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A Comprehensive Overview of the Implementation of Artificial Intelligence in Agriculture

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***Abstract*:** Currently, the primary focus of every country worldwide is to enhance the efficiency of daily human life by embracing smart technology. Achieving a smart country status involves leveraging the internet, which enables various forms of smart work, predominantly through automation. Automation can be accomplished using Wireless Communication, Internet of Things (IoT), Artificial Intelligence (AI), and Machine Learning (a subset of AI). Artificial Intelligence's role is constantly growing in human life and exerting a significant influence on society. In the context of Indian farming, Artificial Intelligence is progressively making its way and playing a vital role.

In recent times, numerous countries have adopted machine learning and Artificial Intelligence in agriculture to predict and forecast crop yields, grade food, implement automated irrigation systems, and enhance the quality and quantity of crop production. This paper presents a comprehensive review of prior research conducted by various scholars, aiming to provide an overview of the applications and significance of Artificial Intelligence in agriculture, paving the way for automated and smart agricultural systems.

Keywords: *Agriculture, Artificial Intelligence (AI), Automated, Internet of Things (IoT), Irrigation, Machine learning, Wireless-Communication.*

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1.1 Introduction

When discussing Artificial Intelligence, the initial question that arises is, "What is Artificial Intelligence?" Artificial Intelligence is a discipline within computer science and engineering that focuses on developing real and simulated systems that exhibit behavior similar to the human mind. These systems are designed to perform tasks akin to human thought processes, utilizing logical and mathematical reasoning [1]. Over the past few years, Artificial Intelligence has found numerous applications across various domains, including weather forecasting, space research, healthcare industries, robotics, and agricultural automation, to name a few.

Agriculture, which engages more than half of the world's population, has also witnessed significant integration of Artificial Intelligence in various aspects. These include farm planning, yield production prediction, assessing the sales and market value of agricultural products, weather forecasting, pest recognition, automated irrigation systems, and ensuring food quality with enhanced production efficiency [2].

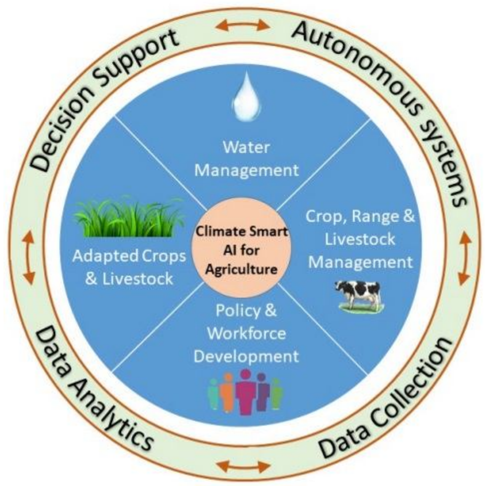

Fig.1: Areas of Agriculture for Artificial Intelligence Research and Development[3]

With the help of Artificial Intelligence, the Artificial Intelligence has proven to be a game-changer for farmers, significantly increasing their yield production compared to traditional farming methods. In the traditional-farming system, farmers handle every task manually, starting from seeding to crop cultivation, and the yield is heavily reliant on various atmospheric factors. However, with the incorporation of Artificial Intelligence, farming has taken a new direction, utilizing AI-based machines and equipment to revolutionize the agricultural field. This innovation has brought about real-time monitoring of crops and significantly improved production efficiency [4].

Artificial Intelligence in agriculture is categorized into three main areas [1]:

- **I.** ***Precision Farming:*** AI-driven precision farming techniques allow farmers to optimize resource utilization, such as water, fertilizers, and pesticides, resulting in enhanced crop productivity.
- **II.** ***Agricultural Robotics:*** AI-powered agricultural robots are designed to perform tasks like planting, weeding, and harvesting, reducing labor costs and increasing overall efficiency.

III. ***Crop Monitoring and Analysis:*** AI systems enable real-time monitoring of crop health, disease detection, and yield forecasting, assisting farmers in making informed decisions for better outcomes.

As the agricultural industry continues to embrace Artificial Intelligence, it holds great promise for further advancements and sustainable growth in agriculture.

