled the problem of differentiating between bird species, which is crucial for academics and birdwatchers. Using CNN, a deep learning model was created to automatically identify 60 different bird species. Using Microsoft's Bing Image Search API, a collection of 8,218 photos of 60 different kinds of birds was collected. With several convolutional and pooling layers intended to extract information from bird photos, the architecture was modelled after VGGNet. 20% of the dataset was put aside for testing, and the remaining 80% was used for training. With an accuracy of 84.91% on the testing set and 93.19% on the training set, the model was trained using the Keras library. The CNN's ability to effectively differentiate between several bird species from photos was demonstrated by its high classification accuracy. An interface was also developed that allows users to upload images and receive predictions on the bird species.

A transfer learning technique using MobileNetV2 was used in a comparable application by Venkatachalam *et al.* (2023) to precisely identify farm disturbance birds from live video feeds. The problem of controlling bird populations in agricultural environments, where certain species can seriously harm crops, was the focus of the study. To identify farm disturbance birds, a deep learning-based algorithm was created and proposed. To improve the accuracy of bird detection, the study used a transfer learning strategy with the MobileNetV2 architecture. An image dataset of birds was used to train the model. Several augmentation techniques were applied to expand the amount of the training dataset, which enhanced the performance and resilience of the model. The model's ability to identify farm disturbance birds was assessed using real-time video settings. It was discovered that the suggested model had efficient classification capabilities by detecting a variety of bird species classified as farm disturbances with about 100% accuracy. After processing live video feeds successfully, the system instantly gave feedback on the birds it had spotted and the degree of confidence in each identification.

Together, these experiments indicate that a focused detection mode can simplify system design while assuring robust and efficient performance across varied applications. While single-mode detection systems have proven useful in focused applications, adding multimode detection might further boost system robustness by exploiting multiple data sources. For instance, Said *et al.* (2024) discussed the critical issue of bird strikes in aviation, which pose significant safety risks and economic costs. A deep learning system was created for real-time bird detection utilising aerial data. The framework leverages ST-CNN that integrates spatial attention processes and temporal analysis to improve detection accuracy. A comprehensive dataset of bird images was collected, including various species and flight patterns. Image augmentation techniques were applied to boost the dataset's diversity. The model was tested against numerous benchmarks, including

Faster R-CNN, R-FCN, SSD, RetinaNet, and YOLO, with performance measures like as precision, recall, and F1 score being examined. It was discovered that the proposed model attained a precision of 97% and an accuracy of 96%, exceeding existing models in spotting birds in complicated situations. The model demonstrated competitive inference times (about 45 ms), making it ideal for real-time applications in flight safety.

Bird Deterrent System

A review of singular mode deterrent techniques suggests that providing a single, targeted signal can effectively alleviate bird-related difficulties across varied environments. Brown & Brown (2021) invented an automated laser scarecrow that utilizes moving green laser beams (532 nm) to prevent bird damage in sweet corn fields, giving a less disruptive alternative to classic propane cannons. The study analysed the performance of automated laser scarecrows as a novel method for decreasing bird damage in sweet corn fields, hoping to provide a more sustainable and less disruptive option. The team built a portable, battery-powered robotic scarecrow that produces moving green laser beams (532 nm wavelength) to repel birds. A split-field experimental design was used across three years, where half of each sweet corn field was treated with the laser while the other half served as a control. The efficiency of the laser scarecrow was measured based on the number of damaged ears in both treated and control areas. The fields had histories of severe bird damage, and the laser scarecrows were planted strategically in respect to bird roosting locations. Damage assessments were performed by counting injured ears at regular intervals during the growing season. In commercial fields, damage was measured immediately following harvest. The data were examined using paired t-tests to compare the number of injured ears between the treatment and control plots. The automated laser scarecrows considerably decreased bird damage to sweet corn. In the 2017 research station trial, the control plots had an average of 48.4 % injured ears compared to 14.6% in the laser-treated plots (P = 0.0002) of the same year. In subsequent years, similar reductions were observed in commercial trials in 2018, the control plots had an average of 23.8% damaged ears versus 13.7% in the laser-treated plots (P = 0.0046), in 2019, the laser-treated plots showed an average of 14.9% damaged ears compared to 20.3% in the controls (P = 0.0332). The automated laser scarecrows proved effective in minimising bird damage, and the study indicated that these devices could serve as a viable alternative to older tactics like propane cannons, particularly in peri-urban agricultural areas where noise pollution is a concern. Further research was proposed to explore the long-term efficiency of laser deterrents and the possibility for habituation by birds.

