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AGRIAR: EMPOWERING FARMERS WITH ARTIFICIAL INTELLIGENCE AND AUGMENTED REALITY

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ABSTRACT

Smallholder farmers face mounting challenges from crop diseases, soil degradation, and increasingly unpredictable weather. Although mobile advisory tools exist, most silo diagnosis, trading, and community networking into separate applications, limiting actionable, real-time decision-making and market access. AgriAR is a mobile platform that integrates Artificial Intelligence (AI) for plant disease diagnosis and Augmented Reality (AR) for in-field guidance with an in-app marketplace and farmer network. This paper presents the problem context, design rationale, system architecture, and commercialization plan for AgriAR. The application consists of five core modules—My Crops & Activities, Disease Diagnosis, Marketplace, Farmer Network, and AR Guidance—with multilingual support for rural inclusivity. We position AgriAR against current agricultural apps and situate its novelty within contemporary AI/AR literature. Preliminary feasibility and due-diligence analyses indicate that, unlike popular apps, AgriAR uniquely unifies diagnosis, trading, and community engagement on one platform while aligning with SDG 2, 12, and 13. A subscription model (RM15/month or RM150/year) and a conservative adoption scenario (10,000 users; 20% Pro conversion) project first-year profitability, supporting sustainable service delivery and R&D. We conclude with limitations and a roadmap for rigorous field trials, model benchmarking, and human-centred AR usability evaluations.

Keywords: Digital Agriculture, Plant Disease Detection, Augmented Reality, Mobile Marketplace, Smallholder Farmers, Sustainable Development Goals.

1. INTRODUCTION

Agriculture faces intensifying biotic (disease, pests) and abiotic (drought, heat, extreme rainfall) stresses that depress yields and farmer income. Digital tools promise timely diagnosis, best-practice recommendations, and improved supply-chain connectivity, yet fragmentation persists disease-ID apps seldom connect farmers to trusted buyers; marketplaces rarely offer in-field agronomy; and community features are often peripheral. Contemporary AI approaches, especially deep learning vision models have shown high accuracy for plant disease identification across many crops, demonstrating the potential for robust, smartphone-based diagnostics in real settings [1]–[3]. Meanwhile, AR is emerging as a complementary modality for step-by-step, spatially anchored guidance and training. Early studies in agricultural AR and smart-glasses adoption highlight potential for hands-free, context-aware support, though usability, connectivity, and workflow integration remain open challenges [4]. This paper presents AgriAR, a unified mobile platform that integrates AI-driven diagnosis and AR guidance with a marketplace and community network to support real-time crop management, knowledge sharing, and market access for smallholders. Farmers are increasingly challenged by diverse agricultural constraints, including recurrent crop diseases, soil nutrient depletion, and unpredictable climatic variations that directly affect yield and productivity. Traditional manual record-keeping practices further reduce operational efficiency, hinder timely decision-making and data accuracy. Moreover, consumers increasingly demand transparency regarding product origin, production methods, and environmental sustainability—needs that current agricultural systems rarely fulfill. Accordingly, this study aims to develop an integrated digital solution with the following objectives:

1. To provide accurate and near real-time diagnosis of crop problems through interpretable, AI-based recommendations.
2. To deliver in-field Augmented Reality (AR) guidance for treatment, scouting, and agronomic operations, thereby enhancing precision and learning.
3. To enable digital trade of agricultural products via an embedded marketplace and establish a farmer networking platform for continuous knowledge exchange.
4. To support sustainable and inclusive farming through data-driven insights and multilingual interfaces tailored for diverse user groups.
5. To validate a commercially viable business model capable of sustaining platform updates, technical support, and rural outreach initiatives.

The key contributions of this study are threefold: **(1)** the development of a problem-driven architecture that integrates AI-based diagnosis and AR-guided assistance with trading and peer-to-peer networking functionalities within a single mobile application; **(2)** the formulation of a commercialization and sustainability plan specifically tailored to Malaysian farmer demographics and digital inclusion requirements; and **(3)** the establishment of a comprehensive research roadmap to assess the system's accuracy, usability, and socio-economic impact through real-world field deployments.