The Artificial Intelligence is categorized in three ways as[1]-

- AGI
- ANI
- ASI

Artificial General Intelligence (AGI) represents a form of intelligent computer systems that can perform tasks just like the human mind. It possesses the ability to learn and adapt, mirroring the capabilities of a human brain. On the other hand, Artificial Narrow Intelligence (ANI) is a more common and prevalent form of AI that is specialized in performing specific tasks. For example, Google Maps utilizes ANI to find the most suitable routes to various locations.

Beyond AGI and ANI, there exists a more advanced form known as Artificial Super Intelligence (ASI). ASI-based systems surpass the capabilities of other AI techniques and even human beings. They exhibit exceptionally high accuracy rates and efficiency in performing tasks. ASI is characterized by its superior wisdom, creativity, and efficiency, making it a transformative technology with far-reaching implications. However, it's essential to approach the development and deployment of ASI with careful consideration and ethical oversight due to its potential impact on society and the world at large.

Apart from the numerous applications of Artificial Intelligence, this technology also faces several challenges [3]:

- **Ethical Concerns:** As AI becomes more advanced and autonomous, there are ethical questions surrounding its use, such as privacy concerns, biases in algorithms, and potential societal impacts. Ensuring that AI systems are developed and used ethically is crucial to avoid harmful consequences.
- **Safety and Security:** As AI systems become more powerful, ensuring their safety and security is vital. Flaws or vulnerabilities in AI algorithms could lead to serious consequences, especially in critical applications like healthcare or autonomous vehicles.
- **Lack of Transparency:** Some AI algorithms, particularly in deep learning, can be highly complex and difficult to interpret. This lack of transparency raises concerns about the decision-making process of AI systems and the ability to understand and trust their outputs.
- **Data Bias:** AI systems heavily rely on training data, and if the data is biased or incomplete, it can lead to biased decisions and perpetuate unfair or discriminatory practices.
- **Unemployment and Job Displacement:** The automation capabilities of AI raise concerns about job displacement in various industries, potentially leading to economic challenges and social implications.
- **Regulatory Frameworks:** The rapid advancement of AI technology has outpaced the development of adequate regulatory frameworks, leading to uncertainties about legal responsibilities and liabilities.
- **Technical Limitations:** AI systems may struggle with handling complex real-world situations and lack common sense reasoning, which limits their ability to generalize effectively beyond their training data.
- **Energy Consumption:** Some AI models, especially large-scale deep learning models, require significant computing power and energy, raising environmental concerns.

- **Interdisciplinary Collaboration:** AI development often requires collaboration between various disciplines like computer science, engineering, neuroscience, and ethics. Establishing effective communication and cooperation among experts in these fields can be challenging.

Addressing these challenges will be crucial to unlock the full potential of Artificial Intelligence while ensuring its responsible and sustainable integration into various aspects of human life.

1.2 Literature Survey

Lal Mohan Bhar et al., (2019)[1] focused on the era of Artificial Intelligence in various aspects. In this study, the authors emphasized the diverse applications of Artificial Intelligence across various domains. Particularly, they highlighted the significant impact of Artificial Intelligence in agriculture, making tasks more streamlined and efficient. The integration of Machine Learning has revolutionized the traditional farming system, leading to the emergence of smart farming practices. The primary applications of Artificial Intelligence in agriculture include crop yield prediction, weather forecasting, pest recognition and detection, and the implementation of automated irrigation systems. Through these AI-driven advancements, agriculture is experiencing a transformative shift towards increased productivity and sustainability.

Deepak Sinwar et al., (2020)[2] presented the use of different techniques and applications of Artificial Intelligence in smart-irrigation system and yield prediction. For farmers, the entire farming system relies on irrigation, making it crucial for them to have timely predictions of water requirements for their crops. The authors of this study also emphasized that an Artificial Intelligence-based system provides ample information about crop yields at an early stage.