Aboltins *et al.* (2021) explored an intelligent acoustic deterrent device that leverages Direct Digital Synthesis (DDS) and Frequency Modulation (FM) to generate biologically relevant sounds, demonstrating that while acoustic signals alone may lead to habituation, their combination with optical deterrents significantly improves efficacy, the researcher explores the development of an intelligent acoustic deterrent device to prevent predatory birds from attacking fish-ponds. Substantial damage caused by birds such as cormorants, which consume large quantities of fish every day, creating economic concerns to fisheries was discussed. The process comprises examining avian hearing features and designing a sound synthesis strategy combining Direct Digital Synthesis (DDS) and Frequency Modulation (FM) to generate biologically relevant deterrent sounds. The device was constructed using a microcontroller and tested in fishponds, where results revealed that while acoustic signals alone had limited long-term impact due to bird habituation, combining them with optical deterrents considerably enhanced results. It was concluded that intelligent sound synthesis can effectively deter birds, but recommended that further developments, such as machine learning-based adaptive deterrence, could enhance long-term efficiency. Similarly, Uzma *et al.* (2021) developed a solar-powered audio bird repellent that generates predator sounds most notably the call of a falcon, to scare off bird species in agricultural settings. Threat caused by birds to agricultural crops, notably in India, where numerous species like crows and starlings was studied. A solar-powered auditory bird repellent system was created to drive away hazardous bird species. The system combines a solar panel, MP3 player, amplifier, battery, and ultrasonic sounds of predator birds. The device was created utilising cardboard tubes and a solid platform, allowing for quick placement in agricultural fields. The efficiency of the gadget was tested over a month, focusing especially on its capacity to dissuade crows, which are important pests. The system analysed 22 distinct predator sounds, with the call of the falcon recognised as the most successful in deterring crows and other bird species. The solar-powered architecture means the device can work independently in the field, reducing reliance on external power sources. The system developed was not an intelligent one, and it was prone to the problem of habituation over a period of time.

Storms (2022) developed the RobotFalcon, a mechanical predator based on the peregrine falcon, which deters birds by simulating natural predatory behaviour without evidence of habituation. The study addressed the recurrent issue of bird strikes in aviation, which represent major safety concerns and economic costs. Traditional deterrence strategies sometimes fail owing to habituation, forcing the creation of more effective remedies. The RobotFalcon simulates the appearance and behaviour of a genuine falcon, allowing for precise targeting and frequent operation, unlike live falcons, effectiveness of the RobotFalcon was tested against numerous bird species, including corvids, gulls, starlings, and lapwings, in agricultural areas. The performance of the RobotFalcon was compared to that of drones and conventional deterrence methods, such as distress calls and pyrotechnics. It was observed that the RobotFalcon successfully cleared fields of birds quickly, with many fields remaining free of bird flocks for extended durations (up to several hours). Throughout the research, it was noticed there was no evidence that birds acclimated to the RobotFalcon, keeping its effectiveness over time. However, the RobotFalcon required a professional pilot and it is restricted by battery life.

In another approach, Ajayi and Akanmu (2022) devised a solar-powered avian pest scarer that employs a PIR sensor to activate an inflatable scarecrow, causing abrupt motions that effectively startle birds. The study addressed the subject of avian pests destroying grain crops, particularly in agricultural settings. A solar-powered avian pest scarer meant to discourage birds successfully was invented. The scarer utilised a Passive Infrared Resistor (PIR) motion sensor to detect the presence of birds within a pre-set range. Upon detection, the gadget starts an axial fan blower that inflates a scarecrow, forcing it to pop up and resemble panic motions, making it more effective at alarming birds. The system is powered by solar energy, making it environmentally sustainable and decreasing dependence on external power sources. The inflatable scarecrow successfully deterred birds through unexpected movement, reducing habituation and assuring ongoing effectiveness. The gadget is meant to defend a field area of around 0.75 hectares.

