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EXPERT SYSTEM FOR AGRICULTURAL EXTENSION: A REVIEW OF RECENT DEVELOPMENTS

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ABSTRACT

The ever-evolving dynamics of agriculture characterized by shrinking resource base, rising demand for quality food due to growing population and mounting climate change threat, makes it information intensive. Complex nature of agriculture decision-making calls for the demand of expert advice. Effective advice in agriculture needs to integrate diverse discipline of agricultural science to provide specific updated information to farmers. Due to several constraints, the traditional source of expert advice is unable to bridge the information gap between the knowledge generated and its end users, i.e., the farmers. Expert system, a branch of Artificial intelligence could be potentially leveraged to upscale agricultural extension. It emulates the human decision-making to provide solution in a narrow domain of expertise. The present study surveys fifty-five (55) literatures on expert systems developed in agriculture domain from the year 2010 to 2023 and presents the comparative analysis of the systems in terms of the region of their development, tools and techniques used, language, authors' expertise, functionality, deployment platform, etc. The findings highlight that most of the Expert systems were developed for horticultural crops, serves single function, was in English language and was web-based. Different tools and techniques were employed in developing the expert systems.

***Keywords*:** Agricultural Extension, Artificial intelligence, Expert system, Information.

Introduction

Information in today's era is regarded as new gold, given its importance as a powerful tool. Similar to other fields, it interacts and influences the farm productivity in various ways. Unlike in the past, where agricultural activities were limited to only food production, recent decades witnessed the evolution of agriculture to activities like processing, value addition, marketing, distribution, export etc. which necessitates demand of information in agriculture. Historically, farmers all around the globe have relied on in-person advice from traditional 'experts' to learn about agricultural innovations and farm management techniques (Rust *et al.*, 2022). In Indian context, agricultural extension has been playing an overriding role in agriculture development for a long time in India since the period of Green Revolution (Babu *et al.*, 2013). Even in the current scenario, the public sector is major extension service provider in country (Nedumaran and Ravi, 2019). However, it has been observed by Reddy (2018) in his study that the public extension in India has been facing shortage of time to attend core extension activities like advising farmers to enhance adoption of new practices and techniques as it is burdened with non-extension responsibilities such as the distribution of subsidies and inputs, which ultimately limit its role as information disseminator.

Artificial Intelligence (AI)-driven solutions are rapidly transforming agriculture by enabling precise soil analysis, optimal sowing time prediction, early pest detection, targeted herbicide application, accurate weather forecasting, valuable market insights, etc. With the advent of Agriculture 5.0, farming is entering a new era driven by intelligent technologies and data-centric solutions. Agriculture 5.0 represents the next stage in agricultural evolution, emphasizing smart innovations that increase productivity, reduce environmental impact, and address global food system challenges (Baryshnikova *et al.*, 2022). Unlike traditional precision agriculture, Agriculture 5.0 delivers highly customized digital solutions tailored to the specific needs of individual fields, livestock, and farmers. By integrating advanced technologies such as Artificial Intelligence (AI), data analytics, and automation, it aims to optimize resource use, enhance efficiency, and promote sustainable farming through personalized and adaptive strategies (Fountas *et al.*, 2024).

Assimakopoulos *et al.* (2025) describes open-field smart farming as a transformative approach integrating advanced technologies such as Internet of Things (IoT), AI, data analytics, drones, and blockchain to boost productivity, resource efficiency, and sustainability. IoT sensors provide real-time data on soil moisture, temperature, and crop health for precise irrigation and management. Drones and Unmanned Ariel Vehicles (UAVs) capture high-resolution images for crop monitoring, while satellite imagery offers large-scale insights on soil, weather, and vegetation. Machine learning analyses this data to generate predictive models and actionable insights. Blockchain ensures supply chain transparency and traceability. Precision agriculture, supported by Variable Rate Technology (VRT), enables site-specific input management. AI-driven predictive analytics forecast crop yields and disease outbreaks. Robotics and automation improve efficiency in tasks like planting, weeding, and harvesting by reducing manual labour, enhancing precision, and increasing production capacity.