Hatim Geli et al., (2019)[3] presented a research on Climate Adaptive Smart Systems for Future Agricultural and Rangeland Production. In this study, the authors shared insights into the advancements in agriculture that enable it to become smart, cost-effective, and highly efficient in yield production through the implementation of an Artificial Intelligence-based system. In addition to discussing its applications, the authors also brought attention to the challenges arising in various aspects concerning this automated system driven by Artificial Intelligence.

Tanha Talaviya et al., (2020)[4] audited the different application of Artificial-Intelligence such as seeding-weeding, irrigation, spraying for pesticides with the use of various sensors embedded in drones and robots in agriculture domain. This technology aids in water conservation by preventing overflow, facilitates pest control, preserves soil fertility, and enhances crop quality and productivity through the efficient utilization of manpower. The authors conducted a comprehensive review of previous research by numerous scholars to gather relevant data on the latest applications of automation in agricultural fields using drones. Additionally, they delved into the implementation of drones in agriculture and various approaches to crop monitoring, including spraying techniques and soil-water sensing methods.

Kirtan Jha et al., (2018)[5] discussed about the enrollment of Artificial Intelligence system in agriculture domain with the help of past breakthroughs. In their research, the authors placed particular emphasis on the water scarcity issue confronted by farmers when irrigating their agricultural fields, prompting a shift from traditional irrigation to the adoption of smart irrigation systems. The implementation of smart irrigation systems results in the efficient utilization of water resources. By incorporating Artificial Intelligence techniques, a fully automated smart irrigation system can offer even more advantages to the automation of agriculture, ultimately leading to higher yield production.

Sai Sree Laya Chukkapalli et al., (2020)[6] developed a connected-cooperative-ecosystem describes sensor's communication between various parameters with a cloud-supported hub. The authors set up a farm and utilized various sensors to gather data, which was subsequently stored in the cloud. This data serves as the foundation for creating an Artificial Intelligence-backed system designed to assist farmers and cooperatives. The study also highlighted the diverse applications of Artificial Intelligence that can be implemented at the cooperative level to enhance the farming system and its overall efficiency.

Kirtan Jha et al., (2019)[7] highlighted the problems facing by the farmers in agriculture like as control of pesticides, irrigation-water management, crop-diseases etc and discussed about the solution of these problems. The challenges faced in agriculture can be alleviated through the adoption of various automation techniques, including Internet of Things (IoT), Wireless Communications, Machine Learning, Deep Learning, and Artificial Intelligence. The automation of the farming system has brought about significant improvements in farming practices and has transformed traditional farming methods. In their study, the authors put forward a prototype system based on the Internet of Things and implemented it in a botanical farm for automated irrigation and identification of flowers and leaves.

B.Ragavi et al., (2020)[8] presented a work on Smart Agriculture with Artificial Intelligence Sensor by Using Agrobot. The authors developed an agrobot equipped with an ARM-Processor and a cloud-based Internet of Things system, which possesses the capability to sow seeds and observe agricultural land. To ensure sustainable power supply for the ARM-Processor, the authors suggested the implementation of solar technology. Additionally, they incorporated an Artificial Intelligence and Internet of Things-based monitoring system for the crop-field. This system alerts farmers about potential errors by sending timely messages to their mobile devices, allowing them to take appropriate actions and enhance overall crop management.

N.N. Misra et al., (2020)[9] gives an overview of role of Artificial Intelligence, Big-Data and Internet of Things in making the future of agriculture system. The authors concentrated on the implementation of these emerging technologies in agriculture, encompassing areas such as greenhouse monitoring, intelligent farming machinery, drone-based image capturing, and various other domains. Furthermore, they emphasized the commercial status and research outcomes resulting from these applications.

Marco Barenkamp et al., (2020)[10] presented the span of Artificial Intelligence system in agricultural area which covers the entire farming system and operates through an independent Artificial Intelligence modules. The modules are interconnected via a cloud-based network. As per the author, this integration forms a network involving commercial users and IT industrial experts, fostering optimism for advancements in the agricultural sector.

