THE FUTURE OF AGRICULTURE:

IOT, AI AND BLOCKCHAIN TECHNOLOGY FOR SUSTAINABLE FARMING

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The Future of Agriculture: IoT, AI and Blockchain Technology for Sustainable Farming

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FOREWORD

In the ever-evolving landscape of agriculture, where the intersection of technology and sustainability has become the driving force of change, "The Future of Agriculture: IoT, AI, and Blockchain Technology for Sustainable Farming" emerges as a beacon of insight and innovation. This book serves as a guiding light as we enter a new era in agriculture, characterized by the urgent need to feed a growing global population while mitigating the environmental impact of food production. Within the pages of this comprehensive volume, readers will embark on a transformative journey through ten meticulously crafted chapters that explore the dynamic synergy between cutting-edge technologies and the timeless art of farming.

The authors of each chapter are experts in their respective fields, and their insight shows the dedication and passion they bring to the task of securing our agricultural future. Their collective vision, presented here, outlines a world where technology and tradition work hand in hand and where sustainability is not just a goal but a way of life.

Each chapter of this book delves into a distinct facet of this remarkable transformation. From the foundations of IoT (Internet of Things) that have revolutionized the way we monitor and manage crops to the incredible potential of AI (Artificial Intelligence) to optimize farming practices and enhance yields, every aspect of modern agriculture is examined very closely and carefully. The inclusion of blockchain technology, a breakthrough in secure and transparent data management, adds a layer of trust and traceability to the agricultural supply chain. In a world where the effects of climate change are felt more acutely each day, the urgency of embracing sustainable farming practices cannot be overstated. This book serves as a call to farmers, policymakers, researchers, and enthusiasts to unite in the mission to reshape agriculture for the betterment of humanity and the planet.

"The Future of Agriculture" is not merely a theoretical exploration; it is a practical roadmap for the farming revival we desperately need. Whether you are a seasoned farmer seeking to modernize your practices, an innovator searching for opportunities in agriculture, or simply a concerned citizen curious about the future of food, this book offers a wealth of knowledge and inspiration.

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PREFACE

In an era defined by rapid technological advancements and an urgent need for sustainable practices, the world of agriculture stands on the verge of transformation. "The Future of Agriculture: IoT, AI, and Blockchain Technology for Sustainable Farming" delves into the intersection of cutting-edge technologies and the age-old practice of farming, offering a comprehensive exploration of how IoT, AI, and blockchain are reshaping the agricultural landscape.

Farming has many challenges, like population growth, climate change, resource scarcity, and the imperative to feed a global population while preserving our planet's health. As we navigate these complex issues, technology emerges as a beacon of hope, providing tools that promise to revolutionize agriculture and enable us to cultivate the future sustainably.

This book embarks on a journey through the realms of the Internet of Things (IoT), Artificial Intelligence (AI), and Blockchain, illuminating their profound impacts on agriculture. There are a total of 10 chapters in this book. The chapters of this book not only present the theoretical underpinnings of IoT, AI, and blockchain, but they also provide practical insights into their application on the farm. From precision agriculture and data-driven decision-making enabled by IoT sensors to predictive analytics and crop management through AI algorithms, along with the secure traceability brought by blockchain, we explore the tangible ways in which these technologies are being integrated into the farming lifecycle.

The book shows how humans and technology work in harmonious collaboration. As the authors of this book, we stand at the threshold of an extraordinary era in agriculture. The integration of IoT, AI, and blockchain promises not just incremental improvements but a fundamental reimagining of how we nourish ourselves and our planet. We invite you to embark on this journey with us, to explore the exciting frontier where technology and agriculture converge, and to envision the future of farming—one where innovation and sustainability thrive hand in hand.

Welcome to "The Future of Agriculture: IoT, AI, and Blockchain Technology for Sustainable Farming".