2. LITERATURE REVIEW

2.1 Artificial Intelligence in Plant Disease Detection

Artificial Intelligence (AI), particularly deep learning (DL), has revolutionized plant disease detection by automating visual diagnosis through image recognition. Traditional machine learning models such as Support Vector Machines (SVMs) and Random Forests achieved moderate success but relied heavily on handcrafted features and limited datasets. The emergence of Convolutional Neural Networks (CNNs) and Vision Transformers (ViTs) has dramatically improved accuracy and generalization across multiple crops [1], [2]. Shoaib et al. [1] provided a comprehensive review of DL-based models, demonstrating classification accuracies exceeding 95% across benchmark datasets like PlantVillage. Similarly, Chen et al. [2] emphasized the value of CNN architectures ResNet, EfficientNet, and MobileNet for mobile-based agricultural diagnosis, noting their efficiency and scalability for real-time applications. Islam et al. [3] proposed PlantCareNet, an advanced system that integrates DL with mobile sensors to deliver disease detection and management insights directly to farmers. However, Upadhyay and Kumar [6] argued that real-world performance lags behind laboratory benchmarks due to environmental noise, lighting variation, and dataset imbalance. To mitigate these issues, Verma et al. [7] proposed a meta-learning framework capable of recommending the optimal CNN architecture for unseen plant species or conditions. These developments underline the growing potential of AI-driven crop monitoring systems while highlighting the need for context-specific datasets, particularly in tropical agriculture like Malaysia's.

2.2 Mobile-Based Agricultural Decision Support Systems

The global proliferation of smartphones has facilitated the rise of mobile agricultural applications that provide weather forecasts, pest alerts, and crop management advice. A study by Siddiqua et al. [4] evaluated major mobile apps such as Plantix, FarmRise, and AgroStar, noting that most focus narrowly on disease identification or crop advisory services. While effective for specific tasks, these apps often lack integrated functionalities for market linkage, data analytics, and community support. Batool et al. [5] observed that despite the high accuracy of modern ML and DL models, user engagement remains low when applications fail to offer holistic value beyond diagnostics. They suggested embedding interactive components such as social learning, data sharing, and trading mechanisms to promote sustained adoption. This supports the design philosophy behind AgriAR, which merges diagnostic and commercial functions into a single interface, thus enhancing the utility retention balance in digital agriculture.

2.3 Augmented Reality (AR) in Agricultural Operations

Augmented Reality (AR) overlays virtual information—text, 3D objects, or guidance arrows onto real-world views, allowing users to visualize instructions spatially. In agriculture, AR has gained traction for its potential to improve training, field operations, and machinery maintenance. Sara and Simões [8] explored the adoption of smart glasses in precision agriculture, highlighting advantages in hands-free operation, efficiency, and safety. Similarly, Lohan et al. [9] developed real-time AR interfaces for tractor control and field management, finding significant reductions in operational error rates. Despite these advances, key adoption barriers persist. These include device cost, network dependency, and user ergonomics, particularly under outdoor field conditions. Nevertheless, as AR hardware becomes more affordable and mobile-device-based AR kits (e.g., ARCore, ARKit) mature, integration into existing smartphone ecosystems like that of AgriAR becomes both feasible and cost-effective.

2.4 Sustainability, Digital Inclusion, and SDGs

Digital agricultural innovation is not solely a matter of technology but also of social inclusion and environmental sustainability. Miller et al. [10] stressed that AI-integrated sensing systems and IoT-enabled farming must adhere to sustainable data governance frameworks, ensuring equitable benefits across socio-economic groups. Integrating AI and AR into agriculture directly supports the United Nations Sustainable Development Goals (SDGs) notably SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action) by improving resource efficiency, reducing waste, and promoting climate-resilient practices.

In Malaysia, where smallholders constitute the majority of agricultural producers, such technologies bridge the digital divide, offering localized tools that respect linguistic diversity and on-ground realities. Hence, AgriAR's multilingual interface, AR-based tutorials, and AI-guided sustainability recommendations directly address these global and national development priorities.

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2.5 Literature Gap

Existing research showcases remarkable progress in AI-driven disease detection and AR-based visualization, but most systems remain domain-specific and fragmented. Current mobile applications fail to merge diagnostic precision, interactive learning, and economic functionality into a seamless digital ecosystem. The literature highlights a need for integrated, user-centered agricultural platforms that go beyond data analytics to include community engagement and supply-chain integration. AgriAR addresses this gap by creating a unified platform that combines AI-based image recognition, AR-guided interventions, and in-app trading and networking, thereby transforming isolated technological solutions into a holistic digital agronomy ecosystem.

