# qCrop: An IoT based Framework to Enhance Crop Productivity in Smart Agriculture

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***Abstract*—Food is crucial in our life. Despite food manufacturers' efforts to meet consumers' needs with manufactured food, it cannot attain the identical level of quality and flavor as natural food. Some fruits and vegetables are classified as food that cannot be manufactured. Also, they play an essential role worldwide. This paper focuses on how farmers can protect their farms from an object that might threaten the crops and cause damage to them. It proposes a framework that farmers may utilize to safeguard the crops against any species of birds. Considering the adverse impact of bird attacks on crop production, this system effectively addresses this problem and consistently enhances the quality and quantity of them. It utilizes computer vision technology to establish a secure environment for the crop. This system is called Quality of Crop Device (qCrop), and it works with a You Only Look Once (Yolov8m) model to detect birds with high accuracy to protect farms.**

***Index Terms*—Quality of Crop (qCrop), Protect Crops, Avert Bird, Issue a Sound, Bird Species.**

## I. Introduction

Although the recent emphasis on technology, promoting smart agriculture is an effective method to offer consumers a portion of nutritious and healthy food [21]. fruits and vegetables represent the same aspect of the other food. They have an essential role in the human body.

Conversely, food manufacturers endeavor to obtain customer satisfaction with the food they provide [**?**], [23]. Currently, ensuring the quality of food continues to be a multifaceted challenge for food manufacturers [24]. Although individuals may have developed a sophisticated palate for food, the original flavors of natural resources persist [1].

Studies have projected that the global population is predicted to reach roughly 9.7 billion people by the year 2050 [21]. furthermore, In 2022 and 2023, people consumed about 791 million metric [19]. So, Proper care for crops is necessary due to the expected many million metric tons rise in fruits and vegetables consumption in 2023 and 2024. This implies that consumers will contribute to an increase in the proportion of natural resource demand. Preserving natural resources is the sole effective method to maintain the superior quality and flavor of food. Currently, there is a growing emphasis among researchers on the field of smart agriculture due to its significant significance.

Farmers frequently have the challenge of bird species targeting their crops [18]. Furthermore, farmers around the world encounter these challenges due to the specific geographical location of crops, which serve as stops for migratory birds. Periodically, birds immigrant emigrate, and farmers begin utilizing conventional methods, such as ropes or their vocalizations, to safeguard crops from potential harm caused by birds. Protecting crops from natural disasters, stray animals, and potential thefts incurs significant financial expenses for farm owners [7], [10]. During the period of bird emigration, farmers initiate preparations to safeguard their crops through various means, including seeking individuals to employ them to evict birds manually [17].

Usually, people who obtain compensation utilize traditional approaches, such as hurling stones and raising loud voices, to remove birds from agricultural land or erect scarecrows along the perimeter of the farm, which is a demanding job. Furthermore, the insufficient educational attainment of farmers has resulted in their deaths [11]. Due to the severity of the situation, an additional problem arises during the birds' migration, namely the current scarcity of human personnel.

From 2018 to 2019, 44.3% of the human population resides in rural areas [3], which means 55% will be located in smart cities. This will diminish the available agricultural land, particularly in rural areas. Economic inflation within the agricultural sector poses a significant challenge, leading to a reduction in crop yield. Fig. 1 depicts the adverse impact of diminishing yield on farmers. Insufficient crop's production in farms hampers fruits and vegetables availability from suppliers, markets, and consumers. qCrop is a capable system that has the ability to protect crops by emitting sounds to evict attacked birds.

The proposed system aims to create a conducive environment for farmers, enhancing their comfort with their crops. Additionally, it seeks to reduce costs by eliminating the necessity for human labor in bird eviction, improving crop quality, and facilitating the provision of flour to suppliers and bread to consumers in bakeries.