Dmitrii Shadrin et al., (2020)[11] presented a system which is embedded with Artificial Intelligence techniques and used for the monitoring at regular analysis and dynamic growth prediction of the plant's leaves. This sensing system incorporates a Graphics-Processing-Unit (GPU) that can effectively run an on-board Neural-Network based Artificial Intelligence. The authors also shared a Tomato-growth farming dataset with another research community.

Additionally, they emphasized the utilization of Recurrent-Neural-Network (RNN) specifically known as Long-Short-Term-Memory (LSTM) network in monitoring crop-yield.

Thiago Alberto Cabral da Cruz et al., (2016)[12] presented the explanation of development of a efficient irrigation system which can be used by the farmer to maintain the soil-water content in the field with the use of a network enabled by Wi-Fi sensors and controllers at low cost.

Savita Choudhary et al., (2019)[13] presented a work on Autonomous Crop Irrigation System using Artificial Intelligence. This autonomous system efficiently irrigates the farmland by utilizing soil-moisture data. As stated by the authors, the system is equipped with prediction algorithms that rely on historical weather data to identify rainfall patterns in accordance with climate change. This intelligent system ensures irrigation is carried out only when necessary, relying on real-time monitoring data.

Ching-Ju Chen et al., (2020)[14] focused in this work on the combined technologies of Artificial Intelligence and recognition of images with Internet of Things for identification of pest in the crop. The fusion of AIoT (Artificial Intelligence of Things) with deep learning has revolutionized the farming and agriculture sector. This system effectively alerts farmers about the presence of different types of pests before their populations escalate. By employing AIoT, the economic value of agricultural fields is enhanced, and the excessive use of pesticides, which causes environmental damage, is significantly reduced.

1.3 Artificial Intelligence's Scope in Agricultural Field

Currently, it is observed that many farmers in various regions of India continue to rely on traditional farming methods in agriculture. However, traditional farming is unable to meet the growing food demand. To address this increasing demand, it becomes essential for farmers to embrace advanced, automated, and up-to-date farming systems that incorporate tools and machinery based on Internet of Things, Artificial Intelligence, and Machine Learning. Unfortunately, in many areas, farmers lack awareness about efficient water usage for irrigation and the appropriate application of pesticides, leading to a decline in crop production and soil fertility. Numerous studies have shown that farmers can enhance their yield and profitability by adopting an Artificial Intelligence-based automated system and other smart technologies for various agricultural tasks.

This work discusses the diverse applications of Artificial Intelligence in the field of agriculture.

1.3.1 Prediction of Crop Disease and Health-Monitoring

Conventional methods of crop monitoring in large farming lands, such as acres, often consume a significant amount of time and may not be sufficient for proper monitoring. To address this challenge, researchers have developed a smart agriculture monitoring system incorporating cutting-edge technologies like Artificial Intelligence and Internet of Things. These advanced systems effectively reduce the crop monitoring time for farmers while providing improved outputs.

The Artificial Intelligence-based crop-disease monitoring system utilizes high-definition cameras attached to Drones or Unmanned Aerial Vehicles to capture numerous images of plants and leaves. These images are then stored as a dataset and transferred to an Artificial Neural

Network (ANN) based deep-learning programming board for analysis. Through the ANN technique, the system extracts essential information from the images to identify and predict any diseases affecting the plants and leaves. Consequently, this system aids in regular monitoring of crop health, offering valuable insights into the required amount of pesticides and the optimal timing for their application [11].

1.3.2 Prediction of Crop Yield

Predicting crop yield can be a challenging task for farmers, as it often requires the use of specialized mapping devices. However, this area has become an interesting focus for researchers, leading to the development of a solution for yield prediction using Convolution Neural Networks (CNN). The CNN method offers a simple and cost-effective approach, making it suitable for farmers.

Through previous research in this field, it has been established that Artificial Intelligence-based systems employing the CNN method offer significant advantages over Machine Learning methods. A flow chart depicting the crop-yield prediction process based on Artificial Neural Networks and smart phones is illustrated in Figure 2. This approach holds promise in assisting farmers with accurate and efficient yield predictions.