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CHAPTER 1

Digital Twin for Sustainable Farming: Developing User-Friendly Interfaces for Informed Decision-Making and Increased Profitability

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Abstract: This chapter endeavors to develop a robust digital model for farm optimization with the primary objectives of enhancing resource utilization, minimizing waste, and increasing productivity while mitigating environmental impact. The proposed digital twin will leverage data from diverse sources, including sensors, weather data, soil moisture levels, and crop yields. Methodologically, the integration and processing of this varied data will be achieved through advanced algorithms, ensuring a comprehensive and accurate representation of the farm. The simulation aspect of the digital twin will explore different scenarios, allowing for a nuanced understanding of the impact of interventions on farm productivity and sustainability. Specific scenarios, such as testing the effects of varied irrigation strategies on crop yields or optimizing fertilizer inputs, will be explored. Methodological considerations will be discussed, addressing challenges related to data integration, format disparities, and accuracy variations across different data sources. Crucially, collaboration with farmers and stakeholders will be a cornerstone of this research. Their insights and real-world experiences will be actively incorporated throughout the development process, ensuring that the digital twin is tailored to the practical needs and challenges faced in agricultural operations. In tandem with this, the development of user-friendly interfaces will be emphasized, providing farmers and stakeholders with accessible tools for interacting with the digital twin. Specific functionalities, tailored to inform periodic decisions and processes, will be integrated into the interfaces, fostering usability and

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adoption. The chapter will examine the assessment of environmental impact. A detailed examination of the criteria and indicators used to measure and minimize the farm's environmental footprint will be discussed. By addressing these methodological considerations comprehensively, this research aims to not only optimize resource use and reduce waste but also contribute to the transformative advancement of sustainable and efficient farming practices.

Keywords: Agro-industry, Bio-diversity, Climate change, Digital twins, Environmental impact, Informed decision, Resource optimization, Smart forming, Soil regeneration, Sustainability.

INTRODUCTION

The 21st-century agricultural landscape grapples with formidable challenges, as the imperative to sustain a burgeoning global population coincides with the pressing need to mitigate environmental impact. Tackling these issues necessitates a transformative shift toward sustainable farming practices. A beacon of promise in this endeavor is digital twin technology, presenting an innovative avenue for optimizing resource utilization and curbing environmental repercussions in farming operations.

This chapter introduces a digital twin prototype tailored for sustainable farming, harnessing data from diverse sources, including sensors, to construct a comprehensive model of a farm. Encompassing critical metrics such as crop yields, soil moisture levels, and weather data, this model serves as a dynamic platform for simulating various scenarios and assessing the impact of interventions on both productivity and sustainability. The chapter delves into the development of user-friendly interfaces, empowering farmers to engage with the digital twin and make informed decisions regarding their operations in real time.

The interfaces provide instantaneous information on crucial factors like crop yields and soil moisture levels, enabling farmers to fine-tune resource allocation and minimize wastage. The potential advantages of this approach are substantial, as it not only bolsters profitability but also diminishes the environmental footprint of farming practices. Against the backdrop of challenges posed by climate change, depleting natural resources, and the imperative for heightened productivity, sustainable farming has emerged as a pivotal paradigm. Within this context, digital twins stand out as a transformative technological innovation, serving as virtual replicas that monitor, simulate, and analyze physical objects and processes in real time.

Moreover, how digital twins are harnessed in sustainable farming to create an integrated and intelligent ecosystem is explored. By facilitating precision agriculture, digital twins empower farmers to monitor crop health, growth, and nutrient requirements with unparalleled accuracy. The integration of data from sensors, satellites, and weather forecasts allows farmers to make data-driven decisions regarding irrigation, fertilization, and pest management. This targeted approach not only minimizes the use of water and chemicals but also augments crop yield and quality, signaling a promising trajectory for the future of agriculture.

Efficient resource management is integral to the fabric of sustainable farming, and digital twins emerge as a transformative tool in this endeavor. These virtual models empower farmers to intricately map out their agricultural landscape, encompassing vital elements such as soil composition, water sources, and machinery. Through a meticulous analysis of these digital replicas, farmers gain the ability to pinpoint inefficiencies, curtail wastage, and optimize the utilization of resources like water, energy, and fertilizers. The resultant effect is not only cost savings but also a tangible reduction in the environmental footprint.

