Mini AgroBot for Smart Farming: An Intelligent Multipurpose Robot for Next - Gen Smart Farming

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I. Abstract

The increased demand for sustainable, precise, and efficient agriculture practices has led to the advancement of robotic farming, which is capable of automating diverse field operations. This literature review encompasses research papers from over the past decade on the integration of robots or smart farming. This review paper focuses on agricultural and field inspection tasks, emphasizing innovations in compact design, precision pest control, and software integration frameworks. Currently, most research focuses on only one application or purpose, such as only harvesting or sowing. It faces issues like high costs, complicated systems for local farmers with zero knowledge of the system, and adaptability across various farming environments. A critical analysis of recent studies highlights the advantages of multi-purpose designs, including improved resource utilization, operational flexibility, and environmental benefits, while also identifying limitations such as technical complexity and initial deployment barriers. The paper proposes an innovative solution focused on the integration of advanced sensing, precision pest control, and accurate ploughing and sowing. It also addresses the gaps, methodology, problems faced, the solutions adopted, and the design of the robot. Finally, it discusses future research directions, including AI-driven autonomy, scalable fleet operations, and strategies for wider adoption in small- to medium-scale farming contexts, underscoring the transformative potential of agricultural robotics in fostering sustainable and resilient food systems.

Keywords: Smart farming, Compact Farming Robot, Multipurpose, Modulation, Agriculture.

II. Introduction

2.1 Background and Contexts

The agriculture industry in India is one of the largest sectors giving employment to over 5 million people. This is one of the most cost-effective and needs-driven sector of the country. This is an employment stability factor and an area with high transformation. It has many issues including financial issues, inadequate investments and resources and inadequate education in agriculture and irrigation (Hua et al. [2]). Every year over a million farmers suffer from natural calamities annually about 1 lakh farmers suicide every year due to agricultural distress (Jeong et al. [1]) Therefore, a robot that can solve multiple problems for farmers can greatly help them, especially in India, where agriculture is suffering from unexpected weather and improper irrigation levels and positioning. Recent research in robotics with multifunctional and modular agricultural robots suggest possibilities (Guri et al. [3]; Barhate et al. [4]; Sathesh et al. [5]).

2.2 Problem Statement

Small and medium-scale farmers in India face multiple challenges that reduce productivity, increase labour costs and create uncertainty in agricultural operations.
These challenges include manual labour shortages, inefficient irrigation and fertilization,
difficulty in pest and weed management, lack of timely guidance on crop health and limited
access to market insights(Hua et al. [2]; Vallejo-Gomez et al. [8]; Obaideen et al. [9])
Existing solutions are often single-purpose, expensive or complex, making it hard for the farmers to adopt technology effectively. There is a need for a multi-functional, affordable and user-friendly agricultural robot that can assist in performing critical tasks, optimize resource use and improve overall farm productivity.(Guri et al. [3]; Barhate & Lahamge [4]; Sathesh et al. [5]; Afriadi [6]).

In conclusion, these issues highlight an urgent need for a shift towards innovative, data-driven, and ecologically harmonious agricultural practices that leverage technology, precise management, and sound ecological principles to enhance efficiency, reduce costs, and minimize environmental harm for a sustainable future in food production.s & Gertsis [15]; Sparrow & Howard [17]; Kulkarni et al. [20]; Kumar et al. [21]).

2.3 Existing Solutions and Their Limitations

While several agricultural robots have been developed in India, many are designed for specific tasks like disease detection, pesticide application or soil sampling (Jeong et al. [1] and Hua et al. [2]). For example, IIT Kharagpur has developed a semi-automatic tracked mobile manipulator that can identify plant diseases and apply pesticides. However, the robot is limited by its battery life (which will last for 1.5 hours) so it won't be able to perform multiple tasks simultaneously.(Guri et al. [3])

One more example is the hybrid drone rover vehicle which is specially designed for weed removal and spraying applications, Which combines the advantages of both drones and rovers, but it still faces challenges like limited flight time and problems while navigating obstacles like canals in the farms.(Barhate & Lahamge [4]).

Such existing solutions often suffer from high initial costs and also lacks technical expertise among farmers and limitations of infrastructure in rural areas. (Sathesh et al. [5] and Afriadi & Muda [6]). Also, many robots need special maintenance and they are not adaptable to the diverse and unstructured environments while farming in India(Wakchaure et al. [7])

These constraints highlights the precision which is needed for next-generation agricultural robots which will be multi-functional, modular, cost-effective, and seamlessly integrated into smart farming ecosystems. (Jeong et al. [1]; Guri et al. [3]; Barhate & Lahamge [4]).