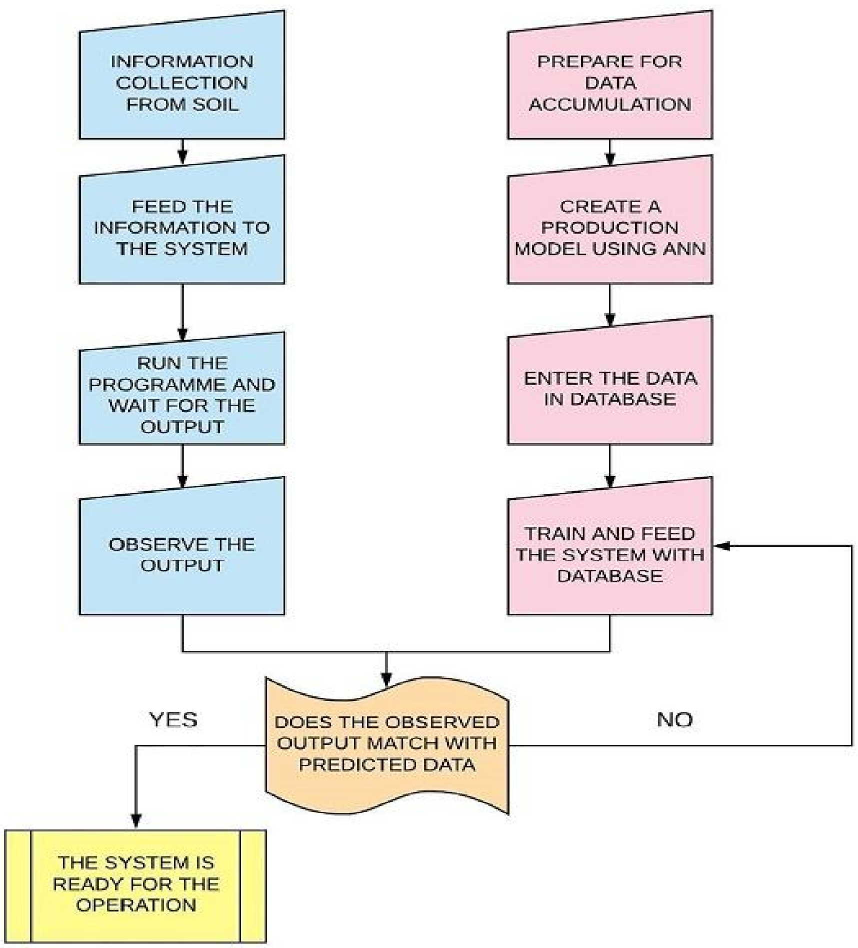

Fig.2: Artificial Neural Network and Smart-Phone based flow chart of Crop-Yield prediction[7]

To achieve better results in prediction and enhance agricultural practices, farmers can follows a time-line and maintain a record based on the following points [2]:

- Determine the required amount of pesticides and the appropriate time for spraying to effectively combat pests and diseases.
- Regularly check the soil fertility and improve it using a combination of organic and inorganic fertilizers, bio-fertilizers, and compost to ensure healthy crop growth.
- Monitor the growth rate of crops closely to identify any abnormalities or potential issues that may arise.
- Apply the right amount of water for irrigation at suitable times and frequencies to maintain optimal moisture levels for the crops.
- Make seasonal estimations of the yield based on the type of crop being cultivated, helping to plan for the harvest and post-harvest activities.
- Identify and address the presence of weeds growing with the main crop by implementing suitable weed control methods that do not harm the primary crop.

By adhering to this comprehensive approach and maintaining detailed records, farmers can significantly improve their agricultural outcomes, enhance crop yield predictions, and effectively manage their farming operations.

The prediction of crop yield incorporates various techniques, as listed below:

- ***Yield prediction based on remote-sensing:*** This technique involves several steps, including data capturing, data interpretation, production of information, and decision making to predict crop yield using remote sensing data.
- ***Yield prediction based on Machine Learning:*** Machine Learning algorithms are utilized to analyze historical data related to crop growth, weather conditions, soil quality, and other relevant factors to make predictions about future crop yields.
- ***Yield prediction based on Big Data:*** Big Data analytics is employed to process and analyze vast amounts of data from various sources, such as weather databases, satellite imagery, and agricultural sensors, to make accurate crop yield predictions.