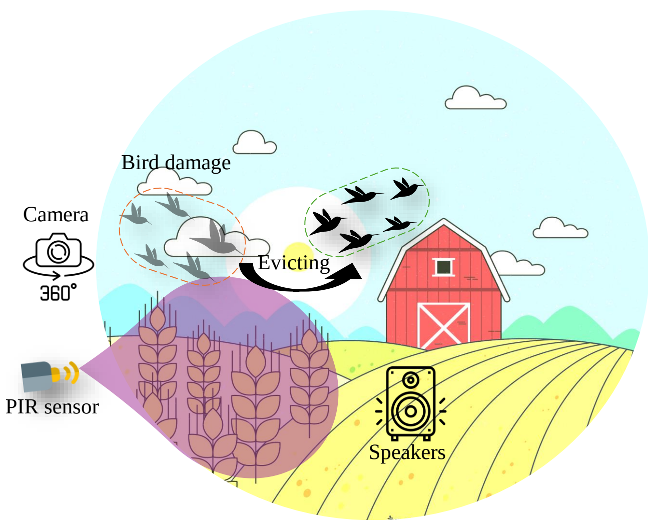


Fig. 1. Motivation for q-Crop to Keep the Crop Safe From Birds

Due to the natural preference of birds for fruits and vegetables as their primary diet, significant crop waste and damage are caused. The suggested system aims to improve crop protection and contribute to several aspects of the country, including farmers' income and the overall economy, through the monitoring and management of farms.

The rest of this paper has been organized as follows: Sec. II presents the contribution of the current paper. It includes the problem being addressed, the proposed solution, and its significance of this solution. Sec. III includes the related work to provide an explanation and comparison of the proposed work's existence with qCrop. Sec. IV depicts the proposed novel methodology for elucidating the system architecture, qCrop's algorithms, and the levels of qCrop. Sec. V provides the experiment and validation process, including the model details and used dataset. Sec. VI presents the conclusion of the work, and discusses potential future research suggestions.

## II. Proposed Contribution of the qCrop System

This study introduces a state-of-the-art approach to safeguard farms in various aspects:

- The paper proposes an Internet of Things (IoT) [9] system that serves multiple functions and includes a full automation system.
- The system is designed specifically to address the difficulties encountered by farmers in protecting their crops. It operates totally automatically, conserves power by operating during daylight, and minimizes labor costs.
- Crop monitoring is the primary method used for protection.
- By integrating Light Dependent Resistor (LDR), Camera, Passive Infrared sensor (PIR), and speaker, the proposed approach ensures an accurate model.

This technique is a completely automated system that does not necessitate any intervention from the farmers to prevent the birds from harming the farms. The reason why farmers do not need to interact with the qCrop system is that it utilizes a variety of sounds to effectively evict birds from the farms. The system operates during the diurnal period, commencing at sunrise when bird flight commences, and transitions into a dormant state upon sunset.

### A. *Problem Addressed*

This research aims to examine a significant challenge consistently encountered by farmers. Given that the primary objective of crops is to supply consumers with food of high-quality, it is essential for farmers to safeguard their crops against any potential assault by animals that could compromise the crop's resources.

The objective of this study is to safeguard the health of crop production over time from any diseases that might impact the fruits and vegetables to be healthy for the consumers. Consequently, the global scarcity of wheat (for example) poses a significant danger to markets, bakeries, and food suppliers [5], [6]. In order to enhance the quality and quantity of crops' production, farmers must safeguard their crops from bird attacking, as birds pose the greatest hazard to fruits and vegetables. Currently, in certain regions, farmers utilize manual methods to safeguard their crops.

### B. *Proposed Solution Through qCrop*

There are a multitude of techniques that can be implemented to establish a secure environment for agriculture in different approaches like weather forecasting to mitigate soil and biological damage. Upon closer examination, it becomes evident that it is necessary to prioritize crop production by addressing potential threats such as soil quality, wild animals, and birds. The qCrop system employs advanced technology to monitor and mitigate the detrimental impact of birds on agricultural production. It achieves this through a fully automated system that operates independently without requiring any human intervention.

### C. *Significance of the Proposed Solution*

This study presents a way for farmers to safeguard their farms from potential harm caused by birds or the deterioration of fruits and vegetables quality by evicting birds. Furthermore, this study aims to enhance the accuracy, low cost, and reduce power consumption of crops cultivation. It is equipped with diverse sensors for crop monitoring. In order to ensure a secure environment for the crop, it is recommended that those sensors be strategically located around the farm. This will assist the system when it begins to sense and observe until it detects any bird species. Subsequently, the system autonomously initiates operations to remove birds from the confines of the farm.