2.4 Research Objectives and Scope

The aim of this research is to address the limitations of current agricultural robotic systems by creating New designs and integration approaches. The key objectives includes exploring the feasibility of robots capable of executing multiple tasks like spraying, monitoring, or tilling to enhance versatility and reduce capital expenses (Guri et al. [3]; Barhate & Lahamge [4]; Sathesh et al. [5]; Afriadi & Muda [6]), develop scalable robotic architectures that will allow easy maintenance, customization, and deployment across farms of varying sizes (Pecka & Osadčuks [34]; Kumar et al. [21]), assess AI-driven crop monitoring and target spraying mechanisms to minimize chemical usage and environmental impact(Jeong et al. [1]; Hua et al. [2]; Wakchaure et al. [7]), evaluate the platforms that enable seamless data exchange and interoperability among robots, IoT devices, and farm management systems (Vallejo-Gómez et al. [8]; Obaideen et al. [9]; Badreldeen et al. [10]; Jensen et al. [49]) and propose strategies for making adaptable, interconnected robotic solutions suitable for all agricultural environments. (Lytridis et al. [11]; Mavridis & Gertsis [15]; Sparrow & Howard [17]).

The scope of this study spans both hardware innovation (robotic design and multi-functionality) and software interoperability (Al algorithms, data integration, and system compatibility).
By combining this, the research makes a foundation for the next wave of intelligent, sustainable, and accessible farming technologies. (Kulkarni et al. [20]; Vougioukas [23]; UK-RAS Network [30]; Shamshiri et al. [31]).

III. Literature Review Methodology

3.1 Introduction to Agrobot Mini

The Agrobot Mini is a small and multipurpose Agricultural robot designed to assist farmers in various necessary tasks at the field including crop monitoring, weeding, spraying, and sowing. This system is offered as a viable and low-cost alternative to larger and frequently expensive farming technologies, which are typically implemented in large farms with small and medium sizes (Jeong et al. [1]; Hua et al. [2]). It has the strength in the fact that it combines automation with cutting-edge sensing technologies, and precision farming techniques, which in combination can enhance crop management, decrease the consumption of inputs such as water and fertilizers, and promote more sustainable farming practices (Guri et al. [3]; Barhate & Lahamge [4]).

3.2 Problems Addressed by Agrobot Mini

Traditional farming relies heavily on manual labor, which is becoming scarce and expensive, especially for repetitive and time-consuming activities(Jeong et al. [1]; Hua et al. [2]).Conventional methods often lead to overuse of water, fertilizers, and pesticides, causing environmental harm and increased costs[8]; Obaideen et al. [9]).Lack of precision in sowing, spraying, and weeding results in uneven crop growth and productivity loss (Guri et al. [3] and Barhate & Lahamge [4]).Manual crop monitoring is laborious and may miss early signs of pest attacks or disease outbreaks, reducing timely interventions (Wakchaure et al. [7] and Kulkarni et al. [20]).Many farmers, particularly in developing regions, cannot afford large-scale, expensive agricultural robots or machines.(Sathesh et al. [5] and Afriadi & Muda [6]).

3.3 Proposed Solutions by Agrobot Mini

By automating operations such as sowing, spraying, and weeding, Agribot Mini reduces the dependency on manual labor and increases operational efficiency (Guri et al. [3] and Barhate & Lahamge [4]).Using sensors and GPS-based navigation, Agribot Mini ensures accurate placement of seeds and targeted application of inputs, optimizing resource use.(Jeong et al. [1]; Kumar et al. [22]; Ünal & Topakci [43]). Integrated monitoring systems allow for timely detection of crop health and environmental conditions, enabling proactive management. (Bayati & Fotouhi [33]; Mavridou et al. [26]; Zhang & Pierce [56]).The compact and cost-effective design of Agribot Mini makes advanced farming technology accessible to small and medium-scale farmers. (Barhate et al. [4]; Afriadi & Muda [6]; Arun Kumar et al. [21]). The robot's precise operation reduces chemical runoff and water wastage, promoting environmentally friendly farming practice.(Vallejo-Gómez et al. [8]; Ogidan et al. [24]; Sudharshan et al. [25]).

3.4 Development Phase

The developmental analysis includes the identification of essential agricultural tasks such as spraying, weeding, and soil monitoring aligned with the target environment of smallholder Indian farms operating under a budget constraint (~₹20,000). The mechanical design emphasizes the assembly of a lightweight, durable chassis, typically utilizing MDF or plywood, integrating 12V DC motors for mobility (Guri et al. [3]; Barhate & Lahamge [4]). Multipurpose tool modules such as water pumps for spraying, seed dispensers, and motorized weeding attachments are mounted (Sathesh et al. [5]; Afriadi & Muda [6]). Solar panels are incorporated for sustainable, off-grid power supply (Barhate & Lahamge [4]).

The electronics system framework employs microcontrollers like Arduino UNO paired with motor drivers (L293D/L298N) to coordinate motor control. Sensors for soil moisture, temperature, and obstacle detection are interfaced alongside Bluetooth modules (e.g., HC-05) enabling remote operation via mobile applications (Wakchaure et al. [7]; Vallejo-Gómez et al. [8]). Programming is conducted within the Arduino IDE environment using embedded C to automate actuation and navigation, supplemented by safety features like obstacle avoidance and motor shutdown protocols (Obaideen et al. [9]; Badreldeen et al. [10]). Prototypes undergo iterative testing, with calibration of sensors and actuators, and performance tuning through trial runs in controlled and field-like conditions (Jeong et al. [1]; Hua et al. [2]).