3. SYSTEM DESIGN AND ARCHITECTURE

3.1 Overview

The AI pipeline performs preprocessing, feature extraction, and classification using a hybrid CNN-transformer model [2], [6]. Recommendations are localized with multilingual support for Malaysian farmers. The AR component delivers step-by-step spatial instructions, ensuring hands-on precision and repeatable workflows [8]. AgriAR consists of six functional modules (Figure 1):

- Sign-in Page – Secure registration and role-based user access.
- Home Page – Personalized dashboard displaying weather and alerts.
- My Crops & Activities – Farm record management and activity tracking.
- Disease Diagnosis (AI) – Image-based recognition powered by CNN models.
- AR Guidance – Overlays real-time recommendations on live camera views.
- Marketplace & Farmer Network – Enables trading and communication.

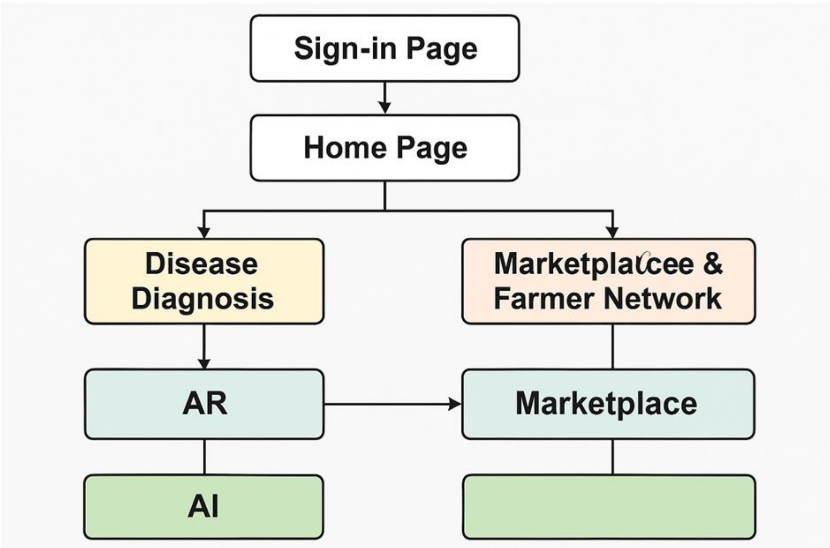

Figure 1: Overview of AgriAR design architecture showing modular system integration between AI, AR, and marketplace components.

3.2 AI and Deep Learning Implementation in AgriAR

Deep learning (DL) approaches currently represent the state-of-the-art methodology for plant disease image classification, offering superior performance in visual pattern recognition compared to traditional machine learning techniques. However, robust real-world deployment necessitates continuous model adaptation and domain-specific retraining using verified field images to ensure reliability under varying environmental conditions [1]. The AgriAR system incorporates an integrated AI diagnosis pipeline comprising four key stages. First, the image capture and pre-processing phase ensures input quality through automated checks for resolution, lighting balance, and motion blur, prompting alerts when image clarity falls below acceptable thresholds. Second, the model inference stage employs a cloud-hosted ensemble of convolutional neural networks (CNNs) and transformer architectures fine-tuned on crop-specific datasets, enabling accurate and scalable disease detection. Confidence thresholds are dynamically evaluated to trigger "additional image required" prompts or escalate uncertain cases to expert review. Third, the recommendation layer maps the predicted disease class to localized treatment guidelines, safety re-entry intervals, and sustainability best practices, which are adapted to regional agronomic standards. Finally, contextual recommendations are linked to relevant marketplace services or agricultural products within the AgriAR ecosystem, providing users with actionable, end-to-end support for crop management.

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3.3 AR Guidance

AR overlays guide where and how to act: e.g., leaf sampling positions, row-by-row scouting routes, sprayer nozzle spacing, or pruning cuts. Hands-free support is planned via smart glasses for certain workflows, contingent on connectivity and ergonomic pilots [8].

3.4 Data, Privacy, and Governance

AgriAR will adopt opt-in data sharing, transparent privacy terms, and role-based access. Aggregated, anonymized farm insights can support extension services while protecting individual farmers, aligned with recommendations for fair data ecosystems in agriculture [10].

4. IMPLEMENTATION STATUS AND INDUSTRIAL COLLABORATION

The app is at idea and prototype stage with screen designs and functional mockups for the five core modules. Industrial engagement supports QA, commercialization readiness, and cross-border regulatory considerations (e.g., agro-inputs listing rules).