Manga *et al.* (2023) and Shaikh *et al.* (2022) highlight AI's growing role in agricultural extension through integrated mobile technologies, IoT, and smart farming. Affordable drones and advanced machine learning methods improve large-scale tasks and disease detection. AI also supports optimized fertilizer and irrigation recommendations, weed detection, and water management using algorithms such as Naive Bayes, Support Vector Machines (SVM), and Random Forest (RF). Models like Long Short-Term Memory (LSTM) and Deep Belief Networks (DBN) enable personalized, real-time yield predictions, enhancing productivity and sustainability.

Expert systems (ES) development is one of the branches of Al (Rauch-Hindin, 1986 & Harmon and King, 1985). Expert system development is the most practical application of Al technology (Liebowitz, 1989) and is considered to be first commercial production of artificial intelligence (Mishra and Jha, 2014). It is an intelligent computer programme which is designed to solve problems and act as an expert, in a narrow domain of expertise (Rani *et al.*, 2011; Mehmat *et al.*, 2016; Janjanam *et al.* 2021). Expert system extracts the knowledge and experience from humans and uses inference technique to solve problem in a specific discipline thus, imitating human experts. Since its development in 1970s, it had successfully been used in wide array of fields including medicine, engineering, agriculture, industries, business etc.

The development of Expert system can be traced back to 1965 when NASA and Stanford university developed DENDRAL, an expert system to automatically generate molecular structure and interpret spectral data. It was followed by development of MYCIN derived from DENDRAL to identify bacteria and recommend antibiotic. By late 1980s onwards, expert systems entered new period of prosperity with use of approaches like fuzzy logic, neural networks and frame-based system for its development (Tan, 2017).

Structure of expert system

Expert system has three main components, Knowledge base, Inference Engine and User Interface (Janjanam *et al.*, 2021). Knowledge base represents the knowledge extracted from the human expert in a particular domain and is stored as facts and rules. There are different ways in which knowledge is represented in the knowledge base namely semantic network, rules, frames etc. Considered as the brain of Expert system, Inference engine applies technique like forward and backward chaining to knowledge base to derive conclusion. User interface is the gateway for a person to communicate with the expert system. It takes the query of the user as input to the system and displays the output. Schematic diagram of Expert system architecture is represented in Fig. 1.

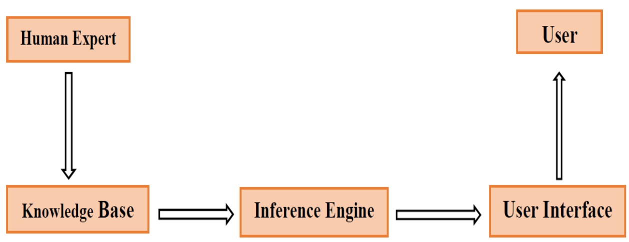

Fig. 1 : Expert system architecture

Expert system for Agricultural Extension

Knowledge based expert system has been used in agriculture since 1980s. Software developed to diagnose soyabean disease is the earliest known Expert system application in agriculture. It was followed by development of Expert systems like POMME for apple orchard management and COMAX for cotton yield prediction etc. (Rafea, 2008). Thereafter, development of expert system has been carried out to solve several problems in agriculture discipline. Services in extension is often question marked with availability of human and financial resources. At the age of fast-growing advanced technologies, best combination of man and machine is required to meet the socio-economic and information needs of the farmers and sustainable agriculture (Bahal *et al*., 2006). Decision making in agriculture is a complex process. A farmer has to integrate multiple discipline at multiple level of abstractions. Decision making ranges from what to grow, which technique to follow, optimum use of inputs, protection from diseases and pest to trading and marketing (Dath and Balakrishnan, 2013). Leveraging the potential of modern technologies can act as a potential bridge in helping provide farmer the information for decision making. Rafea (2008) delineated several information transfer problems that can be overcome by use of Expert system. Static information which may not respond to the grower's need, the need for integration of various disciplines and sources and the constant need for updating the information for sound decision-making necessitates the use of Expert system. The rapid development AI technologies, such as agricultural expert systems, brings new opportunities to the agricultural extension methodology (Rees *et al*., 2000).

