# AgroBot: An ML-Based Autonomous System for Precision Arecanut Farming

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*Abstract—Arecanut is one of India's major commercial crops, but farmers face significant challenges in pesticide spraying due to labor shortages and health risks linked to manual methods. These trees can grow between 15 and 18 meters tall, and they need multiple pesticide applications during the rainy season. This makes traditional spraying both dangerous and inefficient.*

*To tackle these challenges, we propose AgroBot, an autonomous robotic system that uses machine learning. It features sensors and imaging tools to monitor tree health, detect infections, and find out specific treatment needs. With a tree-climbing chassis and a robotic arm, AgroBot performs targeted pesticide spraying, which reduces chemical waste and lowers environmental im- pact.The robot includes real-time monitoring through cameras and sensors to ensure accuracy and safety. IoT connectivity in the future will enable remote operation, live data analysis, and cloud-based health reports, making AgroBot a fully automated, intelligent solution for sustainable farming. This approach will ensure timely control of pests, reduce labor dependency, and increase productivity and yield in arecanut plantations.*

*Keywords—Arecanut farming,Precision Agriculture, Smart Sprayer, Pesticide Spraying, Agricultural Robotics, Automation in Farming, Sustainable Agriculture*

## I. INTRODUCTION

Agriculture is the backbone of India and the principal source of income of millions of farmers in this country. Arecanut, popularly known as betel nut or 'supari,' is an important tropical palm crop that is grown extensively in southern India.That accounts for about 43% of the national production. The increase in demand, coupled with stable prices and scientific methods of farming, has accounted for an appreciable rise in areas under cultivation. However, farmers continue to struggle with pests and diseases at this stage, more so during pesticide spraying operations.

To protect against fungal and pest infestations, arecanut trees which typically grow to heights between 15 and 18 meters require several applications of pesticide throughout the rainy season.. Manual spraying requires climbing the trees, which is labor-intensive, time-consuming, and poses serious health risks due to direct contact with toxic chemicals. Additionally, the lack of skilled labor makes this issue worse, often leading to delays or incomplete pest control, which lowers crop yield and quality.

Recent innovations in smart farming technologies like the

Internet of Things (IoT), machine learning (ML), and robotics offer potential solutions to these challenges . IoT systems allow for real-time monitoring and informed decision-making, while machine learning can predict disease outbreaks and improve pesticide use. Robotic systems, especially tree-climbing robots, remove the need for manual labor, ensuring safe and accurate pesticide spraying.

In this paper, we present AgroBot, an autonomous tree climbing robot equipped with

IoT sensors and ML algorithms for monitoring tree health and spraying pesticides in arecanut plantations. The system conducts real-time health assessments, identifies infections, and applies pesticides only to the affected areas, reducing chemical use by 30–40%. AgroBot addresses labor shortages, lessens environmental impact, and supports sustainable farming practices.

## II. REVIEW

Recent advancements in precision agriculture use robotics, IoT, and machine learning to automate tasks like spraying and monitoring crops. Tree-climbing robots, drones, and IoT systems allow for real-time monitoring and targeted pesticide application. At the same time, machine learning helps detect diseases. However, current solutions often do not provide complete automation or flexibility for tall crops like arecanut. This review points out these gaps and presents AgroBot as a combined solution that brings together robotics, IoT, and AI for sustainable farming of arecanut.

The introduction of the Smart Pesticide Sprayer by Shwetha B. et al. [1], marked an early breakthrough in automating pesticide application for arecanut cultivation. Addressing the twin challenges of labor scarcity and safety risks in manual tree climbing, their system employed an AT89S52 micro- controller–based architecture to design a remotely operated climbing sprayer capable of ascending 30-foot arecanut trees without damaging the trunk. This work demonstrated the mechanical feasibility of automated pesticide delivery systems in vertical plantations. While limited to proof-of-concept experimentation, it established the foundational framework for integrating autonomous climbing and precision spraying key capabilities that later evolved into the AgroBot system.

