

Accepting the Digital Plow: An Empirical Analysis of Internet of Things (IoT) Acceptance among Paddy Planters in Kedah, Malaysia

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ABSTRACT

The adoption of Internet of Things (IoT) technology in agricultural settings has the potential to revolutionize conventional farming techniques by improving efficiency, productivity, and sustainability. This study explores awareness, perceived operational benefits, and critical adoption barriers among smallholder paddy planters in Kedah, Malaysia—the nation's "Rice Bowl." Grounded in the Technology Acceptance Model (TAM), this research utilizes an exploratory qualitative case study design. Semi-structured interviews were conducted with four key informants in the Yan district of Kedah, systematically selected via purposive sampling to span a spectrum of adoption: a traditionalist non-adopter, two partial-adopter renters, and an advanced technology owner. The thematic analysis reveals that while awareness is growing, it is heavily anchored in a narrow "drone-only perception" that obscures the utility of other passive IoT solutions (e.g., soil sensors, automated irrigation). Although farmers recognize substantial benefits—such as rapid pesticide spraying (reducing time from a full day to 3 hours), operational efficiency, and minimized chemical exposure—behavioral intention to adopt is severely constrained. Critical barriers include high capital costs, technical knowledge deficits, rural internet dropouts, and cultural resistance to change. Additionally, this study critically engages with TAM's limitations in rural contexts and highlights the critical role of social influence and peer networks in adoption. Specific policy recommendations are proposed with execution timelines and agency responsibilities to bridge the rural digital divide.

Keywords— Internet of Things (IoT), Technology Acceptance Model (TAM), Paddy Farming, Social Influence, Rural Digital Divide.

INTRODUCTION

Agricultural Internet of Things (IoT) represents an interconnected network of physical devices, environmental sensors, production equipment, and animal-plant systems linked to the internet to facilitate real-time information interaction and communication [24]. The primary objective of agricultural IoT is to establish an intelligent framework for identifying, positioning, tracking, monitoring, and managing agricultural activities through human-machine-thing interconnection [34]. In rice-producing economies like Malaysia, smart farming technologies, including soil moisture sensors, weather stations, and Unmanned Aerial Vehicles (UAVs/drones), have demonstrated vast potential to optimize resource allocation, enhance crop health, and boost yield productivity [6].

Despite these transformative prospects, the overall level of technology acceptance among paddy planters remains low, primarily due to severe knowledge gaps regarding the practical functionalities and financial benefits of IoT [6]. Many traditional farmers are unfamiliar with the concept of smart farming, and this digital gap is further compounded by the scarcity of specialized training and informational extension services in rural regions [40]. In Malaysia, the state of Kedah known as the "Rice Bowl of Malaysia" plays a central role in national food security [4]. Bridging the digital divide and understanding the socio-technical factors influencing technology acceptance among these rural smallholders is critical to achieving sustainable food production. Crucially, in close-knit rural agricultural communities, technology acceptance is not merely an individual cognitive choice but is deeply embedded within community peer networks and collective social systems. Social norms, generational practices, and peer influence represent powerful determinants of behavioral intention that traditional acceptance models often overlook.

Problem Statement

The lack of standardized frameworks, system interoperability, and empirical research on localized technology adoption limits the capacity to build resilient IoT infrastructures tailored to rural smallholders [24]. While several quantitative studies evaluate agricultural innovations in major commercial plantations, there is a prominent research gap concerning the behavioral intention and specific barriers faced by independent paddy planters [38]. Paddy farmers in rural Kedah operate in highly location-specific and capital-constrained environments [4]. Without an in-depth exploration of their baseline knowledge, perceived operational usefulness, and structural constraints such as financial limitations and inadequate rural network connectivity policymakers and technology developers cannot design effective support mechanisms to encourage smart farming [26].

Research Questions and Objectives

This study systematically addresses three core research questions: (1) What is the level of awareness among paddy planters in Kedah regarding IoT technologies? (2) What are the perceived benefits of adopting IoT technologies in their farming operations? (3) What are the main barriers hindering paddy planters from adopting these innovations? Correspondingly, the research aims to achieve three key objectives: to explore the baseline acceptance of agricultural technologies, to evaluate the perceived operational benefits and occupational concerns of planters, and to diagnose the structural, economic, and technical barriers to IoT adoption in paddy farming.