Recent studies indicate the integration of various advancements in artificial intelligence to develop expert systems in the agricultural domain. Turgut *et al.* (2024) presents a system that uses methods like Local Interpretable Model-agnostic Explanations (LIME) and Shapley Additive Explanations (SHAP) to provide clear and localized crop recommendations based on weather and soil data. De (2024) used machine learning techniques like Support Vector Machines (SVM), Random Forest classifiers, and Logistic Regression, to predict suitable crops by analysing soil nutrients, temperature, and other environmental factors with high accuracy. Rehman *et al.* (2024) develop *KisanQRS*, a deep learning-based query-response system using Long Short-Term Memory (LSTM) networks to accurately match farmer questions with relevant expert answers, enabling timely advisory services.

Awais *et al.* (2025) introduced AgroGPT, a large multimodal model combining vision and language capabilities, fine-tuned with expert agricultural data to support complex queries related to pest identification and crop management. Chen and Huang (2025) explore combining reinforcement learning, which allows the system to learn optimal strategies through trial and error, with large language models that offer extensive agricultural knowledge, enhancing crop production management. Together, these recent studies demonstrate how expert systems, powered by advancements in AI, are becoming increasingly intelligent, interpretable, and practical for real-world agricultural applications.

Methodology

The study comprises a review of fifty-five (55) scholarly articles consisting of research articles and conference proceedings focused on expert systems developed in the field of agriculture.

a) Literature search strategy

The literature for the study was retrieved from reputable academic databases, primarily Google Scholar and ResearchGate. Only English-language publications from open-access journals published between 2010 to 2023 were considered. The primary keywords used during the search included **"Expert System"** and **"Agriculture."** 107 no. of literatures were collected

b) Criteria for literature inclusion

The selection process was carried out manually to ensure alignment with the study's objectives. Articles were initially shortlisted based on title relevance. A second level of filtering was conducted by reviewing the abstract, objectives, methodology, and results sections to ensure scientific rigor and relevance. The inclusion criteria focused on the following aspects:

1. Research explicitly related to the development of expert systems in agriculture domain.
2. Studies clearly describing the objective**,** design methodology, and functional scope of the expert system.

Out of 107 collected literatures, 55 literatures were finally considered for the review.

c) Literature survey and data analysis

A structured content analysis was performed, and findings were summarized using descriptive statistics. Each selected article was reviewed to extract methodological details related to expert system development in agriculture. Data were organized using Microsoft Excel and categorized by key parameters, including publication year, country of origin, authors' affiliations, targeted crops, interface language, knowledge representation techniques, programming languages, and deployment platforms. The next section presents a detailed discussion of the results.

Results and Discussion

Table 1 represents the comparative analysis of the expert system reviewed in terms of their utility, techniques/method of inference and development tools used.

