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ARTIFICIAL INTELLIGENCE IN FARMING: ADVANCING CROP MANAGEMENT, PEST CONTROL, AND SUSTAINABLE PRACTICES

Lal Chand Panwar*, Himanshu
Department of Computer Science & Engineering, Punjabi University Patiala, Punjab, India-147002
E-mail*: *Lc.panwar5876@gmail.com*

ABSTRACT

The integration of Artificial Intelligence (AI) in farming has revolutionized the agricultural sector, transforming traditional practices into precision agriculture. This paper explores the current trends and future scope of AI in farming, highlighting its applications in crop monitoring, yield prediction, disease detection, and automation. Systems are being developed to assist agricultural experts in finding better solutions all over the world. The applications of AI techniques in several fields of agricultural research, industrial insights, and the obstacles to AI adoption in agriculture are the major topics of this study. This paper discusses the benefits of AI-powered farming, including increased efficiency, reduced labor costs, and enhanced decision-making. Additionally, this paper also explores the role of machine learning algorithms, computer vision in collecting and analyzing agricultural data. The paper also addresses the challenges and limitations of implementing AI in farming, such as data privacy, security concerns, and the need for standardization. The analysis reveals that AI has the potential to increase crop yields, reduce environmental impact, and promote sustainable agriculture practices. As the global population continues to grow, AI-powered farming will play a vital role in ensuring food security and meeting the increasing demand for food production.

KEYWORDS: Artificial Intelligence, Agriculture, Artificial Neural Networks, Machine Learning, Deep Learning, Applications of AI, Fuzzy Systems.

INTRODUCTION

One of the main fields of research in computer science is artificial intelligence (AI). Since of its broad range of applications and quick technological improvement, artificial intelligence (AI) is quickly becoming ingrained in society since it can effectively address

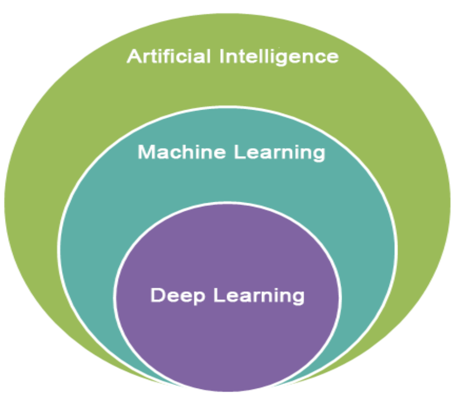

Fig 1. Subset of Artificial Intelligence

problems that humans and conventional computing systems cannot (E. Rich and Kevin Knight,1991). Approximately 30.7% of the world's population engages directly in agriculture on 2781 million hectares of land, which makes it a vital field (Dutta et al,2020). From sowing to harvest, such a venture is fraught with difficulties. The biggest challenges include weed management, yield forecast, inadequate chemical use, drainage and irrigation problems, and pest and disease infestation.as illustrated in Fig. 1, a subset of artificial intelligence is machine learning. One tool for finding, understanding, and analyzing patterns in data is machine learning. The first records of computer use in agriculture date back to 1983. (D.N. Baker,1983). Numerous strategies, from databases (P. Martiniello, 1988) to decision support systems (K. W. Thorpe, 1992), have been presented to address current agricultural issues. Among these options, AI-powered systems have been proven to perform the best in terms of accuracy and resilience. Since agriculture is a dynamic field, it is impossible to generalize problems in order to offer a shared solution. We can now deliver the optimal answer for a given problem by capturing the fine nuances of each scenario thanks to AI approaches. With the development of various AI techniques, increasingly complex problems are being solved.

This paper's main focus is on the important Artificial Intelligence (AI) methods applied to agricultural problems. The three most significant AI methods are artificial neural networks, fuzzy systems, and expert systems. In order to measure the growth of agro-intelligent systems, this research explores the application of AI techniques in a wide subdomain of farming.

LITERATURE REVIEW

The farming sector and agriculture's future mostly depend on creative ideas and technical advancements to boost productivity and enhance resource use by utilizing non-traditional computer technologies.

In agriculture, the use of crop models and decision-making tools to boost output and resource efficiency is growing. By combining cutting-edge technologies to predict agricultural productivity, artificial intelligence has the potential to completely transform the agricultural industry (Dutta et al,2020).

