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Limitations in the Application of Expert Systems in Agricultural Extension Services

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Abstract
Expert systems are sophisticated technological instruments that replicate expert-level reasoning to aid in agricultural decision-making. Their incorporation into agricultural extension services has the potential to enhance the precision, effectiveness, and accessibility of recommendations related to crop management, pest control, and soil health. These systems can notably close the divide between scientific insight and grassroots practices, particularly in areas with limited access to expert advisors. Nevertheless, adoption rates continue to be less than ideal due to various ongoing challenges. Major obstacles include low awareness among farmers, the high expense of digital infrastructure, restricted digital literacy, language and usability issues, as well as ingrained gender inequalities. Extension workers also encounter difficulties such as technophobia, lack of training, and inadequate institutional support. This review consolidates findings from numerous empirical studies performed in Indian agricultural settings to identify and thoroughly examine these constraints. It additionally recommends a multifaceted approach to tackle these issues through policy initiatives, localized content, inclusive training programs, real-time data integration, and partnerships between the public and private sectors. By confronting these challenges, expert systems can become more accessible, reliable, and effective, ultimately leading to more resilient and productive agricultural systems in developing nations. This paper emphasizes the necessity of creating farmer-focused solutions to realize the transformative potential of digital agriculture.

Keywords: Expert Systems, Agricultural Extension, Digital Agriculture, Farmer Adoption, Technological Constraints

Introduction
Agriculture, serving as the foundation of numerous developing economies, has historically depended on conventional wisdom, hands-on experience, and human-led advisory systems for making on-farm choices. Nevertheless, during the Fourth Industrial Revolution, the industry is undergoing a significant transformation driven by Information and Communication Technology (ICT). Among these innovative digital resources, expert systems have surfaced as sophisticated decision-support tools that replicate the analytical reasoning and advisory abilities of human specialists. These systems integrate artificial intelligence, machine learning, and specialized knowledge to offer farmers prompt, context-aware assistance on a wide range of agricultural topics—spanning from pest and disease control to irrigation planning, fertilizer use, and post-harvest management.

Expert systems distinguishes from traditional advisory frameworks is their capacity to operate independently and incessantly, providing immediate diagnostics, forecasting analytics, and actionable suggestions. They act as digital agronomists, closing the geographical and temporal divides between research organizations and users, especially in underserved rural regions. As mobile connectivity and internet accessibility continue to enhance even in isolated locations, expert systems symbolize a scalable and economically viable answer to the persistent extension challenges.

Even with their potential, expert systems have not reached significant adoption and use at the community level. Their limited use arises from a combination of interrelated factors—technological, financial, institutional, and cultural. Small and marginal farmers, who make up a large part of the agricultural labor force, often lack the digital skills, monetary means, and infrastructure needed to fully utilize these systems. Additionally, expert systems often fail in localization—many do not sufficiently include local languages, climate variations, or traditional knowledge systems, which diminishes their significance and trustworthiness among intended users.

On the organizational side, extension staff may not have sufficient training or drive to promote the use of these tools, particularly when their conventional advisory functions are firmly rooted in direct interactions. Gender-related obstacles further complicate the digital split, as women farmers frequently face unequal difficulties in obtaining and employing technological advancements.

In this changing environment, comprehending and tackling these complex limitations is essential for realizing the complete potential of expert systems in farming. This review examines the main obstacles that impede the implementation and efficiency of expert systems, utilizing empirical evidence, field research, and stakeholder perspectives. It also suggests strategic measures—from policy frameworks and capacity-building programs to inclusive design and partnerships between public and private sectors—that can facilitate a fairer, more effective, and significant application of expert systems in agricultural extension services.

Key Limitations Encountered by Farmers and Extension Workers

Research and surveys conducted in rural farming areas reveal numerous common limitations that hinder the efficient utilization of expert systems:

Lack of Awareness and Accessibility

One of the foremost obstacles hindering the widespread usage of expert systems in agriculture is the significant lack of understanding within the farming community. In spite of swift progress in digital technologies and the growing availability of smartphones in rural India, a large segment of farmers still lacks knowledge about the existence, features, and advantages of expert systems. This informational gap is especially pronounced among small and marginal farmers, who frequently function independently from formal extension services. Awareness metrics in empirical research, like the 73.66 reported in field studies, demonstrate a clear shortfall in focused outreach and educational initiatives.