Table 1 : Comparative analysis of Expert systems in Agriculture

Sl. No.	Utility	Techniques/Methods of inference	Development tools	Reference
1)	Rice diseases diagnosis	Rule-based, Backward chaining	Shell ESTA (Expert System for Text Animation)	Sarma *et al.*, (2010)
2)	Maize diseases diagnosis	Rule-based, Ada-Boost algorithm logic	Java Server Pages (JSP) and MYSQL	Korada *et al.*, (2012)
3)	Integrated disease management in finger millet	Fuzzy logic	Not defined	Roseline *et al.*, (2012)
4)	Wheat variety selection	Rule-based, Forward Chaining	Active Server Pages (ASP), VBScript® and JScript™	Islam *et al.*, (2012)
5)	Indian Tobacco Varieties Selection	Rule-based, Forward chaining	Web Ontology Language (OWL). JESS, JENA. java technology using n-tier web	Ravisankar *et al.*, (2012)
6)	Rice diseases diagnosis	Rule-based, Forward chaining	Java Expert System Shell (JESS) and the Java IDE of Netbeans 7.0 SQL.	Robindro and Sharma, (2013)
7)	Rice diseases diagnosis	Not defined	Hyper Text Preprocessor (PHP) as front-end tool and MySQL	Rani *et al.*, (2013)
8)	Stress Management in jute	Object-oriented methodology and heuristic method	ASP.NET (2.0), SQL	Chakraborty *et al.*, (2013)
9)	Integrated system for Soybean Production	Fuzzy logic with forward chaining	Not defined	Prakash *et al.*, (2013)
10)	Barley Variety selection	Rule based with forward and backward chaining	ASP (Active Server Pages technology), Java Script and VB Script	Singh *et al.*, (2013)
11)	Coffee Diseases diagnosis	Forward Chaining fuzzy logic decision tree using a hierarchical classification	Not defined	Suhartono *et al.*, (2013)
12)	Insect pests of agricultural crops	Not defined	Visual Basic .Net as front-end application and Oracle	Ravisankar *et al.*, (2014)
13)	Management Of Water	Not Defined	NetBeans Java IDE with Jdk 1.7.0	Singh and Choudhary, (2015)
14)	Disorder diagnosis of sugarcane	Object oriented programming technique forward and backward chaining	Web 2.0 standards	Hasan *et al.*, (2015)
15)	Insect pest identification in Teak	Not defined	HTML environment using the Sublime Text 2.0 software jQuery 1.9 (JavaScript Library), and PhoneGap	Nascimento *et al.*, (2016)
16)	Balanced Feeding for Dairy Animals	Not defined	Visual BASIC	Angadi *et al.*, (2016)
17)	Coconut Disease Management and Variety Selection	Rule based, Forward chaining	Active Server Pages (ASP) technology and SQL Server.	Dath and Balakrishna., (2016)
18)	Rubber Crop Disease Diagnosis and Management	Rule based, Forward chaining	JAVA, CLIPS	Konyeha and Imouokhome, (2018)
19)	Selection of climate resilient rapeseed-mustard varieties	Rule based, Forward chaining	Java script, Hypertext Markup Language (HTML), CSS is used in conjunction with PHP	Kumar *et al.*, (2018)
20)	Wheat diseases diagnosis	Rule based, Forward chaining	Active Server Pages (ASP) VBScript and Java Script	Islam *et al.*, (2018)

