Design And Fabrication of a Low-Cost Smart Farm Protection System Using Fire and Animal Intrusion Detection

P. RAVICHANDRAN[1], A. RAMESH[2], B. MATHESWARAN[3], P. POOVARASAN[4], S.RAJESHKUMAR [5], S.SIVASANKAR[6]

[1]*GUIDE & HOD / DEPARTMENT OF MECHANICAL ENGINEERING / ANNAI JKK SAMPOORANI AMMAL POLYTECHNIC COLLEGE, T.N. PALAYAM, INDIA.*

[2]*LECTURER / DEPARTMENT OF MECHANICAL ENGINEERING / ANNAI JKK SAMPOORANI AMMAL POLYTECHNIC COLLEGE, T.N. PALAYAM, INDIA.*

[3,4,5,6]*STUDENT / DEPARTMENT OF MECHANICAL ENGINEERING / ANNAI JKK SAMPOORANI AMMAL POLYTECHNIC COLLEGE, T.N. PALAYAM, INDIA.*

***Abstract*—Agricultural fields are increasingly vulnerable to losses caused by fire accidents and animal intrusion, particularly in remote and forest-adjacent regions. This paper presents the design and fabrication of a low-cost smart farm protection system that provides continuous monitoring and automated safety responses using sensor-based detection and IoT communication. The proposed system integrates smoke, flame, and temperature sensors to detect fire hazards, along with PIR motion and IR beam sensors for identifying animal intrusion. A microcontroller-based control unit processes sensor data and triggers appropriate actions, including audible alarms, automated water sprinklers for fire suppression, and real-time alerts to farmers via GSM or Wi-Fi connectivity. To ensure sustainable operation, the system is powered by a solar energy unit with battery backup, making it suitable for rural areas with limited access to electricity. The developed solution is cost-effective, energy-efficient, easy to deploy, and scalable for farms of different sizes. Experimental results demonstrate that the system effectively minimizes crop damage by providing timely alerts and rapid response, thereby improving farm security and supporting sustainable agricultural practices.**

***Index Terms*—Smart agriculture, Farm protection system, Fire detection, Animal intrusion detection, IoT-based monitoring, Sensor networks, Solar-powered systems, GSM communication.**

I. INTRODUCTION

Agriculture plays a vital role in the economic and social development of many countries, particularly in rural regions where farming is the primary source of livelihood. However, agricultural lands are constantly exposed to risks such as fire accidents and animal intrusion, which can result in severe crop damage and financial losses for farmers. These challenges are more pronounced in remote and forest-border areas, where continuous manual monitoring is difficult and access to reliable power infrastructure is limited.

Fire hazards in farms may occur due to dry climatic conditions, electrical faults, or accidental human activities, and they can spread rapidly if not detected at an early stage. Similarly, intrusion by wild or stray animals poses a major threat to crops, especially during night hours. Traditional protection methods, such as fencing, human surveillance, and scare devices, are often labor-intensive, costly, and ineffective for large agricultural fields. Hence, there is a growing need for an automated, reliable, and cost-effective farm protection system.

Recent advancements in sensor technology, embedded systems, and Internet of Things (IoT) communication have enabled the development of smart agricultural solutions. By integrating environmental and motion sensors with microcontroller-based platforms, real-time monitoring and rapid response mechanisms can be achieved. Furthermore, wireless communication technologies such as GSM and Wi-Fi allow farmers to receive instant alerts, enabling timely intervention even when they are away from the field.

This paper proposes a low-cost smart farm protection system that combines fire detection and animal intrusion monitoring into a single automated platform. The system utilizes multiple sensors for accurate detection, solar power for energy efficiency, and IoT-based communication for real-time alerts. The proposed approach aims to reduce crop losses, minimize human effort, and provide a sustainable and scalable solution for modern agricultural protection.

II. PROBLEM STATEMENT

Agricultural farms, especially those located in remote and forest-adjacent areas, face significant challenges in protecting crops from fire hazards and animal intrusion. Fire incidents caused by dry weather conditions, electrical faults, or accidental human activities can spread rapidly and result in extensive crop loss if not detected at an early stage. Similarly, intrusion by wild or stray animals during night hours leads to severe damage to crops, reducing agricultural productivity and farmer income.