Over the past few decades, agriculture production systems have been severely impacted by climate change, growing production costs, depleting irrigation water supplies, and a decline in farm labor (Jinha Jung et al,2021). Furthermore, the COVID-19 pandemic is threatening supply systems and food production (J.L. Outlaw,2020). These elements threaten both the present and future food supply chains, as well as the

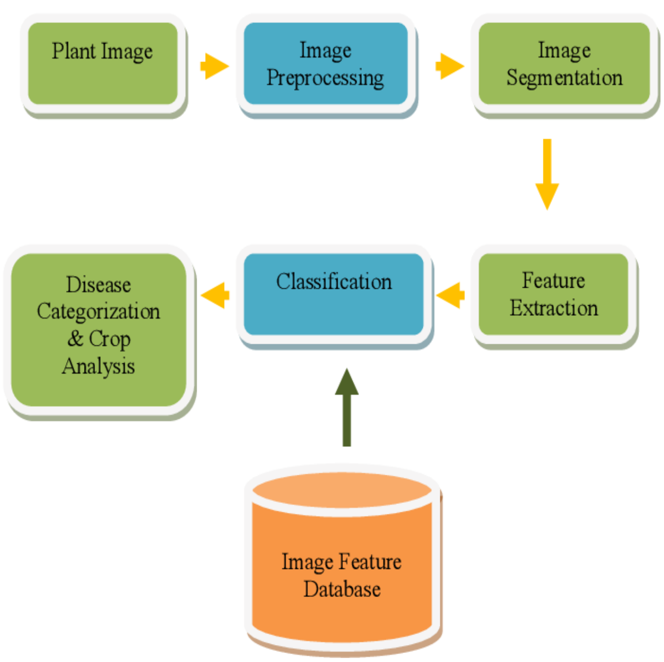

Fig. 2. Disease detection using Image Processing

sustainability of the ecosystem(M. A. Andersen,2018). To keep ahead of the ongoing climate change, significant inventions are always needed (J. Hatfield,2014). It seems sense that the problem here is how to collect enough food to feed the growing population. The research experts are always using their state-of-the-art knowledge and coming up with innovative ways to apply it to the agricultural system (Jinha Jung et al,2021).

GENERAL CROP MANAGEMENT

Generally speaking, the universal crop management system offers a worldwide crop management interface that encompasses all facets of agriculture. The first artificial intelligence method for crop management was put forth by McKinion and Lemmon in their work (McKinion and lemmon, 1985).In his thesis, Boulanger suggested another expert system for protecting maize crops (Boulanger, 1983).POMME is an expert system that Roach suggested in 1987 for managing apple plantations (J. Roach et al., 1987).For crop management, Stone and Toman also developed the expert system COTFLEX (N. D. Stone et al., 1989).Lemmon created a novel rule-based expert system called COMAX (H. Lemmon, 1990) for the management of cotton crops. Remote sensing methods, 3-D laser scanning, and hyperspectral imaging are essential for creating metrics for crops across cultivable land areas. It could result in a creative change in the way farmers spend time and effort maintaining their lands.To prevent damage to citrus orchards on the Italian island of Sicily, Robinson and Mort proposed a complex feed forward neural network-based system (C. Robinson, N. Mort, 1997). The input and output parameters were coded in binary format for the network's training and testing. To produce a prototype with a high degree of reliability, the authors applied various data patterns. Six input and two output classes were used in the best prototype to date, which attained 94 percent precision. Five hidden layers with an average accuracy of 85.9 percent and training up to 300,000 iterations constituted the unmatched network (S. K. Li et al., 2002). Based on fuzzy logic, Prakash's recommended soybean crop management strategy offered.

Pest Management

The most disturbing issue in farming that usually ends in huge financial loss is an infestation of harmful pests. Scientists have been trying to diminish the same threat for decades by developing computer systems that can identify aggressive pests and suggest ways to control pests. The rule-based expert system may be prone to indecision since the information involved in agricultural management is often ambiguous and unfocused (G.M. Pasqual, J. Mansfield, 1988). Several logic-based expert systems were proposed by Saini and Kamal (H.S. Saini et al., 2002) and Siraj and Arbaiy (F. Siraj, N. Arbaiy, 2006) to deal with this ambiguity.