Micaelo *et al.* (2023) proposed an electronic bird repellent system that used a PIR- triggered sound production at up to 85 dB to deter birds in both agricultural and industrial contexts. The research addresses the rising issue of bird-related damage in agricultural and industrial contexts. Birds adapt to urban contexts, leading to severe economic losses and health hazards owing to contamination. An electronic bird repellant device that utilizes sound emission to dissuade birds was proposed and constructed. The system employs sensors, specifically a Passive Infrared (PIR) sensor, to identify the presence of birds within a specified range. Upon detection, the device triggers a sound emission mechanism, using recorded sounds that scare birds away. A microcontroller oversees the detection and activation operations, ensuring the system runs autonomously. A printed circuit board (PCB) was used to hold all electronic components, allowing for efficient functionality and integration. The prototype displayed good bird identification and sound emission, capable of operating up to 10 meters away. The system may emit sounds reaching up to 85 dB, offering a considerable deterrence to birds.

These investigations suggest that unique mode deterrence—whether through laser, visual alerts, audio signals, or kinetic movements—offers robust, efficient, and context -specific methods to limit bird-related damage and safety issues. Lee et al. (2021) improved this notion with the Anti-adaptive Harmful Birds Repelling (AHBR) technique, which employs reinforcement learning to dynamically change threat sounds and limit bird adaptability. The subject of minimising damage to orchards by hazardous birds was studied, notably addressing the issue of bird adaptation to standard repelling methods. High-pathogenicity avian influenza (HPAI) outbreaks have underlined the necessity for effective monitoring and deterrence methods, as birds can quickly learn to ignore static dangers. The Anti-adaptive dangerous Birds Repelling (AHBR) method was suggested, which leverages a reinforcement learning (RL) framework to adaptively repel dangerous birds. The AHBR method leverages a model-free RL methodology to learn birds' reactions to various danger sounds. The Long-term and Short-term (LaS) policy is introduced to analyse and respond to bird adaptation depending on their behavior. The device played a distinct threat sounds in varying sequences to prevent birds from becoming used to them. The RL model modifies these patterns based on detected bird reactions. Experiments were conducted in a controlled environment utilising three bird species: the Brown-eared Bulbul, Great Tit, and Eurasian Magpie. The effectiveness of different sound combinations and loudness was examined to determine their impact on avian behaviour. The AHBR method outperformed typical sound patterns, yielding a 43.5% improvement in delaying bird adaptation compared to static sound methods. The study demonstrated that different bird species respond variably to threat noises, indicating the requirement of adapting deterrent techniques based on individual avian behaviours. The technology showed promise in real-time monitoring, with the possibility for incorporation into automated systems to boost biosecurity on chicken farms.

Snow *et al.* (2021) contributed by testing programmable deterrents (e.g., inflatable scare dancers and metal grates) that greatly limit non-target bird exposure during harmful bait applications. The study addressed the use of toxic bait to decrease wild pig numbers, specifically focused on the unexpected repercussions for non-target animals, particularly birds. The usage of sodium nitrite (SN) as a hazardous bait has led to concerns about avian exposure to spilled bait particles. Field trials were done to evaluate four deterrents aimed at preventing non-target bird species from swallowing spilled harmful bait. A programmed gadget that uses unpredictable motions to scare away birds was utilised, similar to the scare dancer but with different activation patterns. Trials were undertaken in Colorado and Texas, with a focus on evaluating bird visiting rates to bait sites before, during, and after the deployment of deterrents. The inflatable scare dancer proved to be highly successful, lowering bird visiting by an average of 96%. The metal grating likewise considerably reduced bird visiting by 85.7%. The deterrent devices did not negatively affect wild pig attendance to bait sites, allowing for successful control of the pig population while conserving non-target birds. The research noted that putting toxic bait during the summer minimised threats to migrating birds, as they were not present in the area.