Significance of the Study

The findings of this research provide crucial empirical reference for Malaysian agricultural agencies, such as the Malaysian Agricultural Research and Development Institute (MARDI) and the Ministry of Agriculture and Food Security (KPKM), to design targeted training and capacity-building workshops [28]. By understanding how rural farmers perceive and interact with smart tools, extension services can be structured to mitigate technical fears and build self-efficacy [41]. Additionally, this study informs technology developers about the necessity of cost-effective, durable, and localized IoT solutions, supporting Malaysia's progressive transition toward digitalized precision agriculture.

LITERATURE REVIEW

Paddy cultivation in Kedah represents the cornerstone of Malaysia's domestic rice supply and national food security [4]. Historically, the sector has been highly dependent on traditional manual labor and generational practices [6]. However, modern agricultural developments demand a strategic shift toward smart farming, where IoT-enabled devices serve to monitor environmental variables, regulate automated irrigation, and facilitate disease detection [8]. According to recent research, the integration of real-time crop monitoring systems can safeguard seedlings, optimize pesticide applications, and improve water efficiency, substantially minimizing financial and resource waste [9].

Agricultural Internet of Things and Smart Farming

Agricultural IoT operates through a multi-tier architecture consisting of perception nodes (sensors), network transmission protocols, and application dashboards [13]. In rice farming, recent applications include soil moisture probes, water level sensors, and time-series UAV imaging to assess crop development stages and manage variable irrigation [2]. In Malaysia, the deployment of smart farming is heavily supported by national precision agriculture initiatives to double crop yields and improve smallholder livelihoods [46]. Early adopters have shown that the use of smart objects helps automate labor-intensive spraying and fertilization tasks, enhancing productivity and crop quality [3].

Theoretical Framework: Technology Acceptance Model (TAM)

This study is theoretically grounded in the Technology Acceptance Model (TAM) developed by Fred Davis (1989), which represents the most widely validated framework for predicting behavioral intention to adopt new technology. According to TAM, technology acceptance is primarily driven by two cognitive appraisals: Perceived Usefulness

(PU) and Perceived Ease of Use (PEOU) [44]. In the agricultural context, Perceived Usefulness is defined as the farmer's belief that using a specific technological tool (such as a drone or soil sensor) will improve their operational performance, crop yield, and farm profitability [25]. Perceived Ease of Use refers to the degree to which a farmer believes that learning, implementing, and interacting with the agricultural technology will be free of cognitive and physical effort [42]. TAM posits that PEOU directly influences PU, and both constructs collectively shape the user's positive attitude, behavioral intention, and actual adoption of the technology.

TAM's Limitations in Agricultural Contexts

While Davis's (1989) TAM is highly robust in predicting software and systems adoption in corporate or voluntary administrative settings, it exhibits significant limitations when applied directly to smallholder agriculture. Standard TAM operates under the assumption of individual, resource-unconstrained decision-making where cognitive appraisals are the primary bottlenecks. However, in smallholder rice farming, agricultural technology acceptance is heavily bound by severe non-cognitive external variables [15]. These include absolute financial capital constraints, unpredictable weather patterns, geographical infrastructure deficits (e.g., lack of rural broadband), and varying degrees of basic technical literacy among an aging demographic [40]. Consequently, a farmer may possess a highly positive cognitive appraisal of an IoT tool's usefulness (PU) and perceive it as easy to use after initial training (PEOU), yet remain completely unable to translate this intention into actual adoption due to external environmental and economic barriers [26]. TAM must therefore be critically integrated with contextual frameworks such as the Technology-Organization-Environment (TOE) model or unified theories that account for facilitating conditions to realistically capture rural smart farming dynamics.

Theoretical Analysis of the "Drone-Only Perception"

A critical qualitative finding in this study is the presence of a strong "drone-only perception" among rural paddy planters, where the conceptual scope of "agricultural IoT" is narrowed exclusively to unmanned aerial vehicles (UAVs) for spraying. This phenomenon can be explained theoretically through cognitive schema theory and experiential anchoring [17]. Drones are physically prominent, highly active, and visually dramatic technologies that fly over fields, creating an immediate, highly observable impact (such as completing pesticide application on 10 acres in 3 hours). Conversely, other essential agricultural IoT technologies such as sub-surface soil moisture sensors, automated water level gates, and cloud-linked weather monitoring stations are passive, non-visible, or physically unobtrusive data-gathering devices. Because smallholder planters lack exposure to comprehensive, data-driven precision farming, they anchor their understanding of smart technology on visible machinery [39]. This narrow cognitive anchor creates a major barrier to broader IoT acceptance, as farmers fail to recognize the utility of data-driven insights, focusing instead on manual-task automation tools like drones. Bridging this gap requires a shift in informational campaigns to highlight "invisible" data-driven technological benefits.