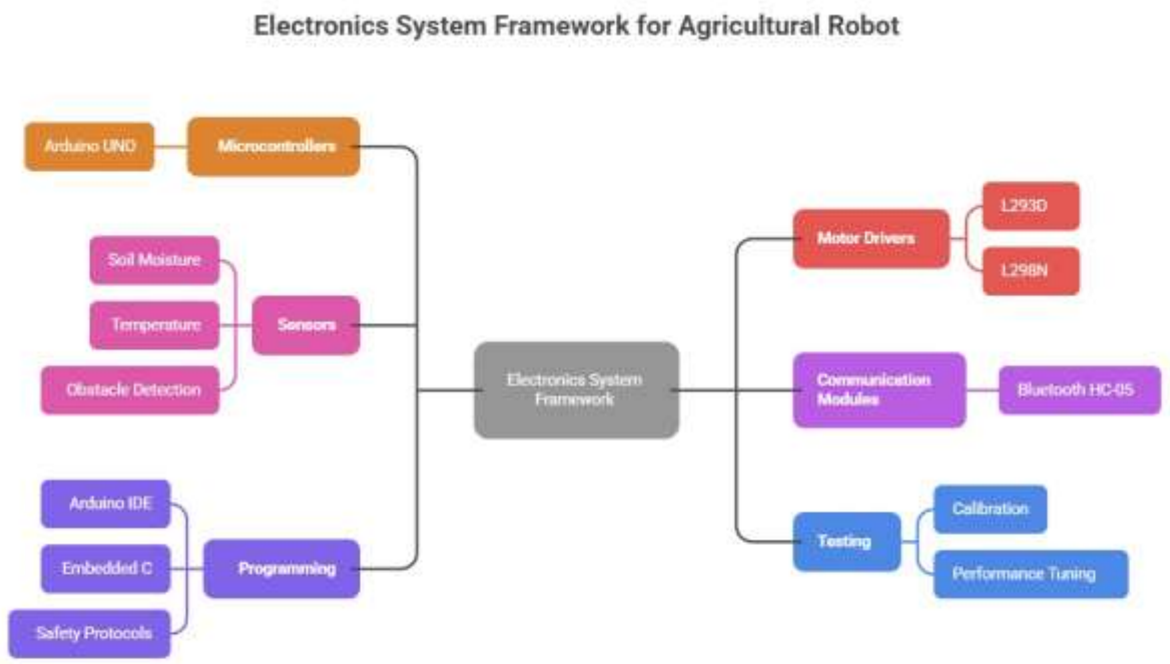

Fig. 01 Electronics system framework for agricultural robot

Classification of Electronic system Framework for Agricultural Robot Microcontrollers which consist of Arduino UNO, Sensors having Soil moisture, Temperature, obstacle Detection. Programming framework with Arduino IDE, Embedded C, Safety Protocols. It also has Communication modules having Bluetooth HC- 05, Motor Drivers which consists of L293D and L298N integrating Circuits and Testing frameworks like Calibration and Performance Tuning.[73]

3.5 Post-Development Execution:

Field deployment encompasses systematic evaluation on farm plots varying in soil and crop conditions (Jeong et al. [1] and Hua et al. [2]). Operational parameters such as battery life, energy efficiency, and task accuracy—including spraying volume, weed removal efficacy, and sensor data fidelity—are closely monitored (Guri et al. [3] and Barhate & Lahamge [4]). Training sessions for operators focus on usability, maintenance, and troubleshooting, ensuring user-friendly interaction with the robot (Sathesh et al. [5]). Feedback loops enable refinement of mechanical alignments and software parameters, ensuring adaptability to diverse agricultural scenarios (Afriadi & Muda [6] and Wakchaure et al. [7]).

3.6 Problem-Solving Approach

Hardware challenges such as motor stalling and battery depletion are addressed through enhanced power management and mechanical reinforcement. (Barhate et al. [4]; Afriadi & Muda [6]). Communication issues with Bluetooth connectivity Communication issues with Bluetooth connectivity are mitigated via signal amplification and alternative wireless protocols. (Bodunde et al. [27]; Jensen et al. [49]). Software improvements include sensor auto-calibration routines and optimization of obstacle detection algorithms.(Ball et al. [36]; Bayati & Fotouhi [33]). Environmental adaptations involve configuring task parameters to soil types and moisture variability, improving chassis suspension for uneven terrains, and optimizing solar charging efficiency.(Grieve et al. [28]; Barhate et al. [4]; Emmi et al. [47]).