The work of Aditya Dwivedi et al. [2], represented a significant advancement in the field of robotic climbing mechanisms through the development of a lightweight pole-climbing robot employing a linear actuator and sliding gripper architecture. Utilizing a Node MCU microcontroller with Io T connectivity, the system incorporated load cell and LiDAR sensors to dynamically regulate gripping force and height control, achieving smooth and stable vertical motion. Its design effectively mimicked human climbing through alternating grip- release actions, enabling ascent speeds of 100 cm/min across cylindrical and rectangular surfaces. Although not intended for agricultural spraying, this work established a reliable and adaptable climbing framework, forming the mechanical foundation upon which AgroBot's autonomous tree-climbing capability could be realized.

The work of Atreya G. Bhat et al. [3], marked a notable step forward in automating pesticide application for arecanut plantations through the design of a semi-autonomous tree-climbing and spraying robot. The system employed spring- loaded gripping arms and a single high-torque motor to achieve stable, lightweight climbing, while a laser-guided, servo-controlled nozzle provided precise pesticide delivery to infected regions. An Atmega32 microcontroller coupled with RF joystick control enabled intuitive operation and spraying coverage for up to six trees from a single position an advancement over earlier single-tree sprayers. By reducing pesticide wastage and enhancing operational efficiency, this research demonstrated the potential of servo-guided, multi- tree spraying systems. Building upon this foundation, AgroBot can integrate AI-based disease detection to achieve a more intelligent and fully autonomous spraying process.

In their contribution, Arshiya Siddiqa et al. [4], addressed the persistent issues of labor scarcity and safety hazards in arecanut plantations by developing a battery-operated robotic climber and sprayer. The study emphasized the significant health risks arising from pesticide exposure and the difficulty of repeatedly climbing trees up to 70 feet high during each spraying cycle. Through an extensive review of actuator-based and arm-based climbing mechanisms, the authors identified critical shortcomings in safety and user-friendliness. Their proposed solution introduced a simplified, microcontroller- based remote-controlled system that prioritized portability, affordability, and ease of use for rural farmers. Although it lacked advanced automation features such as servo or AI integration, this research laid an essential foundation for practical mechanized farming. Building on these principles, AgroBot evolves the concept into a more autonomous and intelligent climbing and spraying platform.

In their contribution, Aishwarya B. V. et al. [5], investigated the integration of robotics and automation in field- level pesticide spraying using a PIC microcontroller–based robotic vehicle. The system is designed for precision spraying operations and is equipped with a joystick and wireless camera to enable real-time navigation and monitoring of crop conditions. Emphasizing farmer safety, the robot eliminates direct human exposure to pesticides while utilizing renewable energy sources such as solar and wind to ensure sustainable field operation. Its architecture supports modular control for detection, navigation, and spraying, thereby improving over- all operational efficiency. Although primarily developed for ground-level crops rather than tree plantations, its energy- efficient and feedback-driven control principles can be effectively adapted for vertical plantation systems. Building on these concepts, AgroBot incorporates similar precision and renewable-powered control mechanisms to enhance autonomy and field coverage in arecanut spraying applications.

In the submitted work, P.V.R. Chaitanya et al. [6], presented a smart pesticide spraying robot that utilizes image processing and automation to improve precision agriculture. Specifically, it uses a Raspberry Pi 3 microcontroller and raspberry-pi-based code in Python to take an image of a plant and analyze it to determine disease or pest-affected areas. Once these areas are identified, solenoid valves and peristaltic pumps initiate spraying pesticides in those areas, minimizing chemical waste and improving crop health. The design also includes motor drivers for movement, Bluetooth modules for communication, and sensors to maintain pesticide levels and adjust parameters while spraying. Overall, the automated detection and spraying in the model allows for reduced farmer exposure to hazardous chemicals while improving efficiency. This work provides the groundwork for integrating vision-based disease detection and selective spraying into our concept and is instrumental in the development of AgroBot's intelligent pesticide management system.l for AgroBot.

The study by Shambulingappa I. N. et al. [7], introduces eAgrobot, an advanced precision agriculture system combining Convolutional Neural Networks (CNN), IoT, and image processing for automated plant disease detection and targeted pesticide application. The Raspberry Pi 3–based robot captures plant images via camera, processes them through CNN for classification, and automatically actuates a servo- controlled spraying arm only when infection is detected. IoT communication notifies the farmer about disease type and pesticide usage. Compared to prior single-stage ML sprayers, eAgrobot demonstrates improved accuracy, automation, and real-time feedback. For AgroBot, it exemplifies deep learning integration, enhancing disease prediction reliability and remote farm management capability.