The escalating challenges posed by climate change, characterized by more frequent extreme weather events impacting crop production, have intensified the urgency for adaptive agricultural strategies. Digital twins, with their predictive capabilities, furnish farmers with the means to simulate diverse climate scenarios. This simulation-driven approach enables the development of resilient farming strategies, helping farmers minimize losses and secure food production in the face of a changing climate.

Sustainable farming, extending its scope beyond crops to encompass livestock management, finds an ally in digital twins. These virtual representations of livestock operations allow farmers to track crucial parameters such as animal health, behavior, and productivity. This data-driven approach not only enhances animal welfare but also optimizes feed efficiency, contributing to a reduction in greenhouse gas emissions from livestock farming.

Digital twins serve as a catalyst for knowledge sharing and collaboration among the agricultural community. By fostering the exchange of data, best practices, and success stories, farmers can collectively elevate their understanding and contribute to the broader scale of sustainable agriculture. The convergence of sustainable farming and digital twin technology heralds an unprecedented opportunity to revolutionize agriculture, making it more efficient, productive, and environmentally friendly. Through the amalgamation of data-driven decision-making and real-time monitoring, sustainable farming with digital twins emerges as a promising avenue to address the contemporary challenges of agriculture, ensuring a more sustainable and prosperous future for generations to come.

CHAPTER 2

Agricultural Resource Management Using Technologies Like AI, IoT, and Blockchain

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Abstract: The future of farming and farmers in India is smart farming, which uses intelligence to integrate information technology and communication tools equipped with sensors and actuators for embedded farm management. This involves using emerging technologies like AI, IoT, and blockchain to employ robots, drones, and artificial intelligence in the agricultural sector, which is modifying traditional farming practices and simultaneously posing a variety of difficulties. The aim is to explore the various tools and equipment used. Pesticides are an essential material used in agricultural land to eliminate insects or other harmful organisms that affect crop yields. However, excessive use of pesticides can result in problems such as decreased soil fertility and an increase in insect species' immunity. To overcome these challenges, a land-specific variable-rate spraying and directional spraying method can be employed, which offers an accurate and flexible alternative strategy. Soil moisture is a crucial parameter in agriculture as it affects plant growth and survival. Various factors like air content, salinity, toxic substances, soil structure, temperature, and heat capacity of the ground can affect soil moisture. Agriculture resource management can be enhanced by designing various technologies like AI, IoT, and blockchain by using IoT sensors, drones and satellites, AI-powered cameras, weather stations, crop yield predictions, disease and pest detection, crop optimization, supply chain transparency, resource optimization, online communities, and data sharing networks. AI optimizes resource allocation and predicts outcomes. IoT provides real-time data for precision farming and livestock monitoring, while blockchain ensures transparency and security in supply chains and transactions, revolutionizing agricultural resource management. Agriculture resource management using technologies like AI, IoT, and blockchain comes with ample potential results like increasing efficiency in agricultural operations, enhancing productivity, improving crop and livestock health, and facilitating knowledge sharing and collaboration.

Keywords: Agriculture, Artificial intelligence, Blockchain, Crop monitoring, Crop yeild prediction, Decision support system, Farm automation, IoT (Internet of Things), Machine learning, Resource optimization, Smart farming.

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INTRODUCTION

Large-scale production of food grains is made possible through sustainable agriculture. Sustainable agriculture encourages farmers to adopt new approaches that help sustain their livelihood and resources. It reduces production costs and focuses on soil quality, thereby minimizing soil degradation. Sustainable agriculture also works on managing water resources and land biodiversity and making the environment more resilient. It is a significant contributor to preserving natural resources, restoring degraded areas, and decreasing the amount of greenhouse gas emissions in agriculture [1, 2]. In sustainable agriculture, farming is a process that preserves and nurtures nature while also considering the basic needs of future generations and improving farming techniques. Crop rotation, controlling nutrient deficiency, pest and disease control, recycling, and water harvesting are essential basics of smart farming that lead to a safer environment. Biodiversity affects living beings, and waste emissions, pesticides, and degraded dead plants have an adverse effect on the environment. The impact of greenhouse gas emissions on animal life, plants, human beings, and the environment emphasizes the need to create a more conducive atmosphere for all forms of life (Fig. **1**).