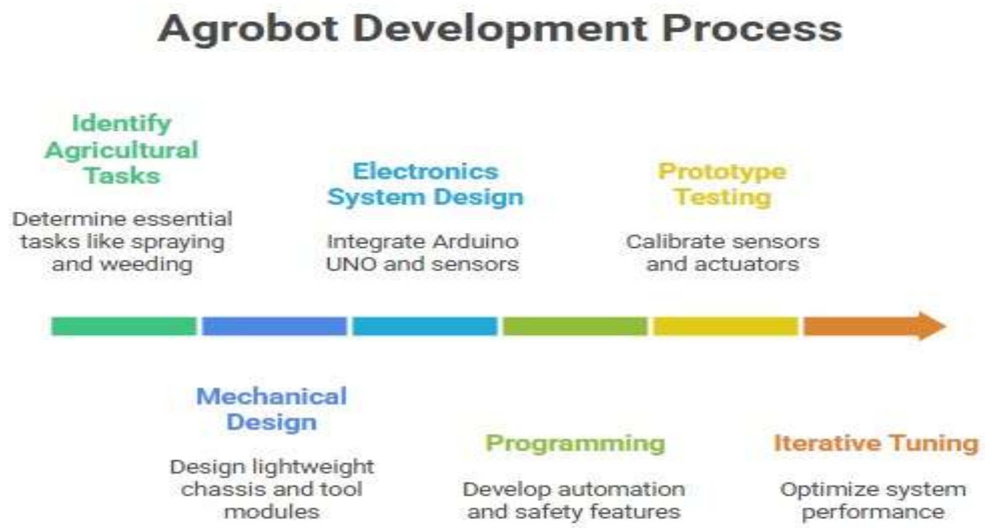

Fig.02 Agrobot Development Process

Diagram illustrating Agrobot Development Process along with it's steps including Identification of Agricultural tasks in which determines important tasks like Weeding or spraying.

Electronics system Design which integrates Arduino Circuits and sensors. Prototype Testing which is done to calibrate Sensors and Actuators, Mechanical Design having lightweight chassis and tool modules , Programming for development of Automation and safety features, and Iterative Tuning for optimizing overall Performance of the system.[73]

IV. Review of Agricultural Robotics Literature

4.1 Evolution of Agricultural Robotics

The evolution of Agricultural robotics has progressed in distinct phases over the last two decades.Early developments were driven by GPS-based automation,enabling precision farming through accurate spatial mapping and field navigation. (Pérez-Ruiz et al. [55]; Guzmán et al. [39]) The subsequent integration of computer vision and machine learning techniques enhanced autonomous navigation, crop identification, and health assessment capabilities. (Chen et al. [67]; Mavridou et al. [26]; Ball et al. [36]) More recently, research has shifted toward multifunctional robotic platforms that employ modular designs, allowing a single robot to perform diverse farming tasks such as seeding, spraying, weeding, and monitoring. (Guri et al. [3]; Barhate et al. [4]; Afriadi & Muda [6]; Pecka & Osadčuks [34]). This trajectory reflects the steady transition from single-purpose automated tools to intelligent, adaptable systems designed for smart farming. (Vougioukas [23]; Shamshiri et al. [31]; UK-RAS Network [30]).

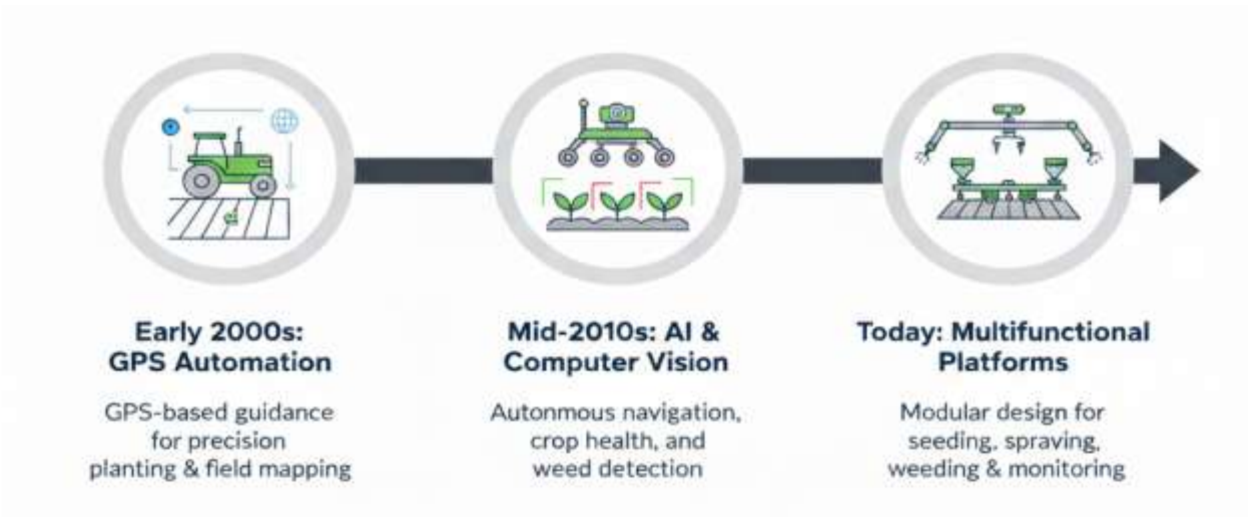

Fig 03. Evaluation of Agriculture Technology

Diagram showing Evolution of Agriculture Technology from GPS Automation System which was based on GPS Guidance for precise mapping and planting developed in early 2000s, 2010s AI based computer vision For Autonomous Navigation and weed detection to Today's Multifunctional Platforms of Modern design for seeding, spraying, weeding and precision Monitoring. [74]

4.2 Classification of Agricultural Robotic Systems

Precision agriculture is a modern management strategy that uses a suite of technologies to observe ,measure , and respond to variability within a field , moving beyond uniform field wide treatments. It relies on the integration of GPS for guidance (Guzmán et al. [39]), IOT sensors for real time data collection (Obaideen et al. [9]; Gondchawar & Kawitkar [41]), and AI driven analytics to generate prescription maps. (Wakchaure et al. [7]; Hua et al. [2]). These maps guide variable rate technology (VRT) equipment to apply resources like seeds and fertilizers only where and when needed , ultimately minimizing waste , reducing cost and maximizing sustainable productivity . (Mohamed et al. [14]; Mavridis & Gertsis [15]).