In their work, P.Krishnaleela et al. [8], developed a cost- effective and versatile agricultural robot aimed at stream- lining multiple farming operations. The system combines dual functionalities performing seed sowing during forward movement and spraying a uniform water-fertilizer mixture in reverse thereby improving operational efficiency in a single run. Managed wirelessly via Bluetooth, the robot offers precise control and user-friendly operation for farmers. Moreover, IoT-enabled sensors gather real-time field data, including soil moisture and system performance metrics, supporting predictive analysis and informed decision-making to optimize input use, reduce costs, and enhance yield. The study highlights affordable automation and multifunctionality, principles that complement AgroBot's goal of creating an intelligent, integrated platform for precision agriculture.

In their research, Vivek Kumar Verma et al. [9], introduced a smart agricultural solution aimed at automating crop protection. Conventional pesticide application methods, such as manual backpack sprayers, are inefficient, labor-intensive, and pose significant health risks to farmers. These methods often result in under- or over-spraying, causing crop damage and environmental concerns. To address these issues, the authors developed a system that combines a 2D Convolutional Neural Network (CNN) with an ESP-32 microcontroller, enabling real-time plant disease detection and targeted pesticide dispensing, thereby improving accuracy, efficiency, and safety in crop protection.

The work of Prof. Mr. S. P. Bangal et al. [10], presents an IoT-based smart pesticide sprayer robot designed to mitigate the health hazards and inefficiencies of traditional spraying in vineyards. Conventional methods expose operators to toxic chemicals and require significant manual effort. To overcome these issues, the system utilizes an automated three-wheeled vehicle powered by a solar-charged battery, reducing operating costs while employing a green energy source. Controlled remotely via an Android application through Bluetooth communication with an onboard microcontroller, the robot provides a practical and efficient alternative to manual spraying, enhancing safety and lowering labor requirements in agricultural operations

Joseph Friday Kayode et al. [11], developed a solar-powered agricultural vehicle designed to simplify and safeguard pesticide application. Traditional manual spraying is labor-intensive and exposes farmers to health risks, particularly in rural areas. The system operates using solar-charged batteries that power the wheels, pump, and sprayers, while farmers control it via a Bluetooth-connected mobile application. Being semi- automatic, it is easy to use and enhances operator safety. The vehicle sprays up to 5 liters per minute and can cover approximately 159 meters in 4 minutes, providing an efficient and practical solution for pesticide application in challenging field conditions.

In their research, Jian Sun et al. [12], introduced a baseline analysis of inchworm crawling dynamics using a three-link articulated robot as a model. Traditional approaches to studying robotic crawling often overlook dynamic effects and surface variability, limiting predictive accuracy. To address this, the authors developed a hybrid dynamic simulation incorporating inertia at different actuation frequencies and validated the pre- dictions through a physical prototype. The study also provides criteria for enhancing performance and robustness against surface friction uncertainty, offering valuable insights into the physics of dynamic crawling applicable to both articulated and soft-robotics systems.

Honglin Shen et al. [13], developed GeiwBot, an untethered soft robot that merges the inchworm gait with gecko-inspired adhesion to achieve climbing. The robot's body and legs are actuated using photo-responsive Liquid Crystal Network (LCN) materials, while adhesion is provided by a Gecko-Adhesive Pad (GAP) controlled via a transient magnetic field and released using UV light. This innovative combination enables the robot to climb vertical walls and even inverted ceilings, demonstrating the potential of hybrid bio-inspired strategies in soft robotics applications.

Benny Gamus et al. [14], proposed a study on dynamic inchworm crawling using a three-link articulated robot with passive frictional contacts. The work developed a hybrid dynamic model to simulate motion and validated it experimentally, showing that performance depends on actuation frequency. Key contributions include criteria for robustnessagainstsurface friction uncertainties, exploration of asymmetric mass distribution to enhance performance, and a time- scaling input shaping method to achieve similar effects without physical changes. This study provides a foundational analysis of dynamic crawling applicable to both articulated and soft robotics.