Ghosh and Samanta created TEAPEST for tea pest management, they structured a rule-based expert system using an object-oriented methodology (I.Ghosh, R.K. Samanta, 2003). For this, a methodical identification and consultation process was employed. A multidimensional back proliferation neural network was used by Samanta and Ghosh to reorganize the system long ago (R. K. Samanta and Indrajit Ghosh, 2012). Banerjee subsequently used a radial basis function prototype to attain advanced sorting rates (G. Banerjee et al., 2017).

Artificial intelligence is used by pest treatment organizations to program and improve anything from pest prediction to pest route planning. Using drone technology, farmers and pest control businesses can virtually visit every crop and give near-real-time monitoring to identify pests, diseases, dead soil, or irregular crop degradation. The farmer can use this information to gather data from any particular agricultural patch and stop the disease from spreading.

Disease Management

The environment, farmers, consumers, and the global economy can all be seriously threatened by plant diseases.Pests and pathogens destroy 35 percent of crops in India alone, resulting in significant losses for farmers. Pesticide use without selection endangers human health because some pesticides are biomagnified and toxic. By keeping an eye on the crop, identifying any diseases, and offering adequate treatment, these impacts can be prevented. It takes an enormous skill and knowledge to identify an ill plant and then take the appropriate steps to recover it. Automated methods are utilized all around the world to analyze the condition and then suggest solutions to control it. In order to detect diseases, image sensing and analysis are done to make sure that the leaves' images are separated into external areas like the background, the infected area, and the non-diseased area. After that, the diseased leaf part is removed and sent to the laboratory for additional analysis.This facilitates the diagnosis of nutrient deficiencies and the identification of pests. Figure 2 shows an all-inclusive framework.

Rule-based systems were first introduced by Byod and Sun (D.W. Boyd and M.K. Sun, 1994). An artificial neural network model was developed by Panigrahi and Francl (L. J. Francl and S. Panigrahi, 1997) to control disease in different harvests. Corresponding fusion systems existed. Huang (K. Y. Huang, 2007) suggested using a neural network model in conjunction with an image dispensation prototype to classify the phalaenopsis seedling illness.

Irrigation and Soil Management

In farming, irrigation is a labor-intensive procedure. In agriculture, issues with soil and irrigation are crucial. Crop losses and contaminated characteristics are the outcomes of poor irrigation and soil management. The irrigation process can be mechanized and overall production increased by trained AI machines that are aware of past weather patterns, crop varieties, and soil quality. About 70% of the fresh water resources in the world are used for irrigation, therefore automating this process might help farmers solve their water-related issues while also saving water. Businesses like Intello Labs, which analyzes photos using Deep Learning, and CropIn, which maximizes per-acre value using Artificial Intelligence, are creating sensors and AI-based technology to track the health of soil.

This section focuses on certain irrigation and soil management studies that have benefited from artificial intelligence methods. Sicat and John (R.S. Sicat, 2005) developed a fuzzy system to distribute harvests according to the appropriateness of the land maps the system produced using the data from agriculturalists. A neural network system was created by Arif (C. Arif, 2013) to measure the moisture content of the topsoil in paddy fields. Using four different inputs, Manek and Singh compared several neural network designs for rainwater forecasting (A. H. Manek, and P. K. Singh, 201). The study discovered that the neural network's radial basis function performs the best when compared to previous models.

Weed Management

One of the most difficult issues for a farmer is weed control, which is also the most prevalent issue in pest control. Herbicides are used more often than any other type of pesticide, including insecticides. Not only does no farmer want to use herbicides, but they also do not want to witness weeds consuming all of the water and nutrients intended for crops. The environment and human health suffer adverse effects by the usage of herbicides.

Many companies and projects are interested in using robots, machine learning, and computer visualization. By controlling weeds carefully and properly, advanced AI techniques have been created to limit the use of herbicides. An intelligent system was developed by Pasqual (G Pasqual, 1994) to detect and remove undesirable plants from harvests of wheat, barley, and oats. Additionally, using the same set of contributions as the previous paper, Burks (T.F. Burks, et al., 2005) matched three different neural networks, mainly back propagation, counter dissemination, and radial based function model, and found that the back propagation setup performs best with 97 percent accuracy.