Social Influence and Community Peer Networks

Rural agricultural communities in Kedah, Malaysia, are characterized by collectivist social structures and high cultural interdependence. Consequently, adoption decisions do not occur in a cognitive vacuum, they are heavily moderated by Subjective Norms (from the Theory of Planned Behavior) and Social Influence (from the UTAUT model) [23]. Peer networks act as critical information channels and trust-building mechanisms. Risk-averse smallholders rely on observational learning, seeing a progressive, respected community leader or successful neighboring farmer adopt a technology and achieve higher crop yields significantly mitigates technical fears and financial risk perception [15]. Conversely, individual early adopters may experience social friction or skepticism if they deviate from long-standing communal farming traditions, which are viewed as culturally safe and reliable [40]. Therefore, leveraging rural peer networks and progressive farmer advocates is essential for accelerating community-wide technology acceptance.

Conceptual Framework

Building upon the Technology Acceptance Model, this study adapts TAM to the specific socio-economic and structural context of Malaysian paddy planters. As illustrated in the original model [45], external variables, including financial resources, technical literacy, peer network social influence, and rural internet infrastructure, act

as core antecedents that shape farmers' perceived usefulness and ease of use. For rural planters, if a smart tool is perceived as prohibitively expensive or too complex to operate without extensive training, its perceived ease of use is heavily compromised, consequently diminishing the behavioral intention to adopt [26]. Conversely, if targeted support, such as government subsidies, peer-led workshops, and localized extension services, is provided, the cognitive appraisals of usefulness and ease of use are expected to rise, driving a systematic transition from traditional manual labor to digitalized precision farming [40].

RESEARCH METHODOLOGY

To explore the nuanced, lived experiences and subjective views of rural farmers, this study adopted an exploratory qualitative case study research design [16]. Given the exploratory nature of the research questions and the need to understand the complex social, economic, and cultural realities of technology acceptance in a specific region, qualitative interviews provide rich, contextually grounded data that quantitative surveys fail to capture [20].

Purposive Sampling Strategy and Comparative Design

The research was conducted in the Yan district of Kedah, Malaysia, a prominent agricultural zone heavily reliant on paddy cultivation. Purposive sampling was strategically utilized to identify and select key informants who fit specific inclusion criteria [14]. Rather than recruiting a homogeneous sample, the sampling strategy was intentionally designed to span a spectrum of technological adoption and operational experience to enable a comparative qualitative analysis. The purposive sampling matrix selected four distinct key informants: (1) a traditional traditionalist relying on manual labor, (2) two partial adopters who lease drone spraying services but do not own equipment and (3) an advanced technology owner who owns and operates drone equipment independently. This structured diversity ensures a comprehensive cross-sectional comparison of technology perceptions, cognitive appraisals, and structural barriers. Rather than predetermining the sample size, the data saturation principle was applied semi-structured interviews were conducted sequentially until no new thematic patterns, operational benefits, or barriers emerged from the transcripts.

Data Collection and Methodological Triangulation

Primary data were gathered through semi-structured interviews conducted between September 30, 2024, and December 17, 2024. A meticulously prepared interview guide, comprising open-ended questions, was used as the primary research instrument, focusing on current farming practices, baseline awareness of agricultural IoT, perceived operational benefits, and major barriers to adoption. Interviews lasted between 30 minutes and 2 hours, conducted in-person or via digital communication platforms to accommodate scheduling preferences. To ensure validity and mitigate subjective bias, interview findings were triangulated with: (1) field observations recorded during on-site visits (2) document analysis of local agricultural reports and guidelines and (3) participant profiles [20]. To overcome the generalizability limitations of this qualitative case study, future research designs should implement formal methodological triangulation by combining qualitative case studies with large-scale quantitative surveys (mixed-methods) to statistically validate these exploratory findings across the broader population of Kedah paddy planters.