4.3 Technology Integration Approaches

A recurring trend across reviewed studies is the reliance on sensor fusion techniques to enhance perception and decision-making. Commonly integrated sensors include RGB and multispectral cameras for crop health monitoring,(Jeong et al. [1]; Mavridou et al. [26]), LiDAR and ultrasonic sensors for navigation and obstacle avoidance, (Ball et al. [36]; Guzmán et al. [39]; Ruckelshausen et al. [63]), environmental sensors (soil moisture, pH, temperature, humidity) for precision decision-making. (Obaideen et al. [9]; Vallejo-Gómez et al. [8]; Badreldeen et al. [10]).

Control architectures range from centralized systems, where data is processed at a single node, to distributed frameworks that allow modular and scalable designs. (Hernandes et al. [40]; Jensen et al. [49]; Craig et al. [64]). Additionally, efforts in human-robot interaction (HRI) are evident, focusing on ease of operation, adaptability, and safety in collaborative agricultural environments. (Lytridis et al. [11]; Sørensen et al. [65]).Power systems are predominantly solar or battery-based, reinforcing sustainability in off-grid farming contexts.(Barhate et al. [4]; Harishankar et al. [48]; Sudharshan et al. [25]).

V. Innovative Solution: Compact Multi-Purpose Agricultural Robot

5.1 Compact Design Philosophy

The robot emphasizes on a compact and modular design , which enables adaptability across diverse agricultural contexts from small farms to advanced precision farming setups.(Guri et al. [3]; Pecka & Osadčuks [34]; Jensen et al. [54]).

5.1.1 Modular architecture benefits :

Modular platforms use standardized plug-and-play components (motors, sensor modules, tool heads). This streamlines the assembly process and minimizes downtime since failed modules are easy to swap without specialized technicians.(Guri et al. [3]; Pecka & Osadčuks [34]; Jensen et al. [54])
Robots can tailor their form and function using detachable modules for tasks such as spraying, mowing, sowing, or soil monitoring. Adaptability is critical for working across diverse crops and varying terrain (Barhate et al. [4]; Afriadi & Muda [6]; Arun Kumar et al. [21]).
The ability to update individual parts (such as upgrading a sensor or actuator) extends the product lifecycle and ensures forward compatibility with emerging technologies.(Hernandes et al. [40]; Jensen et al. [49]; Ruckelshausen et al. [71]).

5.1.2 Size optimization :

Maneuverability in confined spaces and between crop rows:current research focuses on lightweight structures , differential drive mechanisms , and compact footprints to allow for precision navigation in tight spaces for key operations like weeding and precision spraying (Dominic Guri et al. [3]; Afriadi & NRS Muda [6]; Stavros G. Vougioukas [23]).

Reduced soil compaction is smaller or compact robots distribute weight more evenly and can reduce soil disturbance compared to conventional heavy tractors therefore preserving the soil fertility . (Arcot Aashish Arun Kumar et al. [21]; Redmond Ramin Shamshiri et al. [31]; Qin Zhang & Francis J. Pierce [56])
Energy efficiency through light weight design is lightweight frameworks paired with energy efficient motors that contribute to longer operational hours and enable the use of renewable energy sources like solar panels . (Sayali Sukdev Barhate et al. [4]; Harishankar et al. [48]; Sudharshan N. et al. [25]).

5.2 Software Integration Framework

Modern agricultural robotics are built upon strong, interconnected software frameworks. These frameworks leverage cloud-based data management and analytics to gather information from robots, sensors, weather feeds, and remote imagery (Jeong et al. [1] and Hua et al. [2]). This data is then used for in-depth analysis, historical tracking, and predictive modeling for pests and diseases, utilizing scalable computational resources (Mavridis & Gertsis [15]; Idoje et al. [18]). These new platforms are designed to seamlessly integrate with existing farm management systems, ensuring synchronized workflows across various operations like planting, irrigation, pest control, and yield mapping(Wakchaure et al. [7]; Mohamed et al. [14]). Farmers can also access real-time insights and direct system control remotely through user-friendly mobile interfaces, making high-tech systems practical for farms of all sizesSuma [16]; Gupta et al. [19]). Interoperability standards are crucial for building flexible and scalable agricultural robotics systems.

This includes implementing ROS (Robot Operating System) as middleware to facilitate communication and task distribution between different robotic components, which simplifies the integration of future modules or robots(Vougioukas [23]; Jensen et al. [49]). Robust API development enables third-party applications, such as weather stations or analytics tools, to directly integrate with the robotics platform, fostering innovation (Kulkarni et al. [20]). Furthermore, adopting common data formats ensures data standardization for precision agriculture, making insights and actions portable, reusable, and easily shareable across various farm systems and stakeholders, thereby enhancing collaboration within the agricultural technology ecosystem.(Shamshiri et al. [31]; Pivoto et al. [32]).