Yield Prediction and Management

Marketing methods and crop cost estimation both benefit greatly from crop yield forecast. Predictive models can also be used to analyze relevant characteristics that consistently affect yield in the era of precision agronomy. An ecosystem for smart, efficient, and sustainable farming is developing as a result of the development of ground-breaking technologies including artificial intelligence (AI), satellite imagery, cloud machine learning, and sophisticated analytics. The combination of these cutting-edge technologies is helping farmers maintain their profitability by helping them achieve the highest possible average yield and better control over the quantity of food grains.Liu and Minzan (G. Liu et al., 2005) employed an AI neural network model with a back propagation knowledge strategy to forecast harvest from topsoil restrictions.Real-time monitoring, optimal sowing seasons, and statistical climatic data Adequate Moisture AI programs can identify data from soil moisture and frequent raindrop counts to generate forecasts and provide farmers advice on when to plant.

APPLICATIONS

Table 1 lists some Expert Systems developed specifically for agricultural use by Institutes and Organizations. Expert systems are tailored to particular crops. The way that expert systems offer facilities for crops is covered in the description section described above.

Technology Insights

The market is separated into four technological segments: computer vision, predictive analytics, machine learning, and deep learning. A number of agriculture companies employ predictive analytics to implement artificial intelligence. To create AI-enabled farming and agriculture platforms and solutions, for instance, AgEagle Aerial Systems Inc., Microsoft, and Granular, Inc. have partnered on a prediction-based analytics system (Region, And Segment Forecasts, 2019).Despite the fact that predictive analytics improves production in agricultural applications, the market is expected to grow at a steady CAGR over the course of the projected period. Additionally, by using machine learning to analyze sensor data, farm management systems are developing into full artificial intelligence systems, expanding the potential for production enhancement. As a result, the machine learning and deep learning segmentsare expected to grow. Fig. 3 (Region, And Segment Forecasts, 2019) shows the current global share of AI technologies.

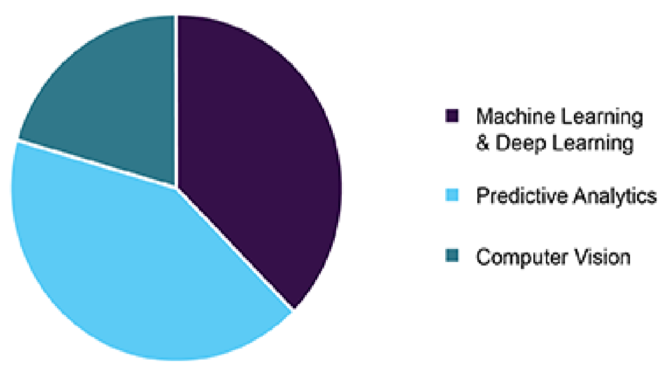

Fig. 3. Global AI in agriculture market share

Table 1. Applications of Expert System in Agriculture

System Name	Crop Name	Description
TEAPEST	Tea	It is a rule-based, object-oriented expert system that can recognize dangerous insect pests of tea and suggest a suitable control method
AMPRAPALIKA	Mango	The intention of this expert system program is to detect a specific mango sickness. Information on the signs and remedies for 14 illnesses that affect mango trees during the fruiting and non-fruiting seasons may be found in the system's knowledge base.
AGREX	Fruits, Vegetables, Paddy	AGREX is an expert system program created by Kerala's Centre for Informatics Research and Advancement (CIRA) that can assist farmers in getting accurate and timely advise. Crop protection, fertilizer application, disease diagnosis, and irrigation scheduling for paddy, vegetables, fruits, and postharvest technology are all areas where this expert program is being utilized more and more.
JAFexpert	Jute	The Central Research Institute for Jute and Allied Fibers (ICAR-CRIJAF) created this web-based expert system. Data for management and precise identification of pathogenic organisms and abiotic damage to jute and other fiber crops can be obtained from it.
AGPEST	Wheat, Rice	The primary objective of this expert system is to identify diseases brought on by rice pests and wheat plants, respectively. Additionally, it supports the decision support module by offering a collaborative console-based user interface (UI) for analysis conducted in conjunction with inquiries regarding a particular medical symptom.
Rice-Crop Doctor	Rice	In order to identify illnesses and rice pests and subsequently suggest a remedy, the National Institute for Agricultural Extension Management (MANAGE) created this expert system program.

CHALLENGES TO ADOPT AI IN AGRICULTURE

Agriculture has a lot to gain from artificial intelligence, but little is known about sophisticated, high-tech machine learning solutions for farming. External factors including weather, pest outbreak vulnerability, and soil conditions have a big impact on farming. Due to the influence of other factors, the intended crop-raising timetable at the beginning of the season could not seem beneficial when harvesting starts.