TABLE I
EXISTING SYSTEMS METHODOLOGIES

| Authors | Years | Animals Detected | Methodology | Drawbacks |
|---|---|---|---|---|
| Ranparia, et al. [13] | 2020 | wild boar, nilgai, deer | ML Model | Those animals don't eat fruits farm's produces |
| Reddy, et al. [14] | 2022 | Not Listed | ML Model | Detects wildlife using ML needs time and power |
| Manikandan, et al. [8] | 2021 | Not Listed | Motion Sensor | Animal might be a bird and used sensors can't detect it |
| Deotale, et al. [2] | 2021 | Not Listed | Arduino+sensors | The wild animals don't eat fruits and vegetables |
| Shaik, et al. [20] | 2022 | Not Listed | Arduino+sensors | No dataset. The system evicts all objects |
| Upadhyay, et al. [22] | 2020 | cattle | Arduino+camera | The system needs an action done by the farmer |

## III. STATE-OF-THE-ART LITERATURE

Given the rapid advancements in technology, researchers are interested in assisting people in resolving world issues. One of the primary challenges in the field of agriculture pertains to safeguarding farms in order to ensure the provision of nutritious and abundant food to consumers. Table I displays some systems that have been developed with the purpose of safeguarding farms. However, these systems mostly focus on addressing non-crop-threatening animals.

An approach to protect crops against Wild Boar, Nilgai, and Deer through the use of machine learning technology (CNN) YOLOv3 in [13].

Another way to present a concept that focuses on guarding the crop from animal damage. It concentrates on particular species of wildlife. The efficacy of this technique is optimal when utilized for the purpose of preventing wild animals from a specified region, such as food warehouses [14].

To continuously monitor all animals, a motion sensor operates around the clock. This motion sensor alone is insufficient for protecting the crops, and a 24/7 system is unnecessary as the activity of animals is low [8].

Another system of crop safeguarding has been proposed. However, the inclusion of additional elements that are unrelated to the primary objective of this system may have an impact on its primary purpose and efficiency, such as the incorporation of temperature sensors and soil moisture monitoring [2].

A proposed system that operates continuously, 24 hours a day, seven days a week. The author specifically identified certain species as targets of the system, although most of the mentioned animals are not considered harmful as they mostly consume meat and do not have a negative impact on farms. [20].

Utilizing a manual eviction method and having the farmer perform the act is deemed inconvenient. In the present era, it is imperative for the system to be completely automated [22].

The proposed qCrop system addresses significant challenges and how their systems contribute to the advancement of Artificial Intelligence in the Smart Agricultural domain on a global scale. Table II depicts the quality and capabilities of qCrop as it presents a proposed significant method that aims to protect crops against bird species. The objective of this study is to explore strategies for safeguarding crops against birds. Safeguarding crops from bird attacks is crucial as they are the sole perilous species capable of causing harm to fruits and vegetables. The bole and height of some fruits and vegetables trees render them impervious to threats or harm from other wildlife, with the exception of birds.

## IV. PROPOSED NOVEL METHODOLOGY

### A. Methodology

The proposed system, as depicted in Fig. 2, has been

designed to operate with optimal efficiency and guarantee the crop's safety and quality of the produce. Once a bird assaults the crop, qCrop emits a sound to evict the bird and thereafter sends a status report to the owner at the end of the day. The system operates on three levels. The interconnection of these three levels serves to enhance proficiency inside the system. These levels are commonly referred to as the software/hardware level, the cloud level, and the end user level and are further elaborated upon as follows:

### B. Hardware/Software level

There are two algorithms, Algo [1, 2], that are used to split the hardware and software levels. These two algorithms demonstrate the approach of the qCrop system and its effectiveness in protecting crop production through using machine learning technology in combination with adaptive sensors.

### C. The Cloud Level

The second level is the cloud. The cloud performs three primary functions, namely farmer notification, data storage, and report delivery. Upon receiving the data, the cloud promptly informs the farm owner, proceeds to count the captured objects, records the date and time of capture, and then stores the information. Ultimately, the cloud sends a report to the intended recipient.