Data Processing and Thematic Analysis

The audio recordings were transcribed verbatim from Malay to text between November 25 and November 30, 2024. Electronic transcripts were organized and safely stored using a password-protected file management system. Data analysis commenced in December 2024 and was completed in January 2025. Due to the textual nature of the data and the emphasis on deep conceptual coding, the researcher conducted manual thematic analysis using Microsoft Word and Canva [33, 37]. Transcripts were read multiple times to ensure familiarity, followed by systematic line-by-line coding. Codes were categorized by highlighting and color-coding to extract major themes and subthemes mapping to the three core research questions [30].

Research Quality and Ethical Considerations

To ensure methodological rigor, credibility, and reliability, multiple verification measures were implemented [43].

Member checking was performed by sharing the transcribed text and preliminary findings with the participants to verify accuracy. A detailed audit trail was kept to document all methodological decisions, raw data, and analytical codes. Ethical clearance was obtained from the institutional review board of Universiti Teknikal Malaysia Melaka (UTeM). Before each interview, participants were fully briefed on the research objectives, their voluntary participation, and their right to withdraw at any point. Transcripts and reports were thoroughly pseudonymized to protect participants' privacy and confidentiality.

FINDINGS

This section presents the empirical findings derived from the qualitative thematic analysis, structured around the participant profiles and the three core themes of level of awareness, perceived benefits, and critical barriers to IoT adoption.

Participant Profiles

Four distinct key informants participated in the semi-structured interviews. To ensure academic transparency and protect participant confidentiality, pseudonyms are used throughout. The demographic and operational profiles of the participants are summarized in Table I.

TABLE I PARTICIPANTS PROFILE

Participants	Age	Experience (Years)	Operation Status
(P1)	54	30	Hire Drones
(P2)	47	25	Manually Operated
(P3)	23	29	Own Drones
(P4)	23	11	Hire Drones

Level of IoT Awareness and Understanding

The qualitative thematic analysis revealed a wide spectrum of awareness and conceptual understanding of the Internet of Things among the paddy planters. As detailed in Table II, the level of awareness was categorized into four subthemes: Zero Knowledge, Understanding of IoT, Limited Exposure, and Drone-Only Perception.

TABLE II THEMATIC ANALYSIS ON THE LEVEL OF AWARENESS AND IOT UNDERSTANDING

Sub-Theme	Sources	Coding References
Zero Knowledge	1	1
Understanding of IoT (Middle)	3	4
Limited Exposure	2	4
Drone-Only Perception	1	7

Participant 1 represented a state of complete lack of knowledge, admitting that he had never heard of the Internet of Things concept before, asking: "What was that again? Internet of what?" However, upon conceptual explanation, he immediately correlated drones with IoT, demonstrating that rural smallholders often possess practical exposure to smart tools without recognizing them as part of the broader IoT framework. Participant 2 and Participant 4 demonstrated a medium level of understanding, explaining that they had heard of the concept in simple contexts. Participant 4 noted: "In the context of farming, what I understand is that IoT refers to the use of smart devices connected to the internet to simplify tasks, such as drones for spraying pesticides and spreading fertilizers." Participant 3 indicated limited exposure, stating that while her father actively owned and operated a drone, the conceptual definitions of IoT were not widely expanded or explained in the local farming community, reinforcing the narrow conceptualization of agricultural technology.

Perceived Benefits of IoT Adoption

All four participants strongly agreed that implementing smart technologies like drones in paddy fields yields significant operational advantages, particularly in terms of operational efficiency (saving time and labor),

increasing crop productivity, and safeguarding health and safety. These thematic categories are summarized in Table III.

TABLE III THEMATIC ANALYSIS ON PERCEIVED BENEFITS OF IOT ADOPTION

Sub-Theme	Sources	Coding References
Health and Safety	1	1
Efficiency - Save Times	4	8
Efficiency - Improved Crop Yield	4	6

In terms of time efficiency, Participant 1 shared his experience renting spraying drones: "With the use of drones, the work becomes much faster. If using manual methods, it might take an entire day... With drones, a 10-acre area can be completed in just about 3 hours." Participant 3 confirmed this advantage, noting: "My father uses drones in his farming because it saves him a lot of time and makes the work of farmers easier." Furthermore, participants identified increased crop yield and financial profitability as significant benefits of precision agriculture. Participant 1 noted: "The use of drones ensures that the pesticide is evenly applied, resulting in healthier crops and leading to an increase in income." Lastly, health and safety emerged as a vital operational benefit. Participant 1 highlighted that automating pesticide spraying safeguards human health by preventing direct contact and inhalation of toxic chemicals: "Our health is safeguarded because we only need to control the drone rather than doing the spraying ourselves... we are standing far from the chemical area."