Existing farm protection methods, such as manual surveillance, traditional fencing, and basic alarm systems, are often inefficient, labor-intensive, and costly to maintain. These approaches also fail to provide real-time alerts or automated responses, making them unsuitable for large-scale or unattended agricultural fields. Additionally, the lack of reliable electricity supply in rural areas further limits the deployment of advanced monitoring systems.

Therefore, there is a need for a low-cost, energy-efficient, and automated farm protection system capable of continuously monitoring fire hazards and animal intrusion. The system should provide early detection, real-time alerts, and immediate preventive actions while operating reliably in remote environments with minimal human intervention.

III. NEED FOR THE STUDY

Agricultural productivity is highly dependent on effective crop protection mechanisms. In many rural and forest-border regions, farmers continue to face recurring losses due to fire accidents and animal intrusion. These threats not only reduce crop yield but also increase financial instability among farming communities. The lack of timely detection and immediate response remains a major concern, particularly in large or remotely located farms where constant human supervision is not feasible.

Conventional protection methods such as manual guarding, basic fencing, and scare devices are often unreliable, labor-intensive, and expensive over long periods. Moreover, these methods do not provide real-time monitoring or early warning capabilities, resulting in delayed action and increased damage. The situation is further aggravated by inconsistent power supply in rural areas, limiting the use of conventional electronic monitoring systems.

With the advancement of sensor technologies, embedded systems, and IoT communication, there is an opportunity to develop an intelligent and automated solution that addresses these limitations. A low-cost, solar-powered farm protection system can provide continuous surveillance, early detection of fire and animal intrusion, and instant alerts to farmers. Such a system reduces dependency on manual labor, enhances response time, and improves overall farm security.

Therefore, this study is necessary to design and implement a cost-effective, energy-efficient, and reliable smart farm protection system that supports sustainable agriculture, minimizes crop losses, and improves the quality of life for farmers in rural and remote regions.

IV. LITERATURE REVIEW

Recent advancements in smart agriculture have led to the development of various automated systems aimed at improving farm safety and productivity. Several researchers have explored the use of sensor-based technologies and Internet of Things (IoT) platforms to monitor environmental conditions and detect potential threats in agricultural fields.

Studies on fire detection systems in agriculture have primarily focused on the use of temperature, smoke, and flame sensors for early identification of fire hazards. These systems demonstrate that multi-sensor integration improves detection accuracy and reduces false alarms. Some researchers have incorporated automatic water sprinklers and alarm mechanisms to control fire outbreaks at an early stage. However, many of these systems depend on grid power and are costly to deploy in remote rural areas.

Animal intrusion detection has also been widely studied, with solutions utilizing infrared sensors, PIR motion detectors, ultrasonic sensors, and camera-based surveillance. While camera-based systems provide accurate detection, they require high processing power, stable network connectivity, and continuous power supply, which increases system complexity and cost. Sensor-based approaches are comparatively simpler and more suitable for low-cost agricultural applications.

IoT-enabled farm monitoring systems using GSM, Wi-Fi, or LoRa communication technologies have been proposed to provide real-time alerts to farmers. These systems allow remote monitoring through mobile applications or SMS notifications, improving response time during critical events. However, many existing solutions address either fire detection or animal intrusion separately, rather than offering a unified protection system.

Furthermore, limited attention has been given to energy sustainability in existing farm protection systems. Solar-powered designs with battery backup are essential for continuous operation in rural areas with unreliable electricity. The review of existing literature highlights the need for an integrated, low-cost, solar-powered smart farm protection system that combines fire detection and animal intrusion monitoring with real-time communication and automated response mechanisms.

V. METHODOLOGY

The methodology of the proposed smart farm protection system focuses on integrating low-cost sensors, an embedded control unit, and wireless communication to ensure continuous monitoring and automated response against fire hazards and animal intrusion. The overall working procedure is divided into the following stages:

A. System Design and Hardware Selection

Appropriate sensors are selected to detect fire and animal intrusion effectively. Smoke, flame, and temperature sensors are used for fire detection, while PIR motion sensors and IR beam sensors are employed for identifying animal movement. A microcontroller such as Arduino or ESP32 acts as the central processing unit, managing sensor inputs and controlling output devices.

B. Sensor Data Acquisition

All sensors continuously monitor environmental and boundary conditions. The analog and digital signals generated by the sensors are collected and processed by the microcontroller. Threshold values are predefined to distinguish between normal and abnormal conditions.