Zhiwu Zheng et al. [15] developed an ultra-thin piezoelectric soft robot capable of bidirectional inchworm motion by controlling ground friction through shape change. The robot uses five coordinated piezoelectric actuators on a flexible steel substrate to create a “seesaw” effect, increasing friction at one end for anchoring during motion. A quasi-static model accounting for gravity and contact force accurately predicts displacement and friction behaviour. Experiments showed up to 30% increase in contact force during lift, enabling crawling speeds of about 1 mm per cycle. This design requires no special adhesives, relying solely on electrical actuation to adjust friction. The work provides a strong foundation for compact soft robots operating in tight spaces.

## III. SYSTEM DESIGN

The integration of IoT, robotics, and machine learning in AgroBot allows for independent tree health monitoring and precise pesticide spraying, which are crucial for managing arecanut plantations sustainably.


Fig. 1: Sample working of AgroBot.

1. AgroBot: Contains all the sensors, grippers, and motors needed to climb the tree and capture images for diagnosis.
2. Real-Time Data Collection: Captures real-time data used for diagnosis and initiating targeted responses.
3. Data Processing and Analysis: The captured images are analyzed to determine tree health, classifying them as healthy or diseased. A machine learning model identifies and classifies disease symptoms such as leaf spots or fruit rots.
4. Automated Spraying: After detecting disease, pesticides are sprayed precisely where needed, reducing chemical usage and minimizing health risks to humans.
5. Monitoring and Feedback: Real-time dashboards display analyzed data, sensor feedback, and crop conditions to the farmers.

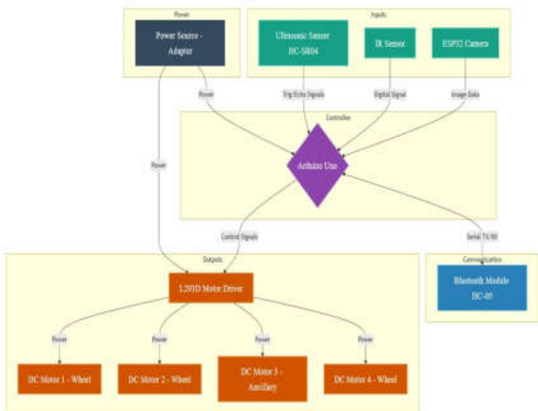


Fig. 2: Hardware Architecture of the Agrobot Prototype

Table 1: Summary of Techniques Used in Arecanut Tree Pesticide Sprayer

| Reference | Method/ Approach | Key Features/ Techniques Used | Findings/ Inference |
|---|---|---|---|
| [1] | RF remote controlled, microcontroller- based sprayerthat climbs arecanut trees using DC motors and sprays pesticide through a pump nozzle, eliminating the need for manual tree climbing. | TRF wireless control using encoder– decoder ICs, an AT89S52 microcontroller for operation, relay-driven DC motors for climbing and sprayer arm movement, a pumping mechanism for pesticide spraying, and an LCD display for monitoring. | The smart pesticide sprayer successfully climbed arecanut trees up to 30 feet in dry and 20 feet in wet conditions without slipping. It reduced manpower, avoided the risks of manual climbing, proved user-friendly and affordable. |
| [2] | The robot employs a controlled gripping system to firmly climb cylindrical and rectangular poles with vari- ous shapes and sizes. | The robot can climb at a fast pace, has wireless control, and has a moderate payload. | Generally, the robot exhibits a realistic and safe mode of climbing over human climbing, showing its potential for use in utility maintenance, agriculture, and other vertical climbing solution-requiring industries. |
| [3] | Designed a semi-autonomous areca nut climbing robot using ATMEGA32 microcontroller with RF transmitter/receiver and HT12 encoder/decoderfor remote control. | The robot features a lightweight aluminum T-frame for strength and easy handling, equipped with adjustable spring grippers to adapt to different trunk sizes. It uses a joystick and footswitch remote control for safe operation, efficiently covering 5–6 trees at once. | The robot weighs 7 kg with a hose and uses an 8 Nm, 30 rpm motor for climbing. Servo motors with 10 kg/cm torque enable 180 nozzle rotation for flexible spraying. |
| [4] | The development of a semi-automatic, Arduino-controlled tree climbing robot that uses spring-loaded wheels to grip the arecanut tree, climbs up to 18 meters using drive motors, and sprays pesticides t hrough a booster pump with a rotating nozzle arm. | Includes a spring-loaded wheel and motor system for tree climbing, RF transceiver-based remote control, and Arduino UNO microcontroller for operation. A booster pump with a rotating nozzle en- ables circular pesticide spray- ing, while a solenoid valve regulates flow. The setup is powered by a rechargeable lithium-ion battery and designed to be lightweight for easy use. | This robot can safely climb arecanut trees, spray pesticides efficiently over a wide area, and reduce labor dependency while being cost-effective, portable, and easy to operate. |
| [5] | A farmer remotely operates the robotic vehicle using a joystick. A wireless camera provides a live video feed to a television for navigation and crop inspection. | The system uses a PIC microcontroller, stepper motors for precise movement, and a joystick for control. It emphasizes cost-effectiveness and uses a renewable power source. | This vehicle is an effective, user-friendly, and economical tool that reduces farmers' labor and health risks from direct pesticide contact. It makes farming safer and more efficient. |