Also, Mhandu *et al.* (2023) designed a solar-powered automated scarecrow that merged PIR sensor-based bird identification with kinetic movement and distress call emission for wheat farms in Zimbabwe. Complementary research by Mano and Sandhiya (2024) and Reddy *et al.* (2023) incorporated solar-powered scarer that integrated sensor-triggered audio signals (including gunshot noises and ultrasonic waves) with visual cues such as flashing lights. Murthi *et al.* (2021) contributed to the field by developing an autonomous bird repeller, combining motion detection and alarm activation powered by renewable energy, while Werber *et al.* (2023) extended multimode deterrence to wildlife conservation by employing a drone-mounted device that uses both auditory and visual signals to alter bat flight paths near wind turbines. Collectively, these studies underline that harnessing the synergistic impacts of numerous deterrents offers a more flexible, sustainable, and successful option for limiting bird and wildlife damage across many sectors.

Recent improvements in integrated detection –deterrence systems have proven promising results in decreasing bird-related crop loss by merging real-time monitoring with instantaneous repellent responses. For instance, Bhusal *et al.* (2023) created an automated UAV-based system that integrates machine vision for recognising bird-like movements with dynamic mission planning and auditory deterrence, achieving over 90% task success in vineyard trials despite navigation obstacles. Varriano *et al.* (2025) further innovated by deploying a micro-drone outfitted with Light Detection and Ranging (LIDAR) for obstacle avoidance and pest detection, providing a low-risk alternative for repelling both birds and rats in agricultural settings. In rice fields, Mohammed *et al.* (2020) demonstrated that mixing visual (reflective boards) and aural (predator and ultrasonic sounds) tactics via drones delivers superior bird scaring outcomes compared to single-mode methods. Contributing to these UAV innovation, Roihan *et al.* (2020) created a Raspberry Pi-based system employing video sensors and sound frequencies—leveraging object detection algorithms like YOLO and Mask R-CNN—to effectively trigger deterrence sounds when birds are recognised in rice crops.

Chen *et al.* (2024) refined the bird repellent concept by connecting deep learning-based detection (using an optimized Mask R-CNN) with a laser mechanism, reaching an 86.5% detection precision and a daily repulsion rate of 40.3% at a duck farm. Marcoň *et al.* (2021) contributed with an AI-driven repellent system that uses video-based detection to activate actuators such as loudspeakers or lasers, reaching a recall rate of 94.3% in preventing European starlings from ripening fruits. Bhusal *et al.* (2022) proposed a smart scarecrow that merges PIR sensor-triggered kinetic movements with a 360-degree Wi-Fi camera for continuous crop surveillance and deterrence. These investigations underline the usefulness of combinational strategies that blend detection with adaptive deterrence, offering a strong, automated option for defending crops against bird pests.

CONCLUSION

Bird pests continue to pose severe challenges to global food security, particularly in high-value and open field crops. While no single method offers perfect security, integrated systems combining visual, aural, laser, physical, and technological deterrents demonstrated the most potential for long-term success. From the review done, it was revealed that habituation mitigation is crucial which means a frequent diversity of procedures is required, AI and drone-based systems enable scalable, automated solutions and integrated systems that simultaneously engage visual, auditory, and physical barrier achieve maximum bird deterrent. Continuous research into species-specific responses, clever detection systems, and affordable farmer-friendly technology is important for sustainable bird pest management in the future.

REFERENCES

Aboltins, A., Pikulins, D., Grizans, J., & Tjukovs, S. 2021. Piscivorous bird deterrent device based on a direct digital synthesis of acoustic signals. *Elektronika ir Elektrotechnika, 27*(6), 42-48.

Ade-Omowaye, J., Ikubanni, P., Onu, P., & Ogunniyi, O. 2024, April. Advancements in Electronic Bird Repellent Technology: A Comprehensive Review of Effectiveness, Environmental Impact, and Practical Applications. In 2024 International Conference on Science, Engineering and Business for Driving Sustainable Development Goals (SEB4SDG) (pp. 1-10). IEEE.

Agossou, H., Assede, E. P., Dossou, P. J., & Biaou, S. H. 2022. Effect of bird scaring methods on crop productivity and avian diversity conservation in agroecosystems of Benin. *International Journal of Biological and Chemical Sciences, 16*(2), 527-542.

Ajayi, A. B., Akanmu, A. A. 2022. Development of a Renewable Energy Powered Avian Pest Scarer. *Acta Technica Corviniensis-Bulletin of Engineering, 15*(3), 43-48.