### D. The End User

The final level of this system is the end-user level. There are two nodes in this level. The first node represents the owner of the farm. The Ministry of Agriculture is the second node, provided the farm is registered. At the end of each working day, two soft copies of reports are dispatched to the aforementioned nodes. This report furnishes the nodes with data regarding the identified transactions during the day. The Ministry of Agriculture requires the storage of this information in its database for convenient backup when necessary. The interconnection of these three levels is facilitated through internet communications.

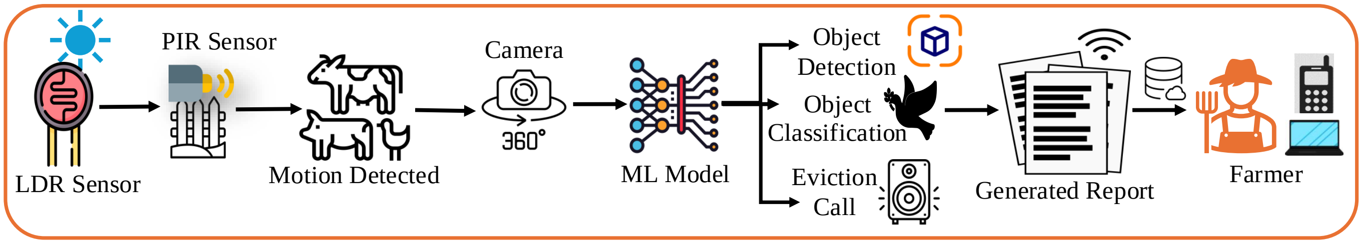


Fig. 2. Architecture of the Proposed qCrop system

**Algorithm 1** qCrop Object Detection Methodology

**Require:** Light Dependent Resistor $LDR$, Passive Infrared Sensor $PIR$, Object Caption $OC$.
**Ensure:** Running or Sleepy Mode and Object Caption

$LDR$ is running for light detection
**if** $LDR$ detects light **then**
  qCrop turns on running mode
  qCrop in Running Mode and sensors begin to sense
  $PIR$ starts sensing the heat energy
  **if** $PIR$ sensed a heat energy **then**
    $PIR$ notifies the system for an object is passing
    The system turns on the camera
    The system takes a $OC$
    Internal system takes $OC$ and introduces it to DL Model
  **else**
    $PIR$ is sensing
  **else**
    qCrop maintains on Sleepy Mode
  **end if**
**end if**

**Algorithm 2** Steps of qCrop From Object Detection to Object Classification

**Require:** Object Caption $OC$.
**Ensure:** Activation Status of the Alert System

$OC$ contains the detected object
Internal system receives $OC$ and forward it to our Deep Learning Model
Deep Learning Model uses $OC$ as an input
The model classifies the object in $OC$
The model outputs the bird species
**if** The bird species is harmful to the farm **then**
  qCrop changes the activation status to risk mode
  Internal system chooses randomly bird distress calls
  qCrop produces bird distress calls
  **if** The chosen sound has been issued recently **then**
    Choose another sound from a list of [tones] = [ton1, tone n]:
    if n == tone1:
    n= tone2
    tone1++
    Alert System keeps altering for a specified period of time
    qCrop turns activation status to safe mode
  **else**
    qCrop plays the chosen bird distress calls
  **else**
    qCrop maintains the activation status as a safe mode
  **end if**
**end if**

## V. Experiment and Validation of the Proposed qCrop System

### A. Model (software)

The YOLOv8m model is used in the qCrop device to attain a notable level of efficiency [15]. The T4 GPU was utilized to train this model. The T4 GPU is a processor used in Google Colab [4] for training models. The T4 GPU operates using 40 GB of RAM. The model was evaluated on a processor with a Core-i5 CPU, 16 GB of RAM, and a 512 GB solid-state drive (SSD) for storage. The assessment of the model is depicted in Fig. 5. It displays the training model's loss with precision and recall metrics, while the lower part displays the validation/testing model loss. Fig 6 depicts the iteration of Mean Average Precision mAP50, precision, and recall as a graph of metrics [12].