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| [6] | The robot captures plant images and uses a Raspberry Pi with machine learning to diagnose diseases. Upon detection,it automatically sprays pesticide directly onto the infected area. | Key features include machine learning for automated disease detection on a Raspberry Pi. The robot provides targeted pesticide spraying, reducing waste and farmer exposure to chemicals. | Machine learning effectively automates disease diagnosis and targeted spraying. This method improves crop health, increases farmer output, and prevents hazardous pesticide exposure through remote operation . |
| [7] | The robot stops at plants, captures a leaf image, and sends it to a Raspberry Pi. A Convolutional Neural Net- work (CNN) processes the image to diagnose diseases for targeted spraying. | Key techniques include using a Convolutional Neural Network (CNN) on a Raspberry Pi for image-based disease detection. The system features precision spraying and sends IoT alerts to the farmer | The e-AGROBOT effectively detects diseases, reducing manpower and boosting productivity. Precision spraying protects farmers' health, saves costs, and min- imizes unnecessary pesticide application on crops. |
| [8] | The robot operates on a dual-function mechanism: it plants seeds when moving for- ward and sprays fertilizer or pesticides when moving back- ward. Operations are wire- lessly managed via Bluetooth. | This multipurpose machine combines planting and spraying to reduce costs. It features Bluetooth remote control for precise operation and uses IoT sensors for real-time data monitoring. | The system proved to be a practical and efficient solution. The Bluetooth interface was user-friendly , and IoT integration enabled effective data-driven decision-making for modern farming. |
| [9] | Integration of a 2 D Convolu- tional Neural Network (CNN) with an ESP-32 microcon- troller to detect plant diseases in real time and automate pesticide application. | 2D CNN for image-based plant disease detection, combined with image pre-processing and deployment through TensorFlow Lite on an ESP-32 microcontroller. It integrates a robotic vehicle with sensors, pump, and servo-controlled nozzles to enable real-time, automated, and precise pesticide spraying . | The system achieved about 88.48% accuracy on PC and 85.64% on ESP-32, proving it effective for real-time plant disease detection and precise pesticide spraying. It reduces labor, costs, and health risks. |
| [10] | This robot is powered by solar energy, and is controlled us- ing a Bluetooth-enabled Android app. The microcontroller processes the user's commands for movement and spraying, and an ultrasonic sensor allows for obstacle de- tection. | The main features of the device seen here are: solar power makes the device cost-effective, and Bluetooth control by An- droid app. The microcontroller based system utilizes an ultra- sonic sensor for obstacle detec- tion while harvesting grapes in vineyard settings. | The robot was successful in spraying pesticides faster than a human could, while eliminating any human health risks from chemical exposure, and low operating costs, and ensuringa farmer safety. |
| [11] | This solar-powered vehicle utilizes remote control and Bluetooth app for operation. The hub motor for forward motion and the spray pump are commanded by an ATMEGA32A microcontroller to process signal com- mands. | Features of this research project include four solar panels with 30W each charging the vehicle's 100AH battery. The vehicle utilizes remote control with an HC-05 Bluetooth module to communicate with the ATMEGA32A microcontroller. | The vehicle successfully traveled 159 meters in 4 minutes. By utilizing the remote control option, the manual labour is reduced, and saves time for the operator. This remote function also protects the operator from harmful chemicals, and enhances productivity. |