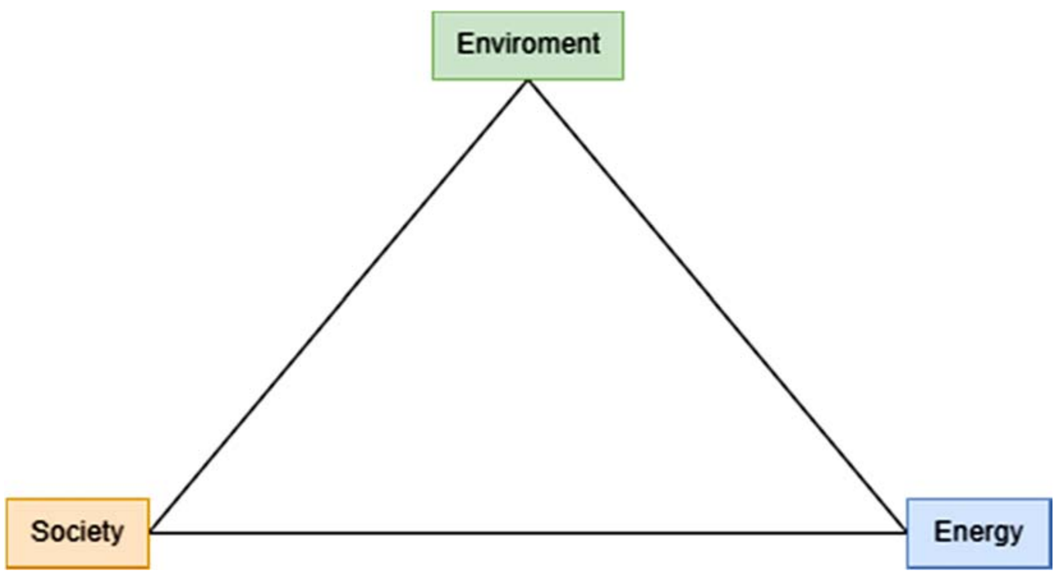

Fig. (1). Sustainable agriculture factors.

Due to soil quality, topography, water resources, climate, and temperature, all available surfaces on the Earth are not suitable for farming, and a homogenous surface is not available throughout [3]. The total availability of land consistently decreases due to rapid urbanization; thereby, total land utilization for food production also declines (Fig. **2**).