Angkaew, R., Round, P. D., Ngoprasert, D., Powell, L. A., Limparung, W. Y., Gale, G. A. 2022. Collateral damage from agricultural netting to open-country bird populations in Thailand. Conservation Science and Practice, 4(11), e12810.

Augustina, P., Nicoleta, V., Dan, C., Mihaela, N., Iuliana, G. 2023, May. Review of effectiveness of visual and auditory bird scaring techniques in agriculture. In *22nd International Scientific Conference "Engineering for Rural Development"*, 275-281.

Bhusal, S., Karkee, M., Bhattarai, U., Majeed, Y., Zhang, Q. 2022. Automated execution of a pest bird deterrence system using a programmable unmanned aerial vehicle (UAV). *Computers and Electronics in Agriculture, 198*, 106972.

Biswas, D., Tiwari, A. 2024. Utilizing Computer Vision and Deep Learning to Detect and Monitor Insects in Real Time by Analyzing Camera Trap Images. *Natural and Engineering Sciences, 9*(2), 280-292.

Brown, R. N., Brown, D. H. 2021. Robotic laser scarecrows: A tool for controlling bird damage in sweet corn. *Crop Protection, 146*, 105652.

Chen, Y. C., Chu, J. F., Hsieh, K. W., Lin, T. H., Chang, P. Z., & Tsai, Y. C. 2024. Automatic wild bird repellent system that is based on deep-learning-based wild bird detection and integrated with a laser rotation mechanism. *Scientific Reports, 14*(1), 15924.

Clausen, K. K., Thorsted, M. D., Pedersen, J., Madsen, J. 2022. Waterfowl grazing on winter wheat: Quantifying yield loss and compensatory growth. Agriculture, Ecosystems & Environment, 332, 107936.

Dokey, M. J., Mihani, M. K., Prasad, M. M., Lohokare, M. I. 2022. Design and Fabrication of Smart Farming Scarecrow. International Journal of Emerging Trends in Research. 3(1); 192- 195.

Kumar, M., Gupta, T., Baghel, V. 2025. Multi-sectoral impacts of the 2023 disasters in Himachal Pradesh and mitigation plans. Infrastructure Asset Management, 1-21.

Lee, C. W., Muminov, A., Ko, M. C., Oh, H. J., Lee, J. D., Kwon, Y. A., & Jeon, H. S. 2021. Anti-adaptive harmful birds repelling method based on reinforcement learning approach. *IEEE Access, 9*, 60553-60563.

Macroň, P., Janoušek, J., Pokorný, J., Novotný, J., Hutová, E. V., Širůčková, A., Gescheidtová, E. 2021. A system using artificial intelligence to detect and scare bird flocks in the protection of ripening fruit. *Sensors, 21*(12), 4244.

Mallick, B., Mohanta, H. C. 2024. Development of Pesticide Spraying Drone Using Sprinkler Mechanism. *Journal of Advancement in Communication System*, *7*(1), 1-9.

Micaelo, E. B., Lourenço, L. G., Gaspar, P. D., Caldeira, J. M., Soares, V. N. 2023. Bird deterrent solutions for crop protection: approaches, challenges, and opportunities. Agriculture, 13(4), 774.

Mano, B., Sandhiya, R. 2024. Design and fabrication of solar powered bird scarer. International Journal of Science and Research Archive. 13(02); 1024–1033

Marcoň, P., Janoušek, J., Pokorný, J., Novotný, J., Hutová, E. V., Širůčková, A., ... Gescheidtová, E. 2021. A system using artificial intelligence to detect and scare bird flocks in the protection of ripening fruit. *Sensors*, *21*(12), 4244.

Mhandu, M. M., Musarurwa, A., & Gudukeya, L. K. Design of a Solar Automated Scarecrow. In Proceedings of the IEOM International Conference on Smart Mobility and Vehicle Electrification Detroit, Michigan, USA, October 10-12, 2023.

Micaelo, E. B., Lourenço, L. G., Gaspar, P. D., Caldeira, J. M., Soares, V. N. 2023. Bird deterrent solutions for crop protection: approaches, challenges, and opportunities. *Agriculture, 13*(4), 774.

Mohammed, 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.