The final crucial component of the trained model's outcome is the confusion matrix. Fig. 3 displays the accuracy of the projected bird results in the dataset and their level of truthfulness. The conversion from PyTorch to TensorFlow lite in YOLOv8m was achieved by the utilization of Open Neural Network Exchange model (ONNX). Fig. [4, 6] display the conclusive result of the YOLOv8m model's exceptional accuracy and its annotation at the end of this section. In order to mitigate the risk of overfitting, mAP50 and precision values were stated as 93% after 100 epochs.

### B. Dataset

The system has been proposed utilizing an online dataset of bird species. The dataset is referred to as the 30birds-dataset [16]. In order to attain a result of high accuracy, it is essential to utilize a dataset including a large number of images depicting various species of birds. The dataset contains 905 original images displaying 30 distinct bird species, devoid of any null images. "Null photos" refers to an image that has been uploaded to the dataset but does not belong to

TABLE II
qCrop vs. Existing Systems

| Authors | Accuracy | ML model type | connectivity (WiFi?) | Automation | Cost-effcient System? |
|---|---|---|---|---|---|
| Ranparia, et al. [13] | NA | Detection | No | Fully automation | No |
| Reddy, et al. [14] | Up to 77% | Classification | Isn't mentioned | Fully automation | No |
| Manikandan, et al. [8] | NA | None | No | Isn't automatic | No |
| Deotale, et al. [2] | NA | None | No | Fully automation | No |
| Shaik, et al. [20] | NA | None | WiFi OR LAN | Isn't automatic | No |
| Upadhyay, et al. [22] | NA | None | No | Isn't automatic | No |
| qCrop | 87% | Classification | WiFi | Fully automation | Yes |

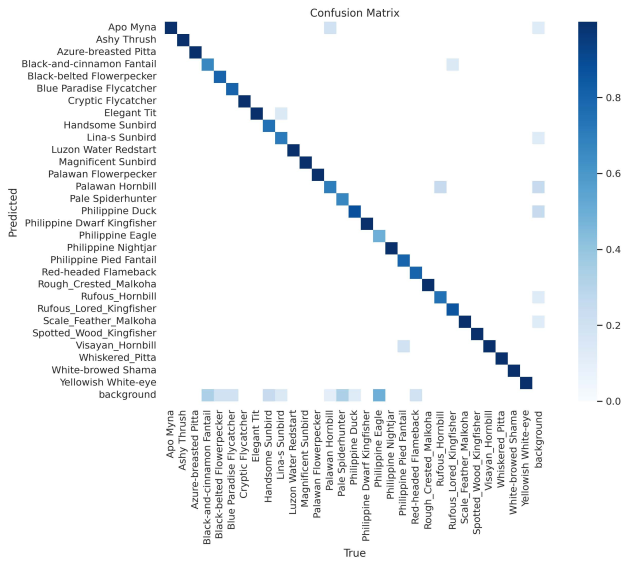


Fig. 3. Confusion Matrix of the Proposed qCrop Model

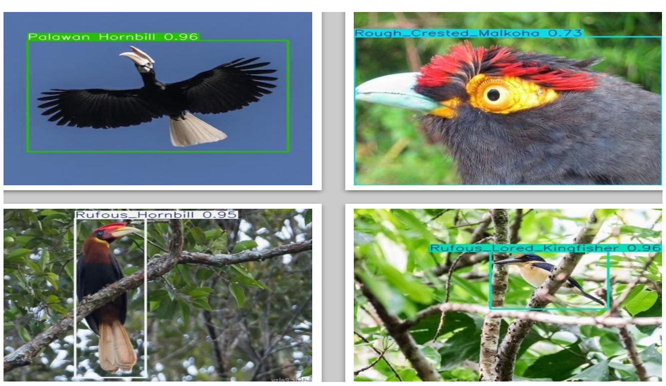


Fig. 4. Obtained Confidence Interval from the Proposed qCrop Object Detection Model

any specific category within the dataset classes. The second significant component of this dataset relates to the health of the dataset. Health, as a whole, exhibits a high degree of sensitivity to various factors. From a technical standpoint, the condition of images significantly impacts any dataset. The presence of a variety of bird species contributes to enhanced farm protection and the preservation of crops against bird threats. The images have been high-quality annotated. The dataset has been expanded from 905 initial photographs to 2171 pictures after performing the augmentation process. In datasets, augmentation is utilized to increase the size of the dataset which helps to avoid any overfitting. To provide further explication on the dataset that was used in this study, it has been divided into three primary components.