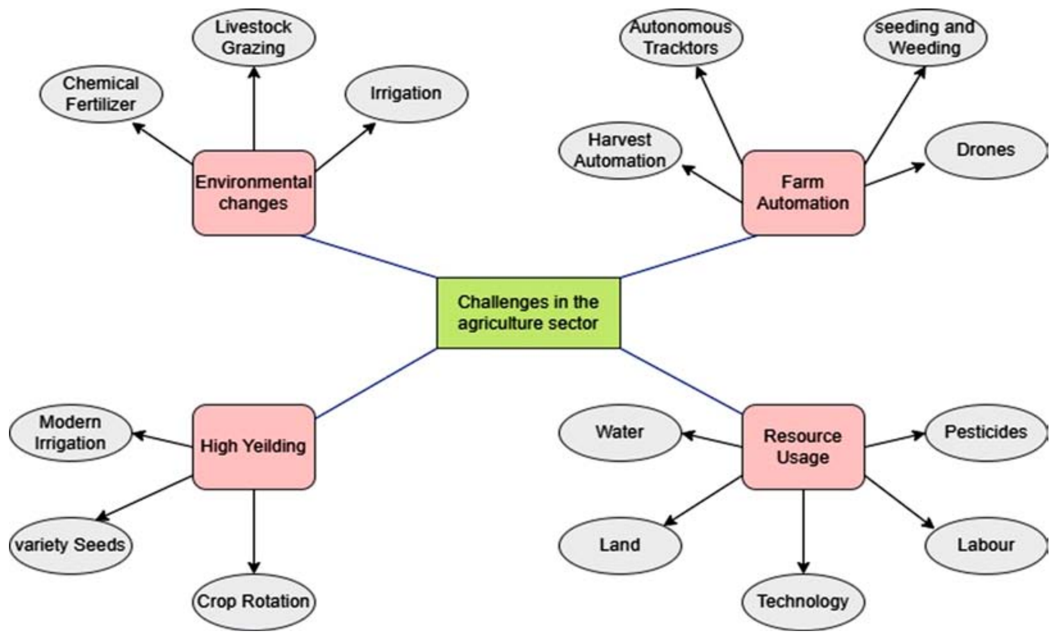

Fig. (2). Challenges in the agriculture sector.

Every crop field has unique characteristics that are critical for achieving both quality and quantity in a particular crop. These characteristics include soil type, irrigation flow, nutrient presence, and resistance to pests. Spatial and temporal differences are crucial factors in increasing growing crops in identical fields, which is achieved through crop rotation using different seed varieties and modern irrigation techniques. In order to increase yield productivity, farm automation with new technology approaches is needed, such as harvest automation, drones, autonomous tractors, autonomous harvesters, robotic weeders, *etc.* They all have sensors attached to them to gather data within a short span of time. However, the above goal needs to be achieved with minimum ecological impact. The new technologies with sensors, actuators, and communication can help farmers to detect current field operations remotely without a physical presence in the field. Farmers come to know the exact requirements of crops and can take action remotely based on this information [4]. Wireless sensors are used to monitor the crops' life cycle stages, from crop sowing to crop harvesting. These wireless sensors provide higher efficiency and can be used to detect early-stage issues or infections. From planting to harvesting of crops, farm automation consistently enables the utilization of intelligent tools. AI is powered by complex algorithms,

CHAPTER 3

Prediction for Increasing Yield Production with IoT and AI Using Soil Properties

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Abstract: 'Wireless Sensor Networks and 'The Internet of Things' are the two imminent commonalities in agricultural science that allow the development of less exclusive systems to install, control, and maintain low-power standard protocols. The work makes use of low-cost sensors and IoT platforms to help farmers improve agricultural systems with better yield and reduce insufficient usage of water. Precision agriculture helps in terms of quality of yield, efficiency of product, decrease in the environmental harness, and minimal usage of natural assets. The proposed precision model obtains raw properties of the given soil and achieves an overall accuracy of 93.33% in predicting the ideal crop that can be cultivated for the given soil sample using the KNN algorithm and develops a continuous crop monitoring system for the expected crop based on the predefined crop properties.

Keywords: Arduino, CSV, Digital farming, Energy-efficient, Food processing, GPS, Green Revolution, IoT, Multi-layer perception SMS, Precision agriculture.

INTRODUCTION

As technologies evolve, modern agriculture mainly depends on physical sciences and engineering technology. Precision agriculture deals with the automation, computing, and monitoring of the crop [1, 2]. With the help of promising technology, precision agriculture incessantly replaces the existing farming schemes with modern automatic sustainable agriculture. With this new invention, modern agriculture integrates WSN, GPS, Wi-Fi, IoT, and GIS [3]. The term "ubiquitous" means "everywhere" and is defined by various attributes. Ubiquitous

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computing senses environment changes and automatically adapts and acts based on these changes and preferences. For crop productivity, soil management is one of the components of environmental-human health sustainability. Fertilizers required for protecting the agriculture field are identified and tested. Crop classification can be done through the spatially distributed information that is provided by satellite remote sensing. The first and foremost thing in agricultural planning is to choose a suitable crop that gives maximum yield. Crop production rate is influenced by a number of factors. To gain maximum yield, different records about the various types of crops over seasons are analyzed. With the help of the predicted values and suitable crops, the maximum yield can be obtained. Mobility plays an important role in IoT applications involving management and monitoring systems with real-time scenarios. Many computer algorithms are used in a variety of real-world applications. They are used to assist farmers in providing a general understanding of the growth, performance, and rise in the yield of their crops. The "KNN (K Nearest Neighbor)" algorithm is utilized in the proposed work to create a precision model that predicts the appropriate crop that can be grown in a given kind of soil. One of the essential elements of agriculture is soil. We can quickly determine the nutritional needs of the soil, including the type of soil, amount of water needed, and fertilizer requirements, by examining its properties [4]. Different types of sensors are available in modern technology to assist in selecting the right soil for specific crops. These recent technical advancements aid farmers in comprehending the characteristics of the soil in which a specific crop thrives and increases agricultural yield.