This minimal level of awareness is exacerbated by restricted accessibility. Numerous rural regions do not have the digital framework required for the utilization of expert systems, which includes dependable internet access, electricity, and support centers for technical assistance. Additionally, expert systems are seldom integrated into the daily routines of farmers; rather, they are frequently presented through brief pilot programs or disjointed initiatives that do not manage to achieve a comprehensive impact or long-lasting effect. Consequently, even if such systems are technically present, farmers might not view them as attainable, beneficial, or pertinent to their requirements.

The gap in digital access between city and countryside populations, as well as among rural communities themselves, worsens this problem. Elements like geographical isolation, limited literacy rates, and insufficient familiarity with ICT resources all lead to a foundational disconnection from digital platforms. Moreover, expert systems are rarely advocated via conventional agricultural extension methods like Krishi Vigyan Kendras (KVKs), agricultural institutions, or on-site demonstrations. This restricts their recognition and trustworthiness among farmers, who generally prefer guidance given by well-known and in-person sources.

To address these obstacles, it is essential to implement a unified strategy for raising awareness that includes government bodies, non-profit organizations, educational institutions, and private sector participants. Programs should feature farmer-focused workshops, demonstration activities, village-based digital literacy initiatives, and the incorporation of expert system awareness into standard extension services. Utilizing local media, community radio, and social platforms can further enhance outreach efforts. In the end, increasing awareness and enhancing accessibility must occur simultaneously to guarantee that expert systems are not only accessible but also recognizable, approachable, and reliable for the agricultural communities they aim to benefit.

High Cost and Infrastructure Gaps

The financial strain tied to implementing expert systems continues to be one of the most significant hurdles for small and marginal farmers. The upfront expenditure needed to purchase digital tools like smartphones, tablets, or computers—together with ongoing costs such as internet plans, software upgrades, and upkeep expenses—can be unaffordable. For many low-income agricultural families, focusing on immediate survival needs allows scant opportunity for technology investment. The problem intensifies when expert systems lack subsidies or assistance from government or non-government organizations, rendering them mostly unreachable for the communities that could gain the most from their use.

The problem of affordability is further exacerbated by the prevalent insufficiency of digital infrastructure in rural areas. Numerous villages still face challenges with inconsistent electricity availability, poor network coverage, and restricted or nonexistent access to broadband services. Even in regions with network coverage, the signal quality frequently varies, resulting in disruptions. Service and inconsistent system performance. These infrastructural weaknesses not only deter adoption but also impede the effective operation of expert systems, diminishing their reliability and user satisfaction.

Furthermore, the absence of nearby support facilities or technical assistance centers further deters farmers from utilizing expert systems. When technical issues arise or users require assistance, the lack of local, easily reachable help centers leads to frustration and diminishes user trust. While users in urban areas might benefit from the convenience of accessible tech support and replacement services, those in rural regions frequently encounter lengthy travel distances and extra expenses to obtain these resources.

In order to tackle these challenges, it is essential for policy-makers and technology creators to embrace an inclusive design strategy that takes into account the economic conditions and infrastructure constraints faced by rural users. Government-sponsored subsidies for devices and internet services, the creation of low-bandwidth applications, solar-powered technology innovations, and the establishment of rural digital service hubs can work together to help close the affordability and infrastructure divide. If these core problems are not resolved, the aspiration to incorporate expert systems into routine agricultural practices will continue to be out of reach for most of India's farming community.

Limited Digital Literacy and Technical Abilities

One of the primary challenges to effectively deploying expert systems in agriculture is the prevalent deficiency in digital literacy and technical skills among farmers. In numerous rural areas, the idea of utilizing digital resources for decision-making remains an unfamiliar concept. A considerable portion of farmers lack knowledge of fundamental computer functions or mobile applications, which complicates their ability to handle expert systems that may include intricate interfaces, online platforms, or multimedia elements. This shortfall in digital preparedness prevents farmers from fully interacting with the systems, even when there is sufficient infrastructure and access.

The difficulty isn't limited to farmers; agricultural extension workers, who are meant to serve as intermediaries in promoting technology adoption, frequently encounter comparable problems. In many cases, these extension agents do not have adequate training in utilizing ICT-based tools or possess minimal experience with expert systems. This diminishes theircapacity to assist farmers or incorporate such tools into their regular advisory services, consequently diminishing the likelihood of broad distribution.