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|---|---|---|---|
| [12] | This robot employs a magnetic-field-assisted strategy that is also photo-driven. The magnetic field provides gecko-like adhesion whilst the UV light on liquid crystal networks creates inchworm-like movement and detachment. | The key characteristics of the robot are it is bio-inspired, uses untethered climbing, uses gecko-like adhesive pads for attachment, and uses photo-responsive liquid crystal networks (LCNs) as actuators for inchworm-like motion. | This untethered robot can successfully climb on a variety of surfaces, including vertical walls and inverted ceilings. This is the first soft robot which automated inverted climbing. |
| [13] | Inchworm-shaped soft robot, NdFeB-PDMS fabrication, 3D Helmholtz coil for magnetic actuation, with force analysis and experiments on magnet spacing, shape, slope, field, and frequency. | Bio-inspired soft design, programmable motion via magnetic fields, capable of crawling, climbing, turning, rotating, pushing/pulling, tested with multiple structures. | Larger magnet spacing increases speed. The dumbbell design is faster but less stable, climbing slows by 50% at 15 degrees, and the robot can carry 0.5 times its weight for microscale transport, assembly, and biomedical use. |
| [14] | The research models and simulates a three-link inchworm robot with passive friction with hybrid dynamics. The robot is actuated using pre- scribed periodic joint angles for performance evaluation. | The main methods used are a hybrid dynamic model for stick- slip transitions and a unique time-scaling method to shape the inputs. Bayesian machine- learning will be implemented to improve performance. | High-frequency gaits yield both high velocity and robustness to frictional uncertainty. Effects of asymmetric mass can also be modeled and instrumented to optimize travel distance using time-scaling and machine learning. |
| [15] | The robot moves like an inch- worm using five small electric parts (actuators). It changes its shape to control how it grips the ground and moves forward or backward. The scientists tested it with real experiments and mathematical calculations. | It doesn’t need extra parts like sticky pads or wheels – just changing its shape is enough to move. The parts are controlled by electric signals to lift one end and slide the other. The shape and force are predicted by a model and checked with experiments. | The robot can move by itself just by changing its shape and friction. The experiments worked as expected and showed the idea is correct. This way of moving can be made smaller without los- ing performance. |

1. Power: An external Power Source/Adapter supplies electricity to the entire system.
2. Inputs (Sensors): Various sensors provide data to the controller:

•Ultrasonic Sensor (HC-SR04): Provides distance data (Trig/Echo Signals) for proximity sensing and automated stopping.

•IR Sensor: Provides a Digital Signal for specific detection and auto-stop.

•ESP32 Camera: Supplies Image Data for the disease detection system.

3. Controller: The Arduino Uno serves as the central processing unit, receiving input signals, executing the control logic, and sending control commands.
4. Outputs (Actuators): The L293D Motor Driver receives control signals from the Arduino and manages power flow to the three DC Motors (two for wheels/climbing and one for an ancillary function, likely spraying).
5. Communication: The Bluetooth Module HC-05 handles wireless Serial TX/RX communication, allowing for external control or data transmission.

## IV. RESULTS AND DISCUSSIONS

The review of studies indicates the potential benefits of adopt- ing IoT in agriculture. Initial trials of AgroBot show positive outcomes in addressing challenges faced by arecanut farmers. Its robotic climbing mechanism, based on an inchworm-type system, securely grips narrow tree trunks, allowing stable movement up and down, and significantly reduces the dangers of human climbing.

The AgroBot system includes an ESP32-CAM module that captures high-quality close-up images of leaves. A Convolutional Neural Network (CNN) model detects common diseases such as Koleroga and Yellow Leaf Disease with an accuracy of 85–90%. While accuracy decreases under poor lighting or blurry images, the CNN model remains suitable for field-level monitoring.