Contributions of the Research Article

The objectives of the research article are:

- A comprehensive analysis of the given properties of soil is done, and the ideal crop that can be cultivated in the given soil is predicted.
- Accessibility of a modular apparatus that is built with cheap components and provides management and automation in the agriculture field.
- Finally, we develop a management model for precise crops.

LITERATURE REVIEW

Various papers on new technologies are reviewed for precision agriculture, including machine learning, IoT, sensors, AI, data analytics, etc. The literature survey is categorized into two main sub-sections. (i) WSN/IoT and (ii) Data Analytics for appropriate crop production.

Wireless Sensor Network (WSN) /Internet of Things (IoT)

WSN has diverse applications in the field of agriculture, which include soil conditions, remote monitoring, watering, and monitoring environmental conditions. A number of authors' contributions are discussed. In order to manage and keep an eye on the agricultural field for rural services, the author put in place a scalable sensor network [5]. The proposed system is implemented with the help of IoT and MAC components. The network components are analyzed, and improvements are made in all respects. The use of MAC routing protocol increases the throughput in terms of increase in energy efficiency with less delay. Along with this component, Wi-Fi LD (Wi-Fi Long Distance) and fog computing are used [6]. In Himachal-Pradesh, for agriculture, they used WSN to configure the Decision Support System (DSS), which was used to identify 'Apple Scab' [7]. To detect this, mill tables were employed. An article highlights how smart, powerful, and inexpensive individual sensor nodes work together to form a collaborative group that aids in crop production [8, 9]. These sensor nodes store the data, aggregate it for further processing, and analyze it for the improvement of croplands [10, 11]. WSN exemplifies IoT technology, which is used for the collection of intelligent devices for environmental applications. Furthermore, in the cloud computing approach, processing and analyzing the sensor data for the proper decision minimize natural resources. This system has a collection of devices, storage systems, sensors, and composition of IoT [12 - 15]. The entire complex management is part of the Big Data system. An in-depth examination of the smart monitoring system's sample methodology was conducted. [16].

Data Analytics

The prior technique involves human error due to manual estimation of quantity and crop loss [17]. This was due to the ignorance of the inspectors. The application of machine learning in the agricultural sector has solved this. In the agricultural field, the solution comes from using ML and data analytics for large amounts of data. It provides the optimal answer for obscure factors that impact horticulture, such as temperature, humidity, and soil moisture. For the purpose of analyzing pests and predicting yield diseases, artificial neural networks (ANNs), support vector machines (SVMs), logistic regression (LR), and fuzzy technology are employed. A classification approach for apple ailments was proposed by Singh S. *et al.* using machine learning [18]. Two diseases are categorized using images of apple leaves: “Apple scab” and “Marsonina”. SVM, K Nearest Neighbor, and Naïve Bayes are used to categorize illnesses. The suggested arrangement is simulated using Matlab. Its accuracy in classifying illnesses is 99.4%. Shinde S.S. et al., in a study, discussed the current systems that are unreliable and expensive [19]. Trilles S. *et al.* advised using machine learning to

CHAPTER 4

Pesticide Prediction and Disease Identification with AIoT

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Abstract: Agriculture is vital to human survival and has a significant impact on the economy of any nation. Crop protection costs millions of dollars per year. Insects and other pests pose a serious threat to the health of a harvest. Excessive use of chemical fertilizers and pesticides negatively affects the crop and soil quality. Therefore, one way to safeguard the harvest and mitigate potential losses is through early identification of the pests. Examining the crop at the right moment is the best technique to determine its overall health. While manual inspection is the standard way of conducting field inspection, it becomes challenging for large fields. In addition, manual inspection would be exceedingly expensive and tedious. To address this, an automated system is needed to detect pests, identify them, and recommend appropriate fertilizers using an IoT system. Therefore, automated pest detection has become a major focus for researchers globally, as it offers a more efficient and cost-effective alternative to manual inspection. In this work, a smart agriculture system has been proposed that monitors crops, identifies pests, and allows remote control. The dataset comprises over 4000 images of corn leaves, categorized into rust, blight, grey spots, and healthy leaves. By employing Convolutional Neural Networks (CNN), the system has achieved a remarkable 99% accuracy in pest detection.