21)	Diagnosing disease and pest on banana	Fuzzy logic Backward chaining	PHP. For data storage, MySQL	Budiyanto *et al*., (2018)
22)	Watermelon diseases diagnosis	Forward Chaining	CLIPS and Delphi XE10.2	Abu-Nasser, and Abu-Naser (2018)
23)	Irrigation Systems Management	Forward chaining	Microsoft visual basic 2013	Eid and Abdrabbo (2018)
24)	Honey Guava diseases diagnosis	Bayesian probability method	Visual Basic 2010 SQL	Abdullah *et al*. (2018)
25)	Expert System for Alfalfa (Disease identification, Variety selection, Weed management)	Forward chaining	ESTA shell	Bondok *et al*., (2018)
26)	Identification of nutrients deficiency/ disorder and their management in Mango	Object-oriented forward chaining method	MS® Visual Basic	Verma *et al*., (2018))
27)	Nutrient deficiency of Rice	Fuzzy logic	MATLAB 7.9.0(R2009b) MATLAB (Matrix Laboratory)	Nath, (2018)
28)	Goat diseases diagnosis	Forward chaining	SWI Prolog	Tesfaye (2019)
29)	Wheat diseases diagnosis	Forward Chaining	CLIPS and Delphi XE10.2	Mansour, and Abu-Naser. (2019)
30)	Diagnosing Guava Disease	Forward Chaining	CLIPS and Delphi XE10.2	Dheir and Abu-Naser (2019)
31)	Diagnosing Castor Disease	Forward Chaining	CLIPS and Delphi XE10.2	Salman and Abu-Naser, (2019)
32)	Citrus Diseases Diagnosis	Forward chaining	CLIPS	El Kahlout and Abu-Naser, (2019)
33)	Sesame disease diagnosis	Forward Chaining	CLIPS	El-Mashharawi and Abu-Naser (2019)
34)	Date Palm diseases diagnosis	Rule-based, decision tree	PHP, Java script CCS. MYSQL	Galala (2019)
35)	Apple diseases diagnosis	Forward Chaining	CLIPS	Al-Shawwa and Abu-Naser(2019)
36)	Apple diseases diagnosis	Forward Chaining	CLIPS and Delphi	Khalil *et al*., (2019)
37)	Spinach disease diagnostic	Forward Chaining	CLIPS	Al-qumboz and Abu-Naser (2019)
38)	Grapes diseases diagnosis	Forward Chaining	CLIPS and Delphi	Alajrami and Abu-Naser (2019)
39)	Sugarcane disease diagnostic	Forward Chaining	CLIPS and Delphi	Elsharif and Abu-Naser (2019)
40)	Soybean crop management (Seed Selection, Soil Preparation, Water and Fertilizers Management, Weed Management etc.)	Forward Chaining	Not defined	Yelapure and Kulkarni (2019)
41)	Papaya Disease diagnosis	Forward Chaining	CLIPS and Delphi	Abu-Saqer and Abu-Naser (2019)
42)	Diagnosis of Coffee disease	Forward chaining	CLIPS	Abu-Mettleq and Abu-Naser (2019)
43)	Seed variety selection and diagnosis of pests of rice	Forward Chaining	Not Defined	Adi and Isnanto (2020)
44)	Pests and diseases diagnosis of Onion	Bayesian probability method	Microsoft Visual Basic Version 2010	Lumbangaol (2020)
45)	Expert system for rice	Forward and Backward chaining	Microsoft SQL .Net	Sailaja *et al*., (2020)
46)	Soybean Variety Identification	Fuzzy Tsukamoto method and Case Based Reasoning	PHP and HTML MySQL	Tosida, *et al*., (2021)
47)	Rice disease diagnosis	Forward Chaining	Java, OWL API, MySQL	Jearanaiwongkul *et al*. (2021)

48)	Broccoli diseases diagnosis	Not Defined	CLIPS	LAfi *et al*., (2022)
49)	Bean diseases diagnosis	Forward Chaining	CLIPS	Abueleiwa *et al*., (2022)
50)	Coriander diseases diagnosis	Not Defined	CLIPS	Aslem *et al*., (2022)
51)	Mint Disease Diagnosis	Forward Chaining	CLIPS	Megdad *et al*., (2022)
52)	Tomato Disease Diagnosis	Forward Chaining	CLIPS	Al-Qadi *et al*., (2022)
53)	Strawberry Disease Diagnosis	Forward Chaining	CLIPS	Sababa *et al*., (2022)
54)	Pineapple disease diagnosis	Bayesian probability method	NetBean IDE application	Pujianto *et al*. (2023)
55)	Mango pest identification	Forward chaining	CLIPS	Altayeb *et al*. (2023)

Among the expert systems studied, the majority were developed for horticultural crops, including popular fruits such as apple, mango, guava, pineapple, and others (Fig. 2). This was followed by expert systems developed for field crops, with a significant concentration on rice. In total, 7 expert systems were identified that specifically addressed various aspects of rice, such as disease diagnosis, nutrient deficiency identification, and variety selection. Rice is a staple food crop in many countries, which likely drives the higher number of expert systems aimed at ensuring its productivity and disease management. A smaller number of expert systems were developed for cash crops, including sugarcane and rubber, focusing on disease diagnosis and management. This distribution suggests a stronger emphasis on high-value horticultural crops and staple crops like rice, likely due to their economic and food security importance.