- Dataset split. The training set consists of 1899 photos, and an accuracy of 87% has been attained.
- Processing. An Auto-Oriented approach was implemented. During the processing stage, the dimensions of the images have been adjusted to 416*416.
- Augmentations. The saturation of the whole photo ranges from -25% to +25%.

The utilized dataset contains high-quality images. The great quality of the image is achieved through the use of several image positions, facilitating easy bird detection and ensuring the protection of farms from birds regardless of their location. The testing set images have been annotated to a total of 929 photographs, with an average size of 0.32 megapixels. The picture size ranges from 0.02 megapixels for the smallest size to 12.44 megapixels for the greatest size. Integrating Hardware and Software in qCrop certifies its ability to effectively safeguard crops' lives beyond the existing systems' capabilities as depicts in table II.

## VI. Conclusion and Future Research

The present research introduces an IoT system named qCrop, which aims to enhance the quantity of produce from farms. The qCrop system offers continuous monitoring and automated control functionalities for farming on a global scale.

Primarily, it operates during the daytime, transitions into sleep mode throughout the nighttime, and awaits a command from the processor. Continuous Issuing of different sounds randomly by the system causes birds to be evacuated from the farms each time they attack crops. Getting used to the same sound by birds will not evacuate them again.

In future studies, the qCrop system might be enhanced with a more recent iteration of the YOLO models and an expanded dataset, hence facilitating the advancement and general utility of the qCrop device.

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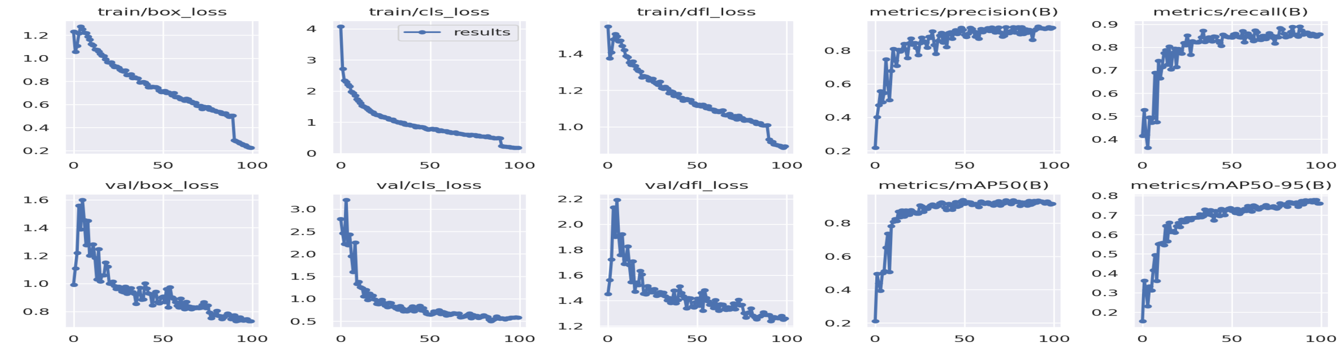


Fig. 5. Precision, Accuracy, Loss Generated from qCrop Classification Model for 100 Iterations.

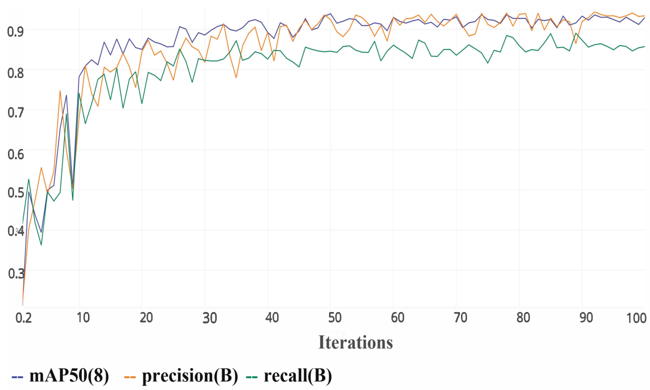


Fig. 6. Performance Metrics of the Proposed qCrop Classification Model.

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