Each of these techniques offers valuable insights and can contribute to more informed decision-making for farmers and stakeholders in the agricultural domain.

1.3.3 Automated Smart-Irrigation

Given the prevailing water shortage in various countries, the development of a low-consumption and cost-efficient automated irrigation system, known as a smart irrigation system, is of utmost importance. Currently, farmers utilize drip irrigation and sprinkler irrigation systems, which employ low-water consumption techniques. However, these systems often require significant human intervention.

To address this limitation and achieve a fully automated smart irrigation system, researchers are actively working on incorporating additional features into the existing irrigation systems. By integrating Artificial Neural Network (ANN) technology, they aim to enhance the capabilities of drip and sprinkler irrigation systems. The use of AI technology allows for more efficient and precise water management, reducing the need for human intervention.

A representation of an automated smart irrigation system based on AI technology is illustrated in Figure 3, signifying the potential advancements in irrigation practices to ensure sustainable water usage in agriculture.

Fig.3: An automated smart irrigation system based on AI technology

The smart irrigation system is fully automated and continuously monitors the crop's water needs based on the soil content and crop requirements. The system combines Artificial Intelligence and IoT through an ANN-based setup. Using a low-cost Arduino board with various sensors, it collects and stores crop data for analysis. These sensors, including temperature, soil moisture, and humidity sensors, gather information from the agricultural field. The collected data is then compared and analyzed against standard data already stored in the system. When discrepancies are detected between real-time and standard data, the system automatically activates or deactivates the motor-pump set, enabling irrigation with drip or sprinkler methods as needed.

1.3.4 Forecasting of Weather

Artificial Intelligence plays a significant role in Agriculture, particularly in weather forecasting, which is among its most valuable applications. By leveraging advanced AI technology, farmers can make informed decisions about crop planning. Nowadays, numerous devices utilize the Long-Short Term Memory (LSTM) technique of AI for predicting weather conditions[11]. These devices, specializing in soil and weather prediction, offer valuable insights to farmers, helping them effectively plan their crop activities and select the appropriate crop types.

1.3.5 Identification of Crop-Readiness

Through the application of Artificial Intelligence, farmers can ensure timely harvesting of crops. The AI-based system gathers crop images from various sections of the fields and analyzes them to determine the crop's readiness in specific areas. Using GSM technology, the system sends a message to the farmer's mobile phone, providing information about the crop's readiness status. Based on market demand, crop readiness, and other quality specifications, the crops are classified into different patterns using cluster technologies such as Fuzzy C-Means (FCM), K-Means, hierarchical clustering, and Expectation-Maximization (EM)[5]. This enables farmers to make informed decisions and take appropriate actions in response to the crop's condition and market demands.

1.3.6 Management of Pest/Weed in crop

Currently, farmers employ a combination of traditional methods and various techniques such as herbicides, Crop-Rotation, and Mechanically weed control technique for managing weeds [15]. Although the market offers several biochemical-based solutions for pest and weed control, their major drawback is the reduction in crop productivity [16]. This reduction in yield often occurs due to farmers' insufficient knowledge about the appropriate amount of pesticides and spraying frequencies in their fields. However, this problem can be addressed with the implementation of

Artificial Intelligence. A group of researchers led by Wyatt McAllister introduced an AI-based robot called "Agbots" designed specifically for weed management in agriculture [15]. The Agbots function autonomously, utilizing a camera to examine images and identify weeds, and subsequently taking appropriate actions to combat them.

Based on previous research conducted by several researchers, a tabulated overview is presented below[7], outlining the utilization of Artificial Intelligence, IoT, and other embedded systems integrated with smart technology for monitoring, controlling, and managing pests, weeds, and the growth of various food and fruit crops.