C. Detection and Decision Making

When sensor readings exceed the preset threshold levels, the microcontroller identifies the event as either a fire hazard or animal intrusion. Based on the detected event, the controller executes predefined decision logic to initiate appropriate actions.

D. Alert and Response Mechanism

Upon detection, the system activates local alert devices such as a buzzer or siren to provide immediate warning. In the case of fire detection, an automatic water pump or sprinkler system is triggered to suppress the fire. Simultaneously, alert messages are sent to the farmer through GSM or IoT-based communication.

E. Communication and Monitoring

The communication module transmits real-time notifications to the farmer’s mobile phone or application dashboard. This allows remote monitoring of farm conditions and ensures timely intervention if required.

F. Power Management

The system is powered by a solar panel with battery backup, ensuring uninterrupted operation even in areas with unreliable electricity supply. Energy-efficient components are selected to minimize power consumption.

VI. BLOCK DIAGRAM

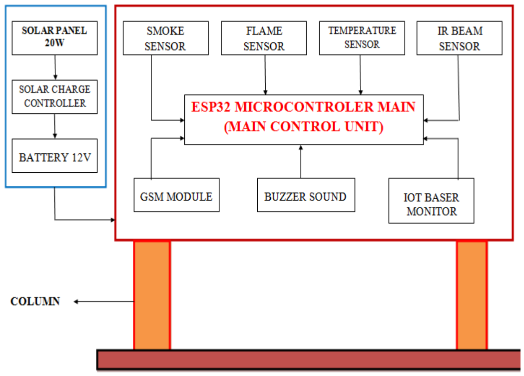


FIG:1

VII. DESIGN AND MODEL IDEA

FIG:2

VIII. MATERIALS USED

A. ESP32 Microcontroller

FIG:3

The ESP32 functions as the main control unit of the system. It receives data from all sensors, executes decision logic, and controls alert and communication modules. Its built-in Wi-Fi capability supports IoT-based monitoring.

B. Smoke Sensor (MQ-2)

FIG:4

This sensor detects smoke and flammable gases

produced during fire incidents and provides early warning signals to the controller.

C. Flame Sensor

FIG:5

The flame sensor identifies the presence of fire by detecting infrared radiation emitted from flames.

D. Temperature Sensor (LM35)

FIG:6

The LM35 measures ambient temperature and helps identify abnormal temperature increases associated with fire conditions.

E. IR Beam Sensor

FIG:7

The IR beam sensor is installed along the farm boundary and detects animal intrusion when the infrared beam is interrupted.

F. PIR Motion Sensor

FIG:8

This sensor detects the movement of animals by sensing variations in infrared radiation.

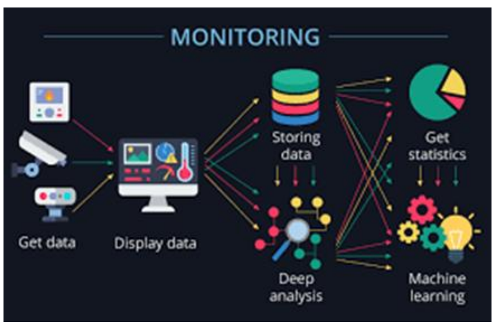
G. GSM Module

FIG:9

The GSM module enables wireless communication by sending alert messages to the farmer's mobile phone during fire or intrusion events.

H. IoT Monitoring Module

FIG:10



This module allows real-time monitoring of farm conditions through a mobile application or web-based dashboard.

I. Buzzer / Siren

FIG:11

The buzzer or siren provides an audible alert to warn the farmer and deter animals from entering the farm area.

J. Solar Panel (20 W)

FIG:12

The solar panel supplies renewable energy to power the system, ensuring continuous operation in remote locations.

K. Solar Charge Controller

FIG:13

The charge controller regulates power flow from the solar panel to the battery and protects against overcharging.

L. Battery (12 V)

FIG:14

The battery stores electrical energy generated by the solar panel and provides power during low-light or nighttime conditions.

M. Protective Enclosure and Mounting Structure

FIG:15

The enclosure safeguards electronic components from environmental damage, while the mounting structure ensures stable field installation.

IX. CONSTRUCTION

The smart farm protection system is constructed using a combination of sensing units, a control unit, communication modules, and a renewable power supply to ensure reliable and continuous operation. The entire system is enclosed in a weather-resistant protective casing and mounted on a stable support structure for field deployment.