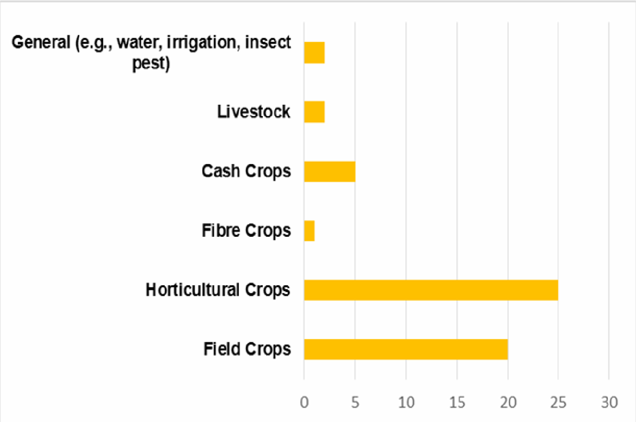

Fig. 2: Distribution of the Expert systems according to their domain

Most of the expert systems developed had a single function, such as disease diagnosis, seed variety selection, or pest detection (Table 2). These single-function systems were more common among the expert systems analysed. Developing a single-function system is generally easier to implement compared to multifunctional systems. 14 expert systems under the study were identified as multifunctional systems for example, those that handle both diagnosis and management of diseases, or systems that combine pest diagnosis with seed variety selection. These multifunctional systems are more comprehensive, as they serve multiple purposes and offer broader support to users.

Table 2: Distribution of the expert system based on their type of functionality

Type of Functionality	Number of Expert system (ES)	Percentage (%)
Single Function	41	74.54 %
Multiple Functions	14	25.45 %
Total	55	100 %

A majority of expert system, 43 were developed in the English language (Fig. 3), likely due to the convenience and widespread use of English in research and technology development. However, only a limited number of systems were created in regional languages such as Indonesian, Arabic, Hindi, and others. Some expert systems were developed in multiple languages. To enhance their practical impact and accessibility, especially among local farmers, it is essential to develop more expert systems in regional languages. This would ensure wider reach, better adoption, and improved usability at the grassroots level.

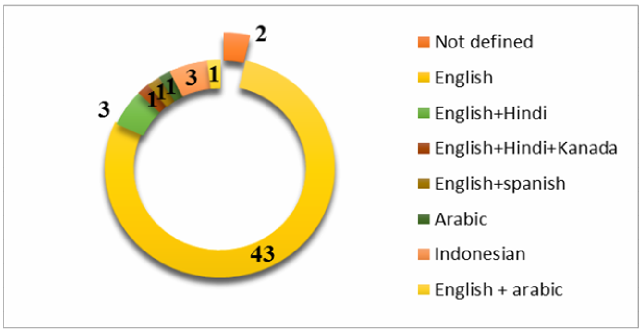

Fig. 3: Distribution of the expert systems based on language of development

Fig. 4 reveals that approximately 93% of the expert systems were deployed in web-based platforms, while 5% were mobile-based, and only 2% were designed for both web and mobile platforms. Assuming that the primary target users of agricultural expert systems are the farming community, it would be more practical and impactful to increase the development of mobile-based expert systems as it offers greater accessibility and convenience, particularly in rural areas where internet infrastructure may be limited and desktop usage is low. Further, analysis of the literature to find out the expertise of authors reveal that most of them are from engineering and IT, which was followed by agricultural sciences and computer science backgrounds (Fig. 5). About the regional distribution of the literatures, most of the literatures were published in Palestine followed by India, Indonesia and other countries.