To train the robots and produce precise predictions, the AI system demands a lot of data. When there is a lot of area available for farming, acquiring geographical data is easy; but, gathering temporal data is more challenging. Making knowledge-based rules and ordering them adequately for a lot of parameters is also complex. Many crop-specific data are available during the annual crop-growing season. It requires a lot of work to develop a robust artificial intelligence ML model since databases take time to mature. This is the main justification for using AI in agricultural products including seeds, fertilizer, and pesticides.

The high price of many commonly available cognitive solutions for agriculture is another major obstacle. To have an effect on the agricultural community, AI-inspired solutions need to be more feasible. Farmers will use AI cognitive solutions sooner and gain greater insight if they are more affordable and easily accessed through an open-source platform.

CONCLUSION

The use of artificial intelligence in real-time data monitoring has shown interest. This was implemented for regulating yield, weeds, pests, and crops. To decide which crops have been set up for harvesting and marketing, the machines exchange information with one another. Farmers may benefit from healthier crops and enhanced field management thanks to the effective approaches. The AI can assist users in developing resilience by delivering timely information through the right channels.

This study looks at how artificial intelligence has been used in agriculture since 1983. The goal of the study is to give as much information as possible regarding the different AI methods that are applied in agriculture. Rule-based expert systems were popular from the 1980s to the 1990s, but fuzzy inference systems and artificial neural networks began to replace them around 1990. Artificial neural networks and hybrid systems, including image processing or neuro-fuzzy, have been deployed in recent years.

By using AI to make better judgments in the field, farmers will be able to reach their aim of a healthier harvest. Since food is the most essential human need, data may be utilized more creatively to forecast risk and analyze possibilities, allowing for action to be taken before hunger becomes a humanitarian issue that could aid in the world's overall development.

REFERENCES

Andersen, M. A., Alston, J. M., Pardey, P. G., & Smith, A. (2018). A century of U.S. productivity growth: A surge then a slowdown. American Journal of Agricultural Economics, 93, 1257-1277.

Arif, C., Mizoguchi, M., &Setiawan, B. I. (2013). Estimation of soil moisture in paddy field using artificial neural networks. arXiv preprint arXiv:1303.1868.

Artificial Intelligence in Agriculture Market Size, Share & Trends Analysis Report. (2019). By Component (Software, Hardware), By Technology, By Application (Precision Farming, Drone Analytics), By Region, and Segment Forecasts.

Baker, D. N., Lambert, J. R., &McKinion, J. M. (1983). GOSSYM: A simulator of cotton crop growth and yield (Technical bulletin). Agricultural Experiment Station, South Carolina, USA.

Banerjee, G., Sarkar, U., & Ghosh, I. (2017). A radial basis function network based classifier for tea pest detection. International Journal of Advanced Research in Computer Science and Engineering, 7(5), 665-669.

Boulanger, J. (1983). The expert system PLANT/CD: A case study in applying the general purpose inference system ADVISE to predicting black cutworm damage in corn (Ph.D. thesis). University of Illinois at Urbana-Champaign

Boyd, D. W., & Sun, M. K. (1994). Prototyping an expert system for diagnosis of potato diseases. Computers and Electronics in Agriculture, 10(3), 259-267.

Burks, T. F., et al. (2005). Evaluation of neural-network classifiers for weed species discrimination. Biosystems Engineering, 91(3), 293-304.

Dutta, S., Rakshit, S., & Chatterjee, D. (2020). Use of artificial intelligence in Indian agriculture. 1, 65-72.

Francl, L. J., &Panigrahi, S. (1997). Artificial neural network models of wheat leaf wetness. Agricultural and Forest Meteorology, 88(1), 57-65.

Ghosh, I., &Samanta, R. K. (2003). TEAPEST: An expert system for insect pest management in tea. Applied Engineering in Agriculture, 19(5), 619.

Hatfield, J., Takle, G., Grotjahn, R., Holden, P., Izaurralde, R. C., Mader, T., Marshall, E., Liverman, D., Melillo, J. M., Richmond, T., &Yohe, G. W. (Eds.). (2014). Chapter 6: Agriculture. In Climate change in the United States: The Third National Climate Assessment (pp. 50-174). U.S. Global Change Research Program.