The robotic spraying mechanism applies pesticides selectively to infected areas rather than the entire tree. This target- based spraying reduces chemical usage, minimizes waste, lowers environmental contamination, and ensures farmer safety by preventing direct contact with toxic chemicals. Compared to traditional methods, AgroBot's precision spraying saves costs, maintains healthy portions of plantations, and enhances overall agricultural productivity.

Despite these advantages, issues such as battery limitations, image quality degradation, and self-calibration errors in robotic functionalities need to be addressed in future versions. Overall, AgroBot shows great promise as a low-cost, environ- mentally friendly, and robotics-enabled solution that integrates traditional farming with intelligent agricultural technologies. With enhancements such as improved energy systems, advanced vision modules, and autonomous movement, AgroBot can become an affordable and scalable tool for small and medium-scale farmers to efficiently manage crop health.

The proposed AgroBot prototype and ML-based disease pre- diction system were experimentally evaluated on arecanut trees under real plantation conditions. The robot climbing mechanism demonstrated stable attachment and locomotion performance on tree trunks of varying diameter (average 14–18 cm).

The dual-wheel motor configuration provided sufficient grip and torque to support vertical movement without slippage. The mechanical structure, shown in Figure 3, remained stable during repeated tests, confirming that the clamping and motor drive system effectively distributed load while minimizing vibration.

Fig. 3: The developed robotic platform attached to an arecanut tree trunk during field testing. The hardware assembly includes motor-driven wheel units, embedded sensors, power circuitry, and the image acquisition module designed for autonomous vertical navigation and data collection.

The vision module successfully captured nut cluster images during tree ascent and transmitted them to the processing unit in real time. The disease classification model analysed the captured arecanut images through the web-based interface and generated automatic health status outputs. As shown in Figure 4, the system correctly identified a test sample as Healthy Nut and provided relevant agronomic recommendations. Across 50 test images, the model achieved an overall classification accuracy of 96%, with 94% precision and 95% recall.

Field evaluation further confirmed system reliability. The sensing unit operated continuously for 38 minutes per charge, and the data transmission delay remained under one second. The prototype successfully detected trunk proximity using the ultrasonic sensor, enabling smooth navigation around curvature. Farmers participating in preliminary usability assessment indicated high satisfaction with automated disease reporting and found the cure-suggestion module beneficial for decision-making.

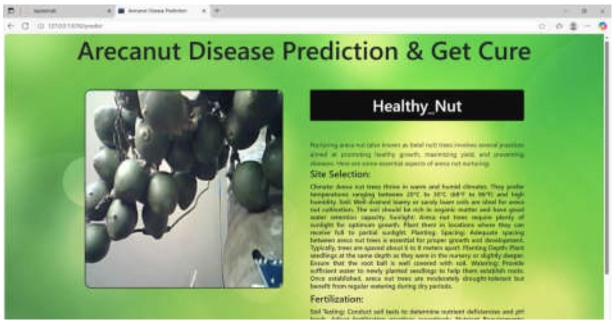


Fig. 4: Disease Detection Output Interface.

These results validate that the integrated hardware–software system can autonomously navigate arecanut trees, acquire fruit imagery, detect disease presence with high accuracy, and present interpreted results through an intuitive application interface. The system's modular design allows scalability and future integration of additional sensors or advanced analytics. Overall, the study demonstrates strong feasibility for real-world deployment, enhanced monitoring efficiency, and potential reduction in manual climbing effort and disease-related yield loss.

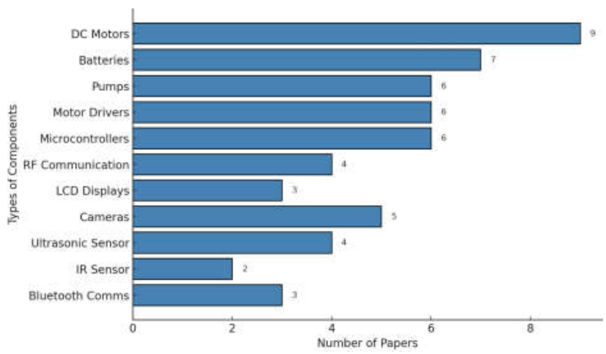


Fig. 5:Electronic components commonly used in AgroBot research, including DC motors, microcontrollers, batteries, cameras, pump, sensors, motor drivers, and communication modules, are essential.