Furthermore, numerous training programs that are available are either single-instance or restricted in their reach, lacking additional sessions or practical demonstrations designed to meet local requirements. Language obstacles and unfamiliar jargon also add to the difficulties in the educational process. In the absence of context-relevant, experiential training, users might experience feelings of being overwhelmed or intimidated by the technology, leading to neglect or insufficient use of expert systems.

To tackle this limitation, it is crucial to implement continuous, community-oriented digital literacy initiatives that focus on agricultural uses. This should encompass visual resources, hands-on demonstrations, and instruction in local languages to enhance user confidence and skills. Furthermore, incorporating digital literacy into educational curricula and adult learning programs in rural regions can establish a sustainable basis for digital involvement. Cultivating a technology-savvy farming community will not only aid in the acceptance of expert systems but also help achieve the wider objectives of agricultural advancement and rural growth.

Language and Usability Barrier

Language and usability obstacles pose major difficulties in the successful implementation of expert systems across various agricultural communities. A significant number of expert systems are designed mainly in English or a few prominent regional languages, neglecting the extensive linguistic variety present in India. This limits accessibility for farmers who are proficient only in local dialects or possess minimal formal education. The absence of multilingual assistance, especially in tribal or isolated regions, diminishes inclusivity and deters potential users from utilizing these resources. Furthermore, the layout of interfaces for expert systems frequently fails to incorporate user-friendly elements that support individuals with limited reading skills. Content that relies heavily on text, devoid of supplementary visuals, icons, audio cues, or video tutorials, poses a significant challenge for seamless navigation. This issue is particularly pronounced among older farmers or those who are just beginning to engage with digital tools. An interface that seems complicated or dauntingAt first sight, it is probable to dissuade continuous usage and diminish the overall perceived value of the system.

Moreover, usability is influenced by the restricted personalization of expert systems in relation to local agricultural situations. When farmers encounter an interface or terminology that feels foreign or when the recommendations seem disconnected from their day-to-day experiences, confidence in the system wanes. To tackle these obstacles, it is crucial to integrate voice-activated assistance in native languages, create icon-focused navigation tools, and incorporate culturally pertinent symbols. The design of user interface (UI) and user experience (UX) should be rooted in collaborative input, engaging farmers in the co-creation process. This method will ensure that expert systems are not just technically sound but also linguistically and culturally pertinent, thus encouraging wider uptake and ongoing usage.

Technophobia and Skepticism

Technophobia—the apprehension or hesitation to embrace technology—serves as a significant psychological obstacle that impedes the use of expert systems in agriculture. This aversion is particularly pronounced among older farmers and individuals with minimal experience using digital tools. Numerous farmers depend significantly on conventional, experience-driven farming techniques handed down over generations. Consequently, they often regard innovative technologies with skepticism, especially when automated suggestions oppose their traditional methods or community-recognized knowledge. This results in a psychological divide that obstructs the establishment of trust between the user and the system. Doubt is heightened by the belief that machines are unable to grasp the subtle, location-specific requirements of varied agricultural settings. When expert systems provide general or overly complex recommendations that are not readily useful, farmers may feel disappointed in their effectiveness. Previous unfavorable encounters with ICT initiatives—like insufficient timely assistance or unfulfilled commitments from trial projects—can strengthen this reluctance, causing farmers to be cautious about adopting new digital platforms.

Furthermore, the lack of success stories at the community level or validation from peers can dissuade novice users from trying out expert systems. In the absence of clear evidence that these tools provide real advantages, numerous farmers prefer to continue using conventional methods.approaches they rely on. To address technophobia and doubt, expert systems should be implemented via inclusive, trust-enhancing methods like farmer-led demonstrations, sharing of testimonials, and gradual, accessible onboarding procedures. Establishing trust through relatable examples and ongoing assistance can aid in altering viewpoints and encouraging a more receptive disposition toward technology within skeptical agricultural communities.

Gender Disparity

Gender inequality continues to be a major and frequently neglected obstacle in the fair adoption and use of expert systems within agriculture. Women farmers, who make up a significant segment of the agricultural labor force, encounter systemic barriers that hinder their access to digital advancements. These barriers encompass restricted ownership or access to mobile technology and digital infrastructure, which are often dominated or prioritized for male household members. Furthermore, societal and cultural standards commonly place limitations on women's mobility, restricting their opportunity to participate in training sessions, extension meetings, or to utilize digital service locations.