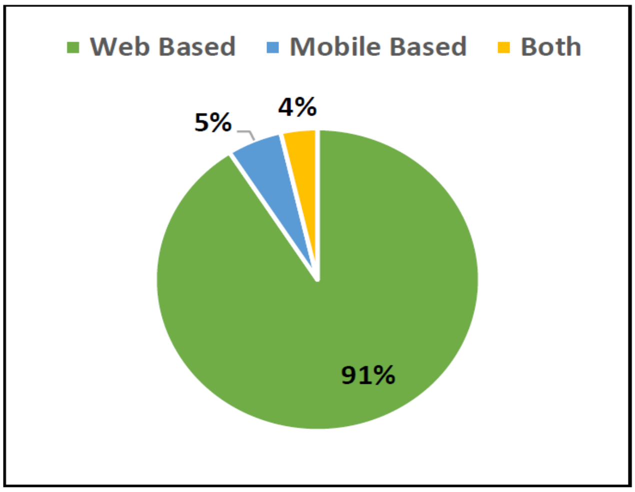

Fig. 4 : Expert system deployment platform

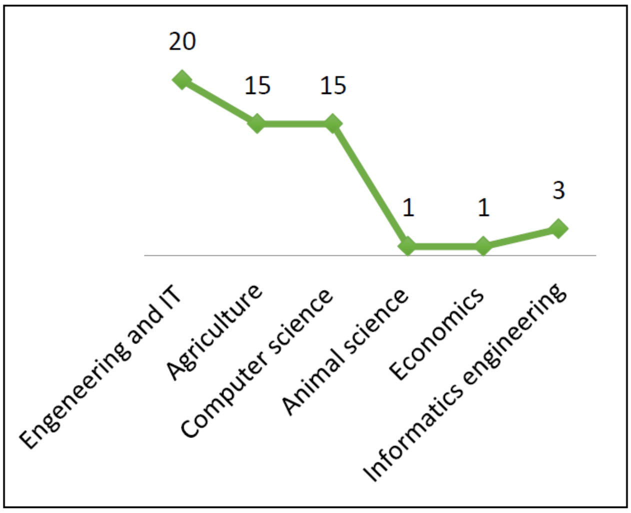

Fig. 5 : Field of expertise of authors

The analysis of various expert systems reveals that a wide range of tools have been used in their development (Table 3). CLIPS (C Language Integrated Production System) is one of the most widely used expert system shells. Programming languages and platforms such as Java, Visual Basic, and Delphi are also popular choices for building expert systems. MySQL is the most commonly used database management system for storing and managing data in these systems.

Table 3 : Distribution of expert systems based on tools used for development

Tool Category	Example Tools	Findings
Web technologies	ASP, JSP, PHP, HTML, CSS, JavaScript	Common for front-end interfaces
Shells	CLIPS, ESTA, JESS	Widely used for expert systems (CLIPS dominant)
Languages and IDEs	Java, Visual Basic, Delphi, NetBeans	Popular languages and platforms
Databases	MySQL, SQL Server, Oracle	MySQL is the most used
Other	MATLAB, OWL API, PhoneGap	Niche/specialized systems

Regarding the primary utility of the expert systems under the present study, it was revealed that most of the systems (37) were developed for disease diagnosis, followed by variety selection (7), pest identification (5), and a few others focusing on nutrient deficiency, integrated crop management, irrigation, stress management, and animal health (Table 4). The analysis highlights that disease diagnosis remains the predominant focus of expert system development in agriculture, indicating a critical need for early detection and management of crop health issues to enhance productivity.