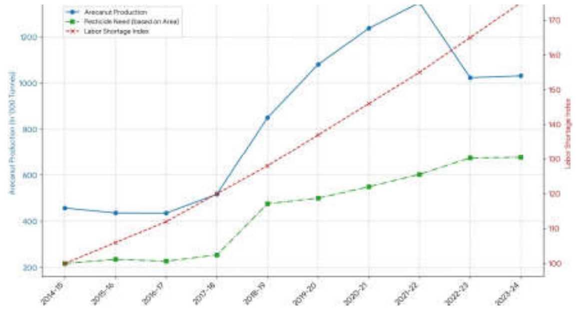


Fig. 6: The growth of arecanut cultivation and labor shortage for pesticide spraying.

**Arecanut Production and Pesticide Demands**

The production and area under arecanut cultivation has been steadily increasing from 2015 to 2024, resulting in a rising total pesticide demand.

**Labor Shortage**

Migration to urban areas has created a labor shortage in agriculture, particularly for menial, labor-intensive work.

**Core Problem**

The gap between increasing pesticide demand and decreasing farm labor highlights the need for mechanization, including drones and robots, to efficiently and safely maintain crop yield.

## V. RESEARCH CHALLENGES

AgroBot will face considerable challenges in climbing trees because of the variability of horizontal trunk diameter, bark texture, and location of branches. Keeping a stable grip on payloads such as pesticide tanks would also be difficult and robots would have to manage variability, while slipping or tipping over on surfaces that are mostly variable. Height and energy limitations mean using lightweight and stiff materials with efficient motors to climb safely and continuously. To this end, environmental conditions such as wind, rain, and unlevel terrain are serious challenges, requiring advanced sensors and control algorithms to avoid obstacles and climb stably.

The pesticide spray mechanism provides additional challenges as it requires targeting the affected area with precision as to avoid using excess chemical that could damage either crop or operator. Careful consideration of fluid dynamics, spray nozzle design and synchronization of all movements are important to achieve uniform coverage while the robot moves or climbs. Real time perception, disease identification, and decision support requires sophisticated image processing and IoT capabilities and always requires at least some wireless connectivity in plantation environments. Cost, maintenance, and scalability would also be considerations, as these robots must not add significant cost to the overall production method, must be durable enough to avoid concern over maintenance (and parts) and must be sufficiently effective in climbing different types of trees as to be plausible in the future for widespread deployment in agricultural settings.

## VI. CONCLUSION AND FUTURE ENHANCEMENT

### 5.1 Conclusion

The paper was aim to not implementing advanced technologies into agriculture but to give the ideas to increase the higher producitvity and reduce the risks of the farmers.AgroBot is a groundbreaking solution for arecanut cultivation, combining machine learning and robotics to tackle challenges like labor shortages and inefficient pesticide use. By autonomously navigating plantations, it uses advanced image processing and convolutional neural networks (CNNs) to detect tree health issues and spray pesticides precisely where needed. This targeted approach reduces chemical usage, enhances worker safety, and boosts overall efficiency.

Equipped with IoT capabilities, AgroBot offers real-time insights to farmers, enabling timely and informed decisions. Designed to be affordable and easy to use, it empowers small and medium-scale farmers while promoting sustainable farming practices. AgroBot not only improves crop yield and disease management but also sets a precedent for tech-driven innovations in agriculture.

### 5.2 Future Enhancement

Future improvements for the AgroBot system will focus on making it stronger, smarter, and more user-friendly for real farm conditions. The current open wiring and exposed components can be redesigned into a fully covered, weather-resistant body to ensure safe operation under varying environmental conditions. Enhancing wheel grip and motor power will enable smoother and more stable climbing on rough and uneven tree surfaces, while improving battery capacity will allow longer uninterrupted operation in the field.

Incorporating fully autonomous navigation and wireless data transmission will enable the robot to operate independently and share real-time information directly with farmers. Overall, these enhancements will improve reliability, efficiency, and practicality, making AgroBot a valuable tool for modern arecanut farming.

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