Critical Barriers to IoT Adoption

Despite acknowledging the substantial benefits of smart farming, paddy planters highlighted critical barriers that restrict widespread technology acceptance. These challenges are categorized into five subthemes: high capital costs, technical knowledge deficits, hazardous concerns, cultural preferences for traditional methods, and infrastructure limitations, as outlined in Table IV.

TABLE IV THEMATIC ANALYSIS ON BARRIERS TO IOT ADOPTION

Sub-Theme	Sources	Coding References
High Cost	4	12
Low Technical Knowledge	3	5
Hazardous Concerned	1	3
Preference for Traditional Methods	1	5
Infrastructure Challenges	2	3

Financial cost emerged as the most dominant barrier, mentioned by all four participants. High initial capital, maintenance costs, and battery replacement expenses represent major economic strains. Participant 1 noted: "Currently, the cost of buying a drone is expensive... a drone with two functions, fertilizing and spraying, costs around RM70,000, and replacing the battery also incurs a high cost." For smallholders, the renting fees of RM10 to RM15 per acre also diminish profitability. Technical knowledge deficits represent another vital barrier, operating modern equipment requires specialized training. Participant 3 highlighted: "Using drones requires self-operation, which demands extensive training and guidance to obtain approval and certification. This makes it challenging for farmers to adopt." Cultural preferences for generational, manual methods also hinder adoption. Participant 2 admitted: "For me, traditional methods are more reliable because I know how they work... technology is hard to trust when you don't understand it." Lastly, infrastructure deficits hinder IoT viability. Participant 4 emphasized that unstable network connectivity in rural Yan makes it difficult to run cloud-based IoT systems, while Participant 1 warned about safety hazards: "At times, drones can become dangerous because they may lose control if the internet connection is lost, potentially getting stuck on power poles or hitting someone."

Implications for Technology Developers

The empirical findings of this study yield critical, actionable design implications for technology developers and commercial manufacturers aiming to penetrate the smallholder agricultural market. Currently, technology

developers design agricultural solutions for highly capitalized commercial plantations, ignoring the unique constraints of smallholders. To encourage widespread IoT acceptance among rural paddy planters, developers must adopt three paradigm shifts: (1) Cost-Effective Modularity (2) Offline-First Systems and (3) Localized and Simplified Interfaces.

First, rather than pushing high-capital RM70,000 monolithic drone systems, developers should design modular, incremental IoT kits. For instance, low-cost water level sensors or soil health probes that interface with existing smartphones via simple Bluetooth protocols allow farmers to adopt digital precision agriculture incrementally, avoiding massive upfront financial risk. Second, to address rural infrastructure deficits, developers must implement offline-first system architectures. Sensing devices and UAV flight systems must possess local data storage on edge nodes, enabling complete operation without active cellular networks and syncing with cloud dashboards only when a stable connection is restored, eliminating connectivity dropouts and safety hazards. Third, to bridge the digital literacy gap among an aging demographic, software applications should be designed in the local Malay dialect with intuitive, graphic-heavy, or voice-guided interfaces, removing cognitive strain and enhancing the perceived ease of use (PEOU) of smart farming systems.

DISCUSSION AND CONCLUSION

Synthesizing the empirical findings with the Technology Acceptance Model (TAM) provides crucial theoretical insights. Under Davis's original model (1989), behavioral intention is heavily determined by Perceived Usefulness and Perceived Ease of Use. The qualitative data demonstrate that while Kedah's paddy planters possess a highly positive appraisal of the usefulness (PU) of smart technologies such as drones citing significant savings in time, reduced labor expenses, and improved agricultural yields their behavioral intention to adopt is severely constrained by a low appraisal of the ease of use (PEOU) [25]. PEOU is undermined by technical complexity, the lack of operational training, and fear of safety hazards, such as losing control of drones during connectivity dropouts [15]. Thus, technology adoption among rural smallholders is incremental farmers must be supported with user-friendly and affordable solutions to build confidence [17].