5.3 Precision pest control

Precision pest control using robots involves deploying autonomous or semi autonomous machines equipped with advanced sensors , cameras,and AI algorithms to continuously scan agricultural fields for pests and diseases, enabling highly accurate detection and treatment-based robots can navigate crops , identify specific pest infested plants and apply targeted interventions such as micro doses of pesticides , physical removal or even introduce beneficial insects all while minimizing disruption to surrounding plants and beneficial organisms(Ahmed, Juraimi & Hamdani [37] and Vougioukas [23]). By integrating real time data analysis and machine learning , robotic systems optimize pest management with unmatched precision , significantly reducing chemical usage, labour costs, and the environmental impact of traditional broad spectrum pest control methods .(Wakchaure, Patle & Mahindrakar [7] and Shamshiri et al. [31]).

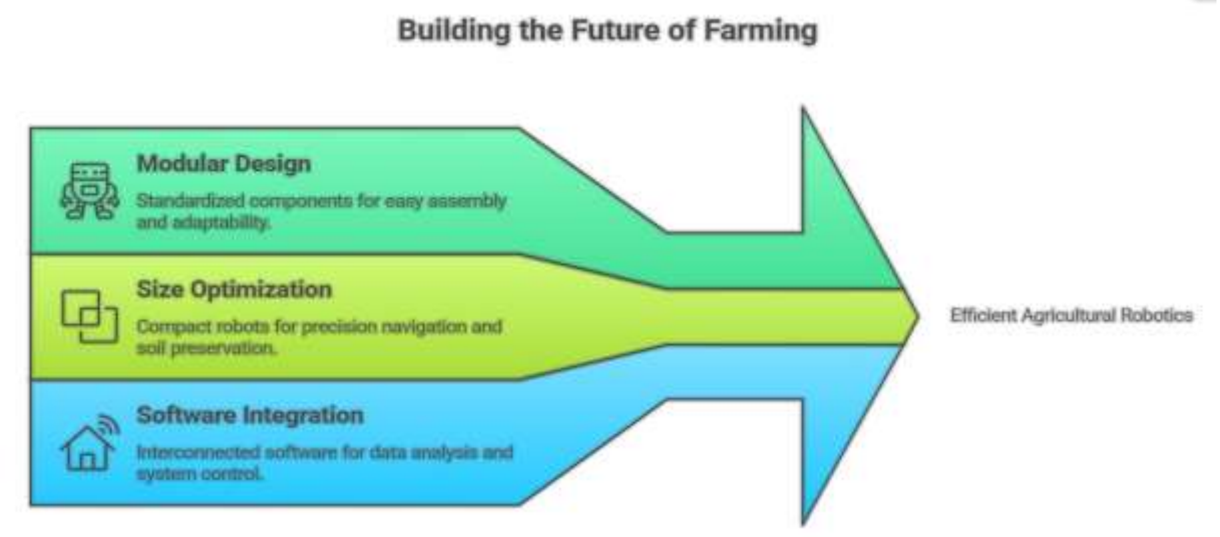

Fig. 04. Building The Future Of Farming

The image showcases Important Roadmap for Future Farming by using Efficient Agricultural Robotics which highlights Key Concepts of Modular Design for Easy Assembly and adaptability, Size Optimization for Precision Navigation and preservation, Software integration for which uses interconnected software for Data Analysis and to takeover Control over System. [73]

VI. Advantages and further analysis

6.1 Advantages of Multi-Purpose Systems

Multi-purpose robotic systems offer significant economic, technical, and environmental advantages for farm operations such as planting, monitoring, spraying, and harvesting.[21]; Sathesh S et al. [5]; Afriadi & Muda [6])

6.1.1 Economic Advantages

- **Reduced Capital Investment:** Farms can significantly cut upfront costs by deploying a single adaptable system instead of purchasing and managing multiple single-function machines.(Barhate et al. [4]; Afriadi & Muda [6]).
- **Lower Operational Costs through Automation:** Automation reduces the need for manual labor, decreasing long-term staffing expenditures and ensuring consistent performance.(Wakchaure et al. [7]; Kulkarni et al. [20]).
- **Improved ROI for Small-Medium Farms:** Scalable technology makes advanced automation accessible to smaller farms, increasing profitability through enhanced efficiency. (Shamshiri et al. [31]; Vougioukas [23]; Emmi et al. [47]).

6.1.2 Technical Advantages

- **Comprehensive Data Collection:** Integrated sensors and analytics continuously gather information on crop health, soil conditions, and operational outcomes, leading to improved decision-making. (Jeong et al. [1]; Hernandes et al. [40]).
- **Consistent Performance & Reduced Human Error:** Automated routines minimize the variability associated with human labor, resulting in reliable and repeatable outcomes.(Wakchaure et al. [7]; Vougioukas [23]; Shamshiri et al. [31]).
- **24/7 Operational Capability:** With sufficient autonomous power and safety features, robots can operate around the clock, maximizing productivity per unit time. (Barhate et al. [4]; Emmi et al. [47]; UK-RAS Network

[30]).