The situation is made worse by the lower literacy levels among rural women, which has a direct impact on their ease and assurance in utilizing technology-based solutions. Women are also less represented in digital literacy and technical training initiatives, whether due to insufficient targeted programs or societal limitations that diminish their involvement. Consequently, even when expert systems are accessible and operational, female farmers frequently remain excluded from the advantages they offer, thus perpetuating existing gender disparities in agricultural productivity and decision-making.

To rectify this disparity, it is vital to adopt gender-inclusive approaches that emphasize the empowerment of women by enhancing their access to technology and opportunities for skill development. This may involve exclusive digital training programs for women, community outreach initiatives spearheaded by female extension agents, and the creation of specialized systems.

Empirical Evidence from Field Studies

Empirical research provides essential insights into the real-world use and constraints of expert systems in agricultural extension services. A detailed survey carried out in the Villupuram district of Tamil Nadu revealed a variety of opinions from farmers about the usability and efficiency of these digital tools. Numerous participants acknowledged the expert systems' ability to accurately identify pest and disease outbreaks and offer timely intervention advice. These systems were especially appreciated for their potential to lessen reliance on external advisory visits and to expedite the process of identifying suitable crop management strategies. Nonetheless, farmers also pointed out significant drawbacks that impede regular use.

A primary issue highlighted was the limited adaptability of expert systems to local agro-climatic conditions. Most systems seemed to provide generalized recommendations that did not consider region-specific factors like soil types, local pests, or microclimates. This often resulted in a disconnect between the advice given and the actual on-ground conditions, diminishing user trust. Another persistent problem was the rare updating of system databases, leading to outdated or irrelevant suggestions during critical farming periods.

To better understand the factors influencing system effectiveness, regression analysis from multiple studies indicated that aspects such as user motivation, technical skills, age, educational background, and prior exposure to ICT significantly influence the benefits derived from expert systems. For example, farmers who showed greater confidence in using mobile phones or computers were more inclined to engage fully with the expert system features, resulting in improved outcomes. In one model, these elements accounted for 88.9% of the variance in perceived effectiveness, emphasizing the importance of user readiness in determining the success of such digital interventions.

These findings underscore the necessity for customizing expert systems not only in terms of content but also in delivery, training, and user interface design. They highlight the significance of participatory methods in the development and rollout processes, wherein end-users actively partake in tailoring the tool to meet their local needs. Such empirical data is crucial for policymakers, developers, and extension agencies aiming to promote expert systems more effectively and inclusively.

Proposed Future Strategies and Improvements Localized Content and Multilingual Interfaces

A vital element for the successful implementation of expert systems in agriculture is their capability to address the linguistic and cultural diversity found in rural communities. Most expert systems are initially crafted in standard or widely spoken languages, such as English or Hindi, creating a considerable barrier for users in areas where local dialects or tribal languages predominate. To ensure inclusivity and effectiveness, these systems must be customized—not just in language but also in agricultural practices, soil types, climatic variations, and cropping patterns that vary across regions.

Localization requires incorporating culturally relevant examples, area-specific data, and recommendations that mirror the realities faced by farmers. Multilingual interfaces, particularly those with voice-based commands, are especially important for users with low literacy. Voice navigation, recognition of regional accents, and audio guides in local dialects enhance usability, ensuring that farmers can engage with the system with ease and confidence.

Visual aids such as pictograms, videos, and animations can further bridge the literacy gap, enabling users to grasp complex farming guidance intuitively. By investing in such inclusive interface design, expert systems can significantly expand their reach, improve user satisfaction, and foster long-term trust among diverse agricultural communities.

Gender-Inclusive Training

Training that includes gender considerations is a crucial measure for ensuring equal access to expert systems in agriculture. Although women play a vital role in farming, they are often excluded from digital training opportunities due to socio-cultural norms, time limitations, and restricted access to digital devices. To close this gap, specific efforts must be dedicated to designing and implementing training initiatives that actively involve women and cater to their distinct needs and schedules.