Table 4: Distribution of expert systems based on Functional Categories and Targeted Crops

Function Category	No. of ES	Examples
Disease Diagnosis	37	Rice, Wheat, Coffee, Apple, etc.
Pest Identification	5	Banana, Onion, Mango, Teak, Rice
Nutrient Deficiency/Disorder	3	Mango, Rice, Mango
Variety Selection	7	Wheat, Tobacco, Barley, Coconut, etc.

Integrated Crop Management	5	Soybean, Rubber, Finger millet, etc.
Water/Irrigation Management	2	Irrigation systems, Water management
Animal Health/Nutrition	2	Dairy cattle feeding, Goat disease diagnosis
Stress/Climate Resilience Management	2	Jute stress, Climate-resilient mustard

A thorough review of the inference techniques used in the development of expert systems (Table 5) reveals that rule-based systems with forward chaining are the most commonly adopted method, likely due ease of implementation in agricultural problem-solving. In contrast, backward chaining is less frequently employed, possibly because it is more suited for goal-driven queries rather than exploratory or diagnostic tasks. Additionally, a few systems have incorporated fuzzy logic to handle uncertainty in data, while others have used decision trees, Bayesian probability models, and case-based reasoning, demonstrating the growing diversity of AI techniques in enhancing the decision-making capabilities of agricultural expert systems.

Table 5: Distribution of expert systems based on inference techniques used

Technique	No. of ES	Findings
Rule-based	27	Most common method, usually with forward chaining
Forward chaining	35	Widely used across crops
Backward chaining	7	Less frequent, often combined with forward chaining
Fuzzy logic	6	Used for uncertain reasoning (finger millet, banana, soybean, etc.)
Bayesian probability	4	Onion, Guava, Pineapple, Honey Guava
Object-oriented & heuristic	4	Applied to stress management, sugarcane, mango
Decision tree	2	Coffee, Date palm
Case-based reasoning	1	Soybean (with fuzzy Tsukamoto method)
Not Defined	7	Incomplete system descriptions

The literature surveyed in the present study provides an extensive description of the design, development, and implementation strategies of various agricultural expert systems. Agricultural expert systems are generally aimed at supporting the broader farming community, who are the ultimate end users. From the perspective of extension education, it is essential to conduct an in-depth analysis of the farmers' information needs, their expectations regarding the user interface, and their technical skills related to the use of such systems. Without this understanding, the system risks being less effective or difficult to use for the target audience. Moreover, to ensure that the developed system is widely applicable and effective the participation of target users must be considered throughout all phases of development from initial requirement gathering to final deployment. This participatory approach helps align the system's functionality with real-world needs and user capabilities.

In addition to development, the assessment of usability, applicability, and the overall impact of these expert systems is critical. This requires systematic post-development evaluation studies, which can provide valuable feedback for improvements and validate the system's effectiveness in practical settings.

In the studies reviewed, participatory involvement of end users and post-implementation evaluations were reported in only a limited number of cases, highlighting a significant gap that future research should address to improve the overall effectiveness and success of agricultural expert systems.

Conclusion

Artificial intelligence solutions can be effectively leveraged to support the farming community by narrowing the gap between them and the vast amount of available information. Based on the findings from the 55 studies reviewed in this research, it can be concluded that considerable efforts have been made to develop expert systems for various crops and commodities, serving a range of purposes. To position expert systems as a key medium for information dissemination, they should be developed in the form of mobile applications and made available in regional languages to enhance accessibility for farmers. The scope of expert system development can also be extended to include a broader range of crops and other economically important commodities. These systems can play multiple roles, including capacity building, diagnostic assistance, and providing timely guidance to farmers.

With the development of new algorithms and advanced AI techniques, there is increasing potential to incorporate more sophisticated methods in the design and development of advanced expert systems in agricultural extension. However, for expert systems to be truly effective and impactful, it is essential to adopt a participatory approach throughout their development and implementation. Moreover, continuous feedback from end users and iterative improvements based on their needs will significantly enhance the systems' usability, accessibility, and overall relevance to the farming community.

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