Murthi, M. K., Kumar, J. R., Revanth, S., Sakunthalanand, M., & Saravanan, K. M. 2021. Fabrication of Bird Repeller for Agriculture Purposes. *International Journal for Research in Applied Science and Engineering Technology, 9*(2), 34.

Odewumi, O. S. 2024. Analysis of rice farmers and avian conflicts in Patigi and Edu Local government areas, Kwara State, Nigeria. Journal of Research in Forestry, Wildlife and Environment, 16(4), 67-86.

Pecaso, J. P. 2021. Farm Bird-Deterrent Device: A Prototype. *Design Engineering*, 530-539.

Raj, S., Garyali, S., Kumar, S., Shidnal, S. 2020. Image-based bird species identification using convolutional neural network. *International Journal of Engineering Research & Technology (IJERT), 9*(6), 346.

Reddy, M. S., Charan, J. S., Jithendhar, D., Babu, C. V., Kumar, A. R. 2023: Smart Solar Scarecrow. International Research Journal of Modernization in Engineering Technology and Science. 5(6); 3938-3940.

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.

Roihan, A., Hasanudin, M., Sunandar, E. 2020, March. Evaluation methods of bird repellent devices in optimizing crop production in agriculture. *Journal of Physics: Conference Series, 1477*(3), 032012.

Said Hamed Alzadjali, N., Balasubaramainan, S., Savarimuthu, C., Rances, E. O. 2024. A Deep Learning Framework for Real-Time Bird Detection and Its Implications for Reducing Bird Strike Incidents. *Sensors, 24*(17), 5455.

Sausse, C., Baux, A., Bertrand, M., Bonnaud, E., Canavelli, S., Destrez, A., Zuil, S. 2021. Contemporary challenges and opportunities for the management of bird damage at field crop establishment. Crop Protection, 148, 105736.

Snow, N. P., Halseth, J. M., Foster, J. A., Lavelle, M. J., Fischer, J. W., Glow, M. P., VerCauteren, K. C. 2021. Deterring non-target birds from toxic bait sites for wild pigs. *Scientific Reports, 11*(1), 19967Storms Rolf F., Carere Claudio, Musters Robert, van Gasteren Hans, Verhulst Simon and Hemelrijk Charlotte K. (2022). Deterrence of birds with an artificial predator, the RobotFalcon *Journal of the Royal Society. Interface.***19**20220497.

Thakur, K., Sharma, A., & Sharma, K. (2021). Management of agricultural insect pests with physical control methods. The Pharma Innovation Journal, 10(6), 306-314.

Ummah, K., Hidayat, M. F., Kurniawan, D., Zulhanif, Z., Sembiring, J. 2022. Bird detection system design at the airport using artificial intelligence. *International Journal of Aviation Science and Engineering-AVIA*.

Uzma, R., Sayeed, Y., Ahmed, M. M., Khan, M. Z., Siddiqui, N., Shrivastava, R., Patil, U. 2021. Design and Implementation of Low-Cost Solar Powered Bird Repellent Technique for Prevention of High Economic Crops. *Anjuman College of Engineering and Technology, Nagpur, Maharashtra, India, 8*, 360-362.

Varriano, S., Snyder, W. E., Smith, J. C., Shariat, N. W., Dunn, L. L. 2025. Deterring Wild Birds during Fruit and Vegetable Production. *Food Protection Trends, 45*(1).

Venkatachalam, S. D., Krishnamoorthy, K., Srilla, J., SenthilKumar, S. B., Velusamy, S., Sabapathi, D. 2023, October. Deep Learning-Based Farm Disturbance Bird Detection. In *2023 International Conference on Self Sustainable Artificial Intelligence Systems (ICSSAS)*, 318-324. IEEE.

Werber, Y., Hareli, G., Yinon, O., Sapir, N., Yovel, Y. 2023. Drone-mounted audio-visual deterrence of bats: implications for reducing aerial wildlife mortality by wind turbines. *Remote Sensing in Ecology and Conservation, 9*(3), 404-419.

Yauri, R., Campos, E., Yalico, R., Gamero, V. 2023. Development of an Electronic Bird Repellent System using Sound Emission. *WSEAS Transactions on Systems and Control*, *18*, 136-143.

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