One effective method involves organizing women-only workshops in secure, community-oriented environments where female farmers can freely participate and learn without societal pressures or disruptions. These sessions should be led by trained female extension workers or community leaders to encourage involvement and create a relatable learning environment. In addition to offering technical training, programs should include modules that focus on building confidence, financial literacy, and digital navigation to ensure comprehensive empowerment.

Access to digital tools also needs to be addressed since owning mobile devices and having internet access are significant obstacles. Providing subsidized smartphones or tablets and community-shared digital kiosks can offer essential infrastructure support. Furthermore, incorporating local language instruction, voice interfaces, and culturally relevant examples will guarantee that content is both accessible and meaningful.

By incorporating inclusivity in both content and delivery, gender-centered training can greatly enhance women's digital skills, thereby increasing their engagement with expert systems and leading to more equitable agricultural development.

Capacity Building and Digital Literacy Campaigns

Building capacity and promoting digital literacy are foundational elements for ensuring the sustainable and effective uptake of expert systems in agriculture. Numerous farmers and even extension personnel lack sufficient exposure to digital tools and online platforms, impeding their ability to utilize expert systems effectively. Addressing this gap necessitates coordinated and ongoing efforts from various stakeholders, including government authorities, non-governmental organizations, and academic institutions. Training programs should extend beyond one-time sessions and instead focus on continuous, iterative learning experiences that adapt to technological advancements.

Mobile-based tutorials can provide flexible, on-demand learning suited to the rural context, while peer learning initiatives foster community involvement and facilitate knowledge-sharing among farmers. Field demonstrations tailored to local circumstances further reinforce digital skill acquisition through hands-on experience. It is imperative that these programs are conducted in local languages and include region-specific agricultural content to optimize relevance and retention. Additionally, enhancing the capabilities of extension personnel to act as digital facilitators can amplify the reach and impact of such initiatives.

Equipping rural communities with fundamental digital skills will not only increase the utility of expert systems but also promote broader digital inclusion. Over time, improved digital literacy will empower farmers to access real-time agricultural information, connect with markets, and adopt other emerging technologies, contributing to a resilient and empowered farming ecosystem.

Public-Private Partnerships and Policy Support

Public-private partnerships (PPPs) and enabling policy frameworks are critical for the sustainable and widespread implementation of expert systems in agriculture. These collaborations harness the strengths of diverse stakeholders—government agencies provide oversight and funding, private technology firms contribute innovation and scalability, and academic institutions offer research-based insights and contextual understanding. By combining resources and expertise, PPPs can lower costs, enhance system design, and facilitate broad dissemination across various areas.

In addition to technological contributions, supportive policies are essential for creating an environment conducive to digital adoption. This includes subsidies for digital devices, incentives for tech companies to localize content, tax exemptions for agricultural software solutions, and specialized funding for digital extension projects. Policies should also tackle issues related to digital infrastructure, gender equity, and ongoing system maintenance. Incorporating expert systems into national extension policies and rural development strategies can guarantee their institutionalization and sustainability.

Moreover, PPPs can strategically contribute to capacity building by facilitating grassroots training programs and deploying last-mile digital access models such as mobile kiosks and community knowledge centers. By aligning public policy objectives with private sector capabilities, these partnerships can significantly enhance the effectiveness, efficiency, and inclusiveness of expert systems in transforming agricultural extension services.

Real-Time Data and AI Integration

The incorporation of real-time data and artificial intelligence (AI) drastically improves the functionality and relevance of expert systems in agricultural extension. Real-time data—such as weather forecasts, pest outbreaks, soil moisture levels, irrigation schedules, and market trends—enables expert systems to provide highly contextual and timely recommendations. This dynamic approach ensures that the advice offered is not only scientifically valid but also directly applicable to the farmer's immediate environment and conditions. For illustration, if a weather report indicates impending heavy rainfall, the expert system can adjust irrigation schedules or suggest pest control actions accordingly.

AI technologies, especially machine learning algorithms, enable expert systems to continuously adapt and enhance based on user interactions and feedback. These adaptive systems can recognize patterns, identify emerging challenges, and customize responses over time to better suit the specific needs of individual users. This personalization enhances user satisfaction and trust, both of which are vital for sustained engagement.