Sr. No.	Name of Food/Fruit Crops	Technology Used	Description & Results	Place	Reference
1.	Seasonal Crop	Rule-based system	Author designed the system for pest detection and their control in general-seasonal crop and found satisfactory output.	Australia	G.M. Pasqual et al., (1988) [17]
2.	Hops Plant	Rule-based system	Researcher developed this system to identify the diseases as weevil, hop-aphid & downy mildew in Hops plant. This system helps in the collection of data such as growth of disease and calculation of side-effects of disease. The system also provided the information about suitable treatment for the particular disease in Hope-plant.	Czechia (Country in Europe)	Martin Mozny et al., (1993) [18]
3.	Lentils Plants	Machines-vision based observation	Author used a scanner with Intel-Pentium processor as hardware and applied the various Neural Network based techniques for different color of lentil plants. As a result author founds almost 90% accuracy in plants grading.	Canada	M.A. Shahin et al., (2001) [19]
4.	Tea Plants	Rule-based Object Oriented expert system	Researcher setup an object oriented system in the tea plants field for two years to monitors the pests in field. Authors studied almost 65 cases collected by the system from real-field and analyzed the various parameters. At the end results found satisfactory for controlling the pests in the field.	India	I. Ghosh et al., (2003) [20]
5.	Mangos & Cassava-plants	ANN technique	Authors developed three neurons in hidden layers Neural Network system based on ANN technique and used for the identification of dryness in fruits of their model.	Mexico & France	J.A. Hernandez-Perez et al.,(2004) [21]

6.	Various seasonal Fruits	Fuzzy-Logic based system	Authors used MATLAB for their research work. They used vector-machine support in MATLAB for shorting of various fruits and Fuzzy-Logic system for grading of fruits. All the results related to shorting & grading of different fruits based on image captured by camera found 99% satisfactory in this work.	Malaysia	Nur Badariah Ahmad Mustafa et al., (2009) [22]
7.	Jute Plants	ANN technique based common structure	Researchers used maximum 9 and minimum 5 neurons in hidden layers of Artificial Neural Network technique for the prediction of regular growth of Jute plants. They used back-propagation in their work for training the system and concluded that the predicted results were almost similar as observed results for various parts of Jute plants.	Bangladesh	M.M. Rahman et al., (2010) [23]
8.	Rice-Grain plants	Pattern shorting based on a back-propagation Neural Network technique	In this work authors designed a system with the use of Neural Network in which 9 structural and 6 color based features through images were taken to develop an algorithm for identification of the variety of rice seeds. The accuracy of shorting data-sets was from 74% to 90%.	India	Sanjivani Shantaiya et al., (2012) [24]
9.	Wheat-Grain plants	Image-Processing technique	In this work researchers classified the category of Wheat-Grain plants on the basis of machine algorithms. Two algorithms were support-vector-machine and Neural-Network. As a results authors found the Neural-Network based algorithm was more accurate over support-vector-machine based algorithm and manual algorithms.	India	Meesha Punn et al., (2013)[25]
10.	Tea Plants	Radial based functions Neural-Network	Authors used the radial based functions network technique for identification of pests in tea plants for their research work. In the Neural-Network there were 31 hidden layers used for identification of active pests. As a result, researchers observed 99 percent accuracy of identification with 1 percent error of testing.	India	Gouravmoy Banerjee et al.,(2017) [26]

1.4 Conclusion

The implementation of a smart automated agriculture-monitoring system is essential to reduce human intervention effectively. As the demand for food continues to rise, traditional agricultural methods alone cannot meet the growing requirements. This work explores the diverse applications of smart agriculture monitoring systems based on Artificial Intelligence (AI) techniques.

By leveraging AI, smart agriculture systems can minimize labor efforts, save time, and significantly contribute to yield monitoring, resulting in increased crop production both in terms of quantity and quality. AI implementation in the agricultural domain aids farmers in making informed decisions such as crop selection, optimal harvesting times, and appropriate fertilizer usage based on weather conditions. The integration of AI with deep-learning methods has revolutionized the agricultural industry and opened up various industrial applications, surpassing the benefits of machine learning methods.

Ultimately, an AI-based smart automated agriculture-monitoring system plays a crucial role in boosting the overall economic growth of a country as food remains a fundamental source of sustenance for human life.

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