6.1.3 Environmental Advantages

- **Precise Application Reduces Chemical Usage:** Targeted interventions significantly decrease the amount of chemicals released into the environment, benefiting both crops and surrounding ecosystems.
- **Minimal Soil Compaction:** Robots designed with optimized weight distribution apply less force per area, which reduces soil structure damage and preserves fertility.
- **Data-Driven Sustainability Practices:** Captured analytics provide insights for smarter strategies, from crop rotation to resource management, fostering sustainable practices at scale.

Fig. 05 Technical Advantages of multi purpose system

Diagram describing Core Technical Advantages of Multi Purpose Systems for Comprehensive Data Collection, Providing More operational capabilities and enhancing performance. It has advantages like Economical Advantages which Improves ROI for Small Farmers making more Profit and thereby spending or investing less money. And Environmental Advantages for Data driven sustainability and minimal soil compaction for precise Application and saving natural resources like Water, Soil etc. [74]

7.1 Quantitative Analysis of Robotics Growth and Applications

- **Milking** and **Harvest Management** appear to be the largest application segments driving the market in 2030.
- The market size is nearly **doubling** between **2024 ($14.7B)** and **2030**, reflecting significant investment and adoption in agricultural automation.
- The overall market expansion suggests increasing adoption of **automation** to address labor shortages and improve **farm efficiency** and **yields**.
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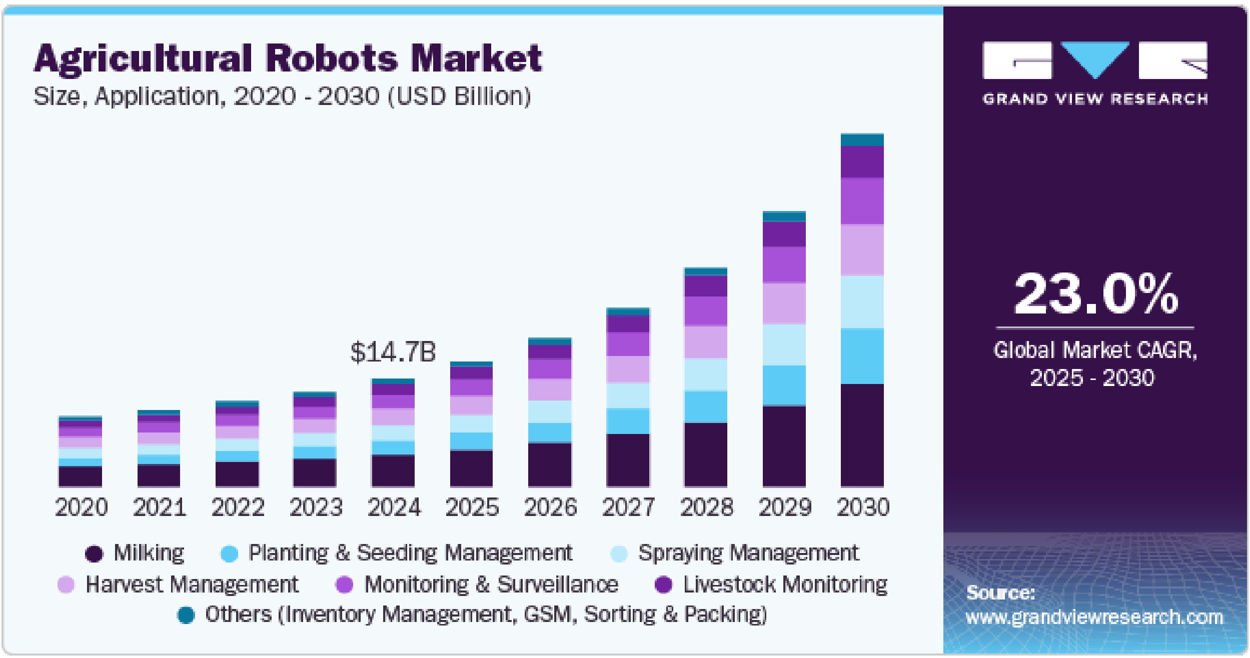

Fig. 06 Agricultural Robots Market (2020-2030)