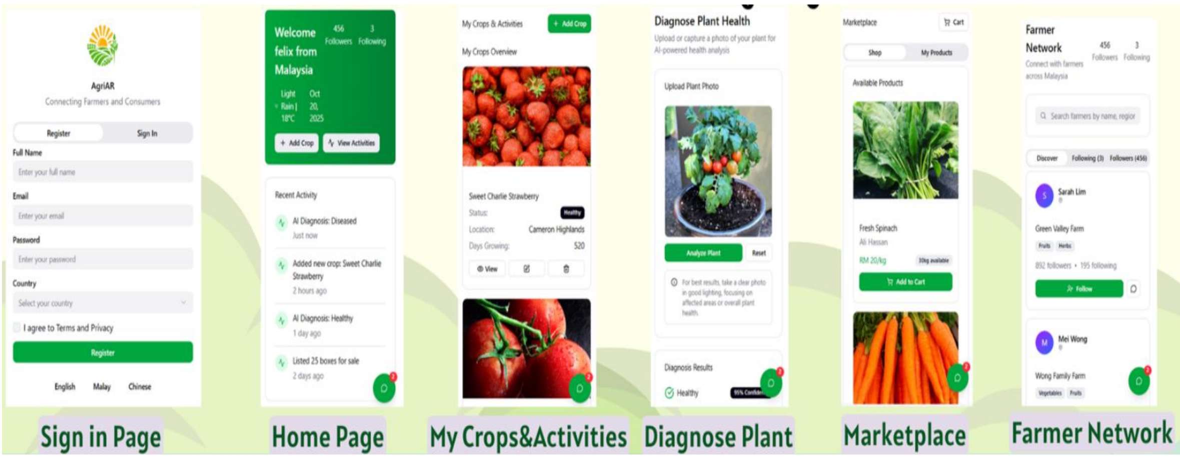

Figure 2: Prototype screens: Sign-in, Home, My Crops & Activities, Diagnose Plant, Marketplace, Farmer Network.

5. NOVELTY AND INVENTIVENESS

The AgriAR system introduces several novel design features that collectively enhance the practicality, inclusiveness, and sustainability of digital agriculture. First, it establishes a unified workflow that seamlessly integrates AI-based diagnosis, AR-guided field interventions, a digital marketplace, and a farmer community network within a single mobile application. This integration minimizes context switching between multiple tools, thereby improving user engagement, efficiency, and overall actionability compared to existing single-purpose platforms. Second, the system provides localized and multilingual support, specifically designed to promote rural inclusion and practical adoption among farmers with varying literacy levels and linguistic backgrounds. Third, AgriAR incorporates data-driven sustainability prompts that encourage responsible agricultural practices such as optimized chemical usage, improved water stewardship, and adherence to safe re-entry intervals after pesticide application. These features are aligned with global sustainability frameworks, particularly the United Nations Sustainable Development Goals (SDGs) 2, 12, and 13, which emphasize zero hunger, responsible consumption and production, and climate action, respectively. Finally, the platform establishes dynamic knowledge loops in which verified farmer actions and observed outcomes are systematically fed back into the learning model. This continuous feedback mechanism enhances model accuracy and enables the generation of more context-relevant recommendations over time, ensuring that AgriAR evolves adaptively with user participation and field data.

6. APPLICABILITY AND USE CASES

The AgriAR platform demonstrates wide applicability across multiple domains of agricultural practice and research. It enables real-time crop management through field-level disease diagnosis and AR-guided operational support, allowing farmers to execute precise agronomic interventions with enhanced accuracy and confidence. The system further facilitates trading and logistics by providing verified listings of agricultural produce and input materials, each accompanied by standardized quality metadata to ensure transparency and trust in market transactions. In addition, AgriAR supports community extension through peer-to-peer knowledge exchange, localized advisories, and digital event participation, thereby strengthening collective learning and rural collaboration networks. Finally, the platform contributes to research and policy development by generating anonymized datasets that capture patterns of digital adoption, user behavior, and sustainability practices—valuable resources for evaluating the broader socio-technical impact of digital transformation in agriculture.

Table 1: AgriAR functional modules and exemplary user stories.