Huang, K. Y. (2007). Application of artificial neural network for detecting Phalaenopsis seedling diseases using color and texture features. Computers and Electronics in Agriculture, 57(1), 3-11.

Jung, J., Maeda, M., Chang, A., Bhandari, M., Ashapure, A., Landivar-Bowles, J. (2021). The potential of remote sensing and artificial intelligence as tools to improve the resilience of agriculture production systems. Current Opinion in Biotechnology, 70, 15-22.

Lemmon, H. (1990). Comax: An expert system for cotton crop management. Computer Science in Economics and Management, 3(2), 177-185.

Li, S. K., Suo, X. M., Bai, Z. Y., Qi, Z. L., Liu, X. H., Gao, S. J., & Zhao, S. N. (2002). The machine recognition for population feature of wheat images based on BP neural network. Agricultural Sciences in China, 1(8), 885-889.

Liu, G., Yang, X., & Li, M. (2005). An artificial neural network model for crop yield responding to soil parameters. In Proceedings of the International Symposium on Neural Networks (pp. xx-xx). Springer, Berlin, Heidelberg.

Manek Comparative study of neural network architectures for rainfall prediction. In Proceedings of the Technological Innovations, A. H., & Singh, P. K. (2016). in ICT for Agriculture and Rural Development (TIAR) (pp. 171-174). IEEE.

Martiniello, P. (1988). Development of a database computer management system for retrieval on varietal field evaluation and plant breeding information in agriculture. Computers and Electronics in Agriculture, 2(3), 183-192.

McKinion, J. M., & Lemmon, H. E. (1985). Expert systems for agriculture. Computers and Electronics in Agriculture, 1(1), 31-40.

Outlaw, J. L., Fischer, B. L., Anderson, D. P., Klose, S. L., Ribera, L. A., Raulston, J. M., Knapek, G. M., Herbst, B. K., Benavidez, J. R., Bryant, H. L., &Ernstes, D. P. (2020). COVID-19 impact on Texas production agriculture. Agricultural & Food Policy Center, Texas A&M University Research.

Pasqual, G. (1994). Development of an expert system for the identification and control of weeds in wheat, triticale, barley, and oat crops. Computers and Electronics in Agriculture, 10(2), 117-134.

Pasqual, G. M., & Mansfield, J. (1988). Development of a prototype expert system for identification and control of insect pests. Computers and Electronics in Agriculture, 2(4), 263-276.

Prakash, C., Rathor, A. S., & Thakur, G. S. M. (2013). Fuzzy-based agriculture expert system for soyabean. In Proceedings of the International Conference on Computing Sciences WILKES100-ICCS2013 (pp. xx-xx). Jalandhar, Punjab, India.

Rich, E., & Knight, K. (1991). Artificial intelligence. McGraw-Hill.

Roach, J., Virkar, R., Drake, C., & Weaver, M. (1987). An expert system for helping apple growers. Computers and Electronics in Agriculture, 2(2), 97-108..

Robinson, C., & Mort, N. (1997). A neural network system for the protection of citrus crops from frost damage. Computers and Electronics in Agriculture, 16(3), 177-187.

Saini, H. S., Kamal, R., & Sharma, A. N. (2002). Web-based fuzzy expert system for integrated pest management in soybean. International Journal of Information Technology, 8(1), 55-74.

Samanta, R. K., & Ghosh, I. (2012). Tea insect pests classification based on artificial neural networks.

Stone, N. D., &Toman, T. W. (1989). A dynamically linked expert-database system for decision support in Texas cotton production. Computers and Electronics in Agriculture, 4(2), 139-148.

Thorpe, K. W., Ridgway, R. L., & Webb, R. E. (1992). A computerized data management and decision support system for gypsy moth management in suburban parks. Computers and Electronics in Agriculture, 6(4), 333-345.

International Journal of Computer Engineering Science (IJCES), 2(6), 1-13.

Sicat, R. S., Carranza, E. J. M., &Nidumolu, U. B. (2005). Fuzzy modeling of farmers' knowledge for land suitability classification. Agricultural Systems, 83(1), 49-75.

Siraj, F., &Arbaiy, N. (2006). Integrated pest management system using fuzzy expert system. In Proceedings of KMICE-2006, University of Malaysia, Sintok, June 2006.