Fire detection is achieved by integrating a smoke sensor, flame sensor, and temperature sensor. These sensors are positioned strategically to monitor environmental conditions in the farm area and are interfaced with the main control unit for continuous data acquisition. For animal intrusion detection, PIR motion sensors and IR beam sensors are installed along the farm boundary to detect movement or beam interruption.

An ESP32 microcontroller is used as the central processing unit of the system. It collects data from all sensors, analyzes the readings based on predefined threshold values, and initiates appropriate responses. The controller is interfaced with a buzzer or siren for local alerts and with a communication module for remote notifications.

Wireless communication is enabled through a GSM module or an IoT-based Wi-Fi module, allowing alert messages to be sent to the farmer's mobile phone or monitoring application. This ensures real-time notification during fire or intrusion events.

The system is powered by a 20 W solar panel connected to a solar charge controller and a 12 V battery. This power arrangement ensures uninterrupted operation even in remote areas with unreliable electricity supply. The modular construction of the system allows easy installation, maintenance, and scalability for farms of different sizes.

X. WORKING PRINCIPLE

The smart farm protection system operates by continuously monitoring environmental conditions and farm boundaries using integrated sensors. The system performs two primary functions: fire detection and animal intrusion detection. All sensor data are processed by the ESP32 microcontroller, which controls the alert and response mechanisms.

For fire detection, the smoke sensor, flame sensor, and temperature sensor constantly monitor the surrounding area. When any of these sensors detect abnormal conditions, such as the presence of smoke, flame, or a sudden increase in temperature beyond the predefined threshold values, the microcontroller identifies a fire hazard. Immediately, the system activates an audible alarm and triggers the water pump or sprinkler system to suppress the fire. At the same time, an alert message is transmitted to the farmer through the GSM or IoT communication module.

For animal intrusion detection, PIR motion sensors and IR beam sensors are placed along the farm

boundary. When an animal enters the protected area, the sensors detect movement or beam interruption and send signals to the controller. The microcontroller then activates a siren to scare away the animal and sends a real-time notification to the farmer's mobile device.
The solar-powered energy system ensures uninterrupted operation by supplying power through a battery backup. This working principle enables early detection, quick response, and effective protection of agricultural land with minimal human intervention.

XI. APPLICATIONS

1.Protection of agricultural farms such as paddy, wheat, maize, and sugarcane fields.
2.Use in plantation areas including tea, coffee, rubber, and fruit orchards.
3.Suitable for farms located near forest regions affected by wild animal intrusion.
4.Applicable to remote and rural agricultural lands with limited manpower.

XII. ADVANTAGES

1.Low-cost system developed using easily available electronic components.
2.Solar-powered operation ensures energy efficiency and uninterrupted functioning.
3.Early detection of fire hazards reduces crop damage and financial loss.
4.Effective prevention of animal intrusion through automated detection and alerts.
5.Real-time notification to farmers enables quick response and timely action.

XIII. FUTURE SCOPE

The future scope of the proposed smart farm protection system can be extended by incorporating advanced technologies to enhance accuracy, reliability, and functionality. The integration of camera-based monitoring and image processing techniques can enable precise identification of fire sources and animal types, thereby reducing false alarms. The use of artificial intelligence and machine learning algorithms can further improve decision-making by analyzing sensor data patterns. Long-range communication technologies such as LoRa or NB-IoT can be implemented to support monitoring over large agricultural areas. In addition, the development of a dedicated mobile application with cloud-based data storage can allow real-time visualization, historical analysis, and remote control of the system. The system can also be expanded to monitor additional environmental parameters, such as soil moisture and weather conditions, and integrated with smart irrigation systems to support precision agriculture and sustainable farm management.

XIV. CONCLUSION

The proposed smart farm protection system provides an effective and reliable solution for safeguarding agricultural fields against fire hazards and animal intrusion. By integrating low-cost sensors, an ESP32-based control unit, and wireless communication, the system ensures continuous monitoring and timely detection of critical events. The use of solar power with battery backup enables uninterrupted operation in remote and rural areas with limited electricity supply. Automated alerts and response mechanisms reduce the need for manual supervision and help minimize crop damage and economic loss. Overall, the system offers a cost-effective, scalable, and sustainable approach to improving farm safety and supporting modern agricultural practices.

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