Module	Purpose	Example user story
My Crops & Activities	Plot & task logging	"Record fertilizer application and cost for Plot A"
Disease Diagnosis (AI)	Identify problems	"Capture tomato leaf image → receive blight diagnosis + action list"
AR Guidance	Spatial instructions	"Overlay inspection path and sampling points in the field"
Marketplace	Buy/sell products	"List 100 kg chili; match buyer; arrange pickup"
Farmer Network	Social learning	"Ask for best practice on low-volume sprayers in Malay language"

7. PRELIMINARY MARKET ANALYSIS AND COMMERCIAL MODEL

Malaysia's individual farmer base is substantial. The project's preliminary plan adopts a freemium approach with Pro Plan = RM15/month or RM150/year including AI diagnosis, trading enhancements, and analytics features. Under a 10,000-user scenario with 20% Pro conversion, the first-year profit is estimated at ~RM360,000, supporting maintenance, farmer training, and R&D (poster assumptions).

Table 2: Commercial model summary

Item	Value
Pricing	RM15/month; RM150/year (Pro)
Adoption scenario	10,000 users; 20% Pro conversion
First-year profit (est.)	~RM360,000
Value levers	AI accuracy, AR usability, trusted marketplace, community growth

8. EVALUATION PLAN

Because AgriAR is currently at the prototype stage, a mixed-methods evaluation framework has been proposed to assess its technical performance, usability, and socio-economic impact. First, model benchmarking will be conducted by comparing AgriAR's classifiers against public and field-acquired datasets using key performance indicators such as accuracy, F1 score, calibration error, and robustness to image blur and illumination variation, following the established protocols outlined in recent deep learning literature [1]. Second, human-centered AR trials will be performed on real farms to evaluate user experience through metrics including task completion time, error rate, NASA-TLX workload index, and the System Usability Scale (SUS). Determinants of adoption will be analyzed using conceptual models of smart-glasses and AR intention frameworks reported in the literature [8], [9]. Third, the socio-economic impact will be measured through pre- and post-intervention studies that capture changes in input costs, income stability, market access, and knowledge exchange. These results will be triangulated with privacy-preserving platform telemetry data to identify behavioral patterns and adoption trends among farmers. Finally, a comparative application study will extend existing frameworks for evaluating mobile disease-identification apps [4] to include additional dimensions such as marketplace efficiency, community engagement, and sustainability awareness, thereby testing AgriAR's integrated value proposition within a broader digital agriculture context [5], [10].

9. CONCLUSION

AI-driven diagnostic tools have demonstrated the large-scale feasibility of automated crop disease identification and remote agronomic advisory systems. However, these platforms are typically designed as single-purpose applications and are not universally integrated with localized marketplaces, community collaboration tools, or multi-language support. This limitation reduces their accessibility for smallholder farmers, who often require an end-to-end solution that combines diagnosis, intervention guidance, trading, and social interaction within a unified digital ecosystem. The AgriAR framework addresses this gap by merging these components into a single platform tailored to local agricultural contexts. The synergy between Artificial Intelligence (AI) and Augmented Reality (AR) underpins AgriAR's innovation. AI provides analytical intelligence determining what actions should be taken through disease diagnosis and prescriptive recommendations while AR delivers the spatial and procedural context, showing how and where those actions should be performed in the field. This combination ensures that decision-making is both data-informed and operationally precise, promoting consistency in field practices. Recent studies indicate that farmers are increasingly receptive to AR-based smart-glasses and mobile interfaces, provided that these tools offer tangible hands-free utility, intuitive interaction, and ergonomic design, supporting AgriAR's user-centered interface development.

In alignment with sustainability and inclusion goals, AgriAR integrates localized language options, privacy-aware data management, and low-bandwidth operational modes to ensure equitable access for farmers across varying technological capacities and connectivity environments. These design choices directly respond to digital divide concerns identified in recent reviews of AI and IoT integration in agriculture, enabling broader adoption while supporting the United Nations Sustainable Development Goals (SDGs) 2, 12, and 13, which advocate for zero hunger, responsible production, and climate action.

AgriAR operationalizes AI + AR in a single farmer-centric app that couples diagnosis, spatial guidance, trading, and community networking. Grounded in current literature and designed for rural inclusion, the platform targets measurable gains in farm productivity, cost efficiency, and environmental stewardship while providing a credible commercialization pathway. Upcoming field pilots will validate technical performance, usability, and socio-economic outcomes at scale.

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