The integration of AI also facilitates predictive modeling, allowing expert systems to anticipate potential threats such as pest infestations or declines in market prices and suggest preventive measures. Coupled with real-time data from sensors, satellite imagery, and IoT devices, these systems evolve from static advisory platforms into intelligent, interactive companions that adapt alongside agricultural practices and challenges. This transformation renders them indispensable tools for immediate problem resolution and long-term farm planning.

Offline and Voice-Based Access

In rural and remote areas, inadequate internet infrastructure and unreliable electricity supply remain persistent obstacles to adopting digital technology. Many farmers either lack access to internet-enabled devices or reside in regions with weak connectivity, limiting their ability to utilize real-time agricultural advisory services. To address this challenge, expert systems should be designed to function in offline modes, allowing users to download material, access suggestions, and perform updates when a connection becomes available. Offline capabilities guarantee that the benefits of these systems are not restricted to urban or well-connected users.

Additionally, voice-based access is a vital feature for improving inclusivity, especially among farmers with low literacy levels. Basic voice command interfaces compatible with simple mobile phones can offer information in local dialects, making expert systems more user-friendly. Voice navigation simplifies interaction and fosters confidence and familiarity with the system. This aspect is particularly crucial for older users or those who may feel daunted by text-heavy interfaces.

Combining offline capabilities with voice-enabled features addresses a significant accessibility hurdle, permitting even the most underserved communities to benefit from expert systems. Such functionalities can further be supported by community kiosks or shared devices in agricultural centers to ensure collective access and knowledge sharing, thereby encouraging equitable and widespread adoption.

Robust Feedback Mechanisms

Establishing strong feedback mechanisms is vital for ensuring the continuous improvement, user contentment, and long-term relevance of expert systems in agricultural extension. Feedback loops allow developers and stakeholders to grasp how users interact with the system, recognize challenges, and make informed adjustments to enhance system functionality. Structured feedback systems should extend beyond mere data collection and engage users actively through surveys, in-app inquiries, community gatherings, and farmer-led discussions.

Regular analysis of this feedback enables iterative system updates that align with the evolving needs, challenges, and preferences of farmers and extension personnel. When users observe their concerns being addressed in subsequent updates, it fosters trust, ownership, and a collaborative spirit. Moreover, feedback data can reveal region-specific issues that may not be captured by centralized system designs, enhancing localization and contextual relevance.

To further strengthen feedback channels, collaborating with local agricultural institutions and extension agents can serve as intermediaries for gathering, interpreting, and acting upon user contributions. Ultimately, an expert system that adapts through continuous user feedback is better equipped to remain effective, inclusive, and widely adopted in dynamic agricultural environments.

Conclusion

Expert systems have emerged as promising digital solutions aimed at revolutionizing agricultural extension by providing precise, timely, and customized advice to farmers across diverse agro-ecological regions. By mimicking human expertise through AI-driven algorithms, these systems can fill critical knowledge gaps, decrease reliance on physical extension services, and empower farmers to make informed choices. Their applications encompass a wide variety of fields such as pest and disease recognition, nutrient management, irrigation planning, and market connections—making them comprehensive tools for enhancing farm productivity and resilience.

The effectiveness of expert systems is heavily influenced by socio-economic, infrastructural, and cultural aspects that shape user acceptance and engagement. As discussed throughout this review, challenges such as low digital literacy, limited internet access, cost issues, technophobia, gender disparities, and inadequate localized content remain significant barriers. Overcoming these obstacles necessitates a collaborative, multi-stakeholder approach involving policymakers, private sector innovators, academic researchers, and grassroots extension agents.

Essential to the future success of expert systems is an inclusive, user-centered design philosophy. Systems must be co-developed with the intended user base, integrating local languages, cultural practices, and community feedback to guarantee relevance and ease of use. Training and support frameworks must be embedded within the agricultural ecosystem to provide ongoing learning opportunities and real-time assistance. Moreover, integrating expert systems into larger digital agriculture initiatives and rural development strategies will ensure their sustainability and scalability.

As agriculture continues to face challenges linked to climate change, market fluctuations, and labor shortages, expert systems can serve as intelligent allies in fostering adaptive and knowledgeable farming communities. Their true potential will be realized only when every farmer—regardless of gender, locality, or educational level—can access, understand, and trust the guidance provided. With strategic investment, inclusive design, and ongoing policy support, expert systems can become pivotal drivers of equitable and digitally empowered agricultural transformation.

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