Methodological Synthesis and TAM Evaluation

By critically evaluating the TAM framework, this study demonstrates that standard cognitive models must be expanded to accommodate external environmental and economic variables. While PEOU directly influences PU, the presence of severe structural constraints specifically cost, rural broadband deficits, and low digital literacy prevents planters from acting on positive perceptions of usefulness. The resulting behavior is a "temporary adoption equilibrium" where smallholders opt to lease spraying services on an ad-hoc basis rather than investing in permanent technology ownership. This renting model represents a rational socio-economic strategy that mitigates financial risk and eliminates technical operational burdens. Therefore, policy frameworks should pivot from encouraging individual technology purchase to supporting collective, co-shared technology leasing structures [40].

Practical and Policy Recommendations

To foster extensive IoT acceptance, a comprehensive, multi-stakeholder strategy is required, moving beyond vague suggestions to concrete, scheduled policy interventions. The Ministry of Agriculture and Food Security (KPKM), the Muda Agricultural Development Authority (MADA), and MARDI must play central, coordinated roles. Specific practical recommendations, responsible agencies, and implementation timelines are detailed in Table V.

TABLE V PRACTICAL RECOMMENDATIONS

Actions	Agency	Time Span
Alleviate high capital cost via low-interest loans & drone purchasing grants.	KPKM & Agrobank	Short (1-2 Years)
Smart Farming Training Centers (SFTC): Localized hands-on training workshops for technical skills & safety licenses.	MADA & MARDI	Middle (3-4 Years)
Edge Computing & Rural Broadband: Reinforce rural connectivity & 5G coverage in agricultural sectors.	MCMC & KPKM	Long (5+ Years)

First, agricultural agencies must alleviate economic barriers in the short term by establishing co-shared drone cooperatives and financial subsidies via Agrobank, ensuring smallholders can access precision spraying without massive capital debt. Second, MARDI and MADA must collaborate in the medium term to build regional Smart Farming Training Centers (SFTCs) in rural Kedah. These centers should provide structured, hands-on certification courses in local dialects, building technical literacy and self-efficacy among aging farmers. Third, MCMC and telecommunication providers must prioritize the deployment of rural cellular infrastructure and edge computing nodes in the long term, guaranteeing uninterrupted broadband signals across agricultural grids to prevent signal dropouts and drone flight accidents.

LIMITATIONS AND FUTURE RESEARCH DESIGNS

This study possesses certain limitations that should be acknowledged. First, the small sample size of four purposively selected participants in the Yan district of Kedah limits the statistical generalizability of the findings to the entire population of Malaysian paddy planters. While highly valuable for generating qualitative depth, localized findings may not represent planters in other agricultural states with different socio-economic or geographical terrains. Second, the qualitative research relies on self-reported interview data, which is susceptible to response and recall bias.

To address these shortcomings, future research designs must employ specific, robust methodologies: (1) Mixed-Methods Sequential Explanatory Designs: Researchers should combine a large-scale quantitative survey ($N \geq 350$) to measure the relationship between TAM constructs and external barriers across multiple states (Kedah, Perak, and Selangor), followed by qualitative case studies to contextualize numerical trends and outliers (2) Longitudinal Designs: Conduct a multi-year longitudinal study tracking 100 farmers over six consecutive crop seasons to record empirical, quantifiable metrics such as chemical fertilizer savings, water use efficiency, and net crop yield increases proving the long-term financial feasibility of IoT and (3) Social Network Analysis (SNA): Map the interpersonal networks and communication pathways of village farmers to analyze how technological knowledge and trust diffuse through collective farming communities.

CONCLUSION

In conclusion, the integration of the Internet of Things (IoT) in Kedah's paddy farming offers transformative potential to modernize traditional agriculture, safeguard human health, and improve crop productivity. However, realizing these prospects demands a holistic strategy to address structural barriers, including high costs, technical knowledge deficits, and rural digital infrastructure gaps. Bridging the digital divide in the "Rice Bowl of Malaysia" is not only essential to empower independent smallholders but represents a vital national imperative to safeguard long-term agricultural sustainability and national food security.

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