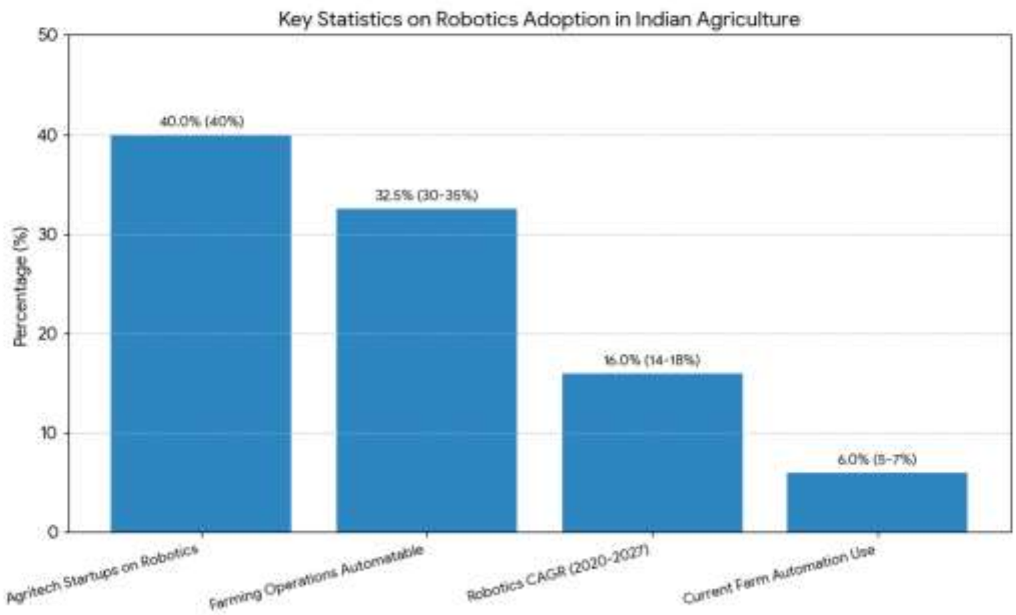

Fig. 07 Farming the Future: Agricultural Robotics Market Explodes to 2030

VII. Future Scope and Research Directions

This Mini AgroBot has the potential to revolutionize agriculture in India by combining robotics, artificial intelligence, and sustainable farming practices (Wakchaure et al. [7]; Vougioukas [23]). By 2030, an Industry 5.0 inspired agricultural robot in India could act as a smart, multi-functional farming partner, performing tasks like sowing, weeding, fertilizing, irrigation, harvesting, pest control and navigating autonomously through uneven terrains and crop rows (Barhate et al. [4]; Afriadi & Muda [6]; Arun Kumar et al. [21]). Equipped with advanced AI and computer vision, it would detect diseases, pests, nutrient deficiencies and predict irrigation and fertilization needs, offering personalized recommendations to each farmer (Hua et al. [2]; Ganesh et al. [22]; Mavridou et al. [26]).

Human-robot collaboration would be seamless via voice commands, multilingual support, AR interfaces and remote supervision through smartphones (Lytridis et al. [11]; Sparrow & Howard [17]). The robot would prioritize sustainability with precision resource use, solar-assisted power, and soil health monitoring (Barhate et al. [4]; Mavridis [15]). IoT sensors, edge computing, and blockchain traceability would provide real-time insights, market guidance and crop tracking (Suma [16]; Gondchawar & Kawitkar [41]; Gupta et al. [19]).

Lightweight, modular and durable, it could work safely alongside humans, coordinating with other robots for large-scale operations, making it an intelligent and indispensable partner for Indian farms (Guri et al. [3]; Pecka & Osadčuks [34]; Emmi et al. [47]; UK-RAS Network [30]).

VIII. Conclusion

This technology fosters a more productive, resilient, and sustainable future for agriculture by addressing global challenges such as food security, climate change, and labour shortages (Mavridis [15]; Sparrow & Howard [17]; Shamshiri et al. [31]). By integrating AI and IoT, mini agro-robots enhance efficiency and productivity, performing tasks like planting, harvesting, and weeding faster and more accurately than human labor, which increases yield and output (Wakchaure et al. [7]; Gondchawar & Kawitkar [41]; Arun Kumar et al. [21]).

By precision agriculture, we can optimize the use of resources like water, fertilizers, pesticides, reducing waste, minimizing runoff, improving soil and water health (Vallejo-Gómez et al. [8]; Obaideen et al. [9]; Badreldeen et al. [10]; Ogidan et al. [24]). Although automation can give solutions to labor shortages by taking over repetitive and physically demanding tasks, which will simultaneously support social sustainability. (Lytridis et al. [11]; Vougioukas [23]).

Environmentally, these robots reduces chemical usage and promotes sustainable farming, while AI-powered monitoring systems can detect pests and diseases early, thereby ensuring healthier crops and good quality yields (Ganesh et al. [22]; Ahmed et al. [37]; Chen et al. [67]). Economically, it contributes growth by lowering labor and resource costs while improving overall profitability (Kulkarni et al. [20]; Pivoto et al. [32]; Grieve et al. [28]).

In future, Demand for Smart Farming will rise through *Agriculture 4.0*. It will strengthen resilience against climate or resource constraints but also inspire innovation and entrepreneurship which will attract newer generations into farming and will ensure long-term global food security (Mavridis [15]; Gupta et al. [19]; UK-RAS Network [30]).

Author Contributions (CRediT)

The CRediT for the paper "Mini Agrobot for Smart Farming: An Intelligent Multipurpose Platform for Next-Generation Farming" primarily involves students and an assistant professor from MIT World Peace University, Pune, who collaboratively developed the platform. Arpita Vishwakarma, Om Kulkarni, Pranav Bam, Shrinivas Kulkarni, and Neel Pendse are listed as students and likely performed the Investigation, Methodology, Software, Hardware Design, and Validation of the Mini Agrobot system. S.N. Patil, the Assistant Professor, likely provided the Supervision, Conceptualization, and Project Administration for the research.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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