Keywords: Agriculture, Automation, Convolutional Neural Network (CNN), Crop protection, IOT system, Irrigation, Image processing, Pest infestation, Pest identification.

INTRODUCTION

India is known as the "land of agriculture", with the agricultural sector serving as the backbone of the country. A significant 75% of the nation's population is employed in the agricultural sector, underscoring the critical role of producing

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high-quality and high-quantity food crops. Various modern techniques are introduced to assist the farmers in achieving this goal. However, farmers continue to face multiple challenges and significant economic losses in creating a better food crop. These challenges include issues with acquiring high-quality fertilizers and seeds, harvest storage, and pest infestation.

Despite governmental solutions for various agricultural issues, pest infestations remain a concern that necessitates an appropriate response to the pest problem. Pests inflict substantial damage to various crops, resulting in significant reductions in crop quality and quantity and, consequently, economic losses. In addressing this issue, farmers have resorted to the use of insecticides. However, a more comprehensive understanding of pests and pesticides is of vital importance before the application of such solutions. A farmer who sprays pesticides without sufficient expertise may encounter many issues. Manual application of pesticides without adequate expertise may lead to skin ailments, respiratory issues, skin cancer, and other health concerns. Moreover, manual approaches not only lead to ineffective results but also pose environmental risks. In addition, as a precaution, farmers resort to spraying pesticides in large quantities, causing harm to crops and the environment.

Various pest identification and monitoring methods have recently been used, including image processing and complex algorithms, for pest detection and classification. The best approach is automatic detection, which uses image processing methods to identify and categorize the pests based on the various attributes of the images. In this study, images of agricultural field leaves were obtained, and then different processing methods were performed. The 'threshold approach' was used to differentiate the normal and diseases portion of the leaves. This approach is straightforward and effective for detecting pests from photos. Different image properties are extracted and used as input for support vector machines (SVM) to classify images with and without pests. This research emphasized white flies that are incredibly minute and complicated to inspect with the human eye yet may cause widespread crop damage. The suggested method detects pests on plants and then calculates how many white flies are on each leaf. This study describes a technique for automatically identifying white flies in leaves. ResNet-18 is a CNN model used for disease detection, known for its skip connection mechanism and 18-layer efficiency and accuracy. The suggested approach has proven to be highly useful for implementing early preventative steps and saving the environment from the adverse effects of widespread pesticide use.

LITERATURE SURVEY

Different Techniques for Pest Detection

Different pest detection techniques were explored in a recent study. Three distinct approaches were demonstrated: one using global features from insect images, another using local features, and a third combining both. A hierarchical feature combination was used for classification, with global characteristics at the top level and local features at the bottom. An insect recognition model for green leafhoppers was suggested by H. Nagar and R. S. Sharma using digital photos, employing the colors and forms of insects as identifying characteristics [1]. P. Rajan proposed a methodology for pest identification that uses color features by dissecting the picture into its component colors (RGB) [2]. The pixel-to-pixel intensity difference was also calculated. Pixels with values over a certain threshold in any of the three color channels (R, G, or B) are unwanted intrusions. Later, SVM was utilized to classify. Javed *et al.* devised a model for insect detection [3]. This model's picture segmentation facilitated insect image detection, which was done by refining the K-means segmentation technique. The process of feature extraction makes use of the discrete cosine transform. Using ANN, they were able to improve classification accuracy to 97%.

Image Processing in the Field of Agricultural Research

Samantha and Ghosh introduced an automated system for identifying insect pests in tea using artificial neural networks [4]. This research examined the insect pest data from tea estates in the North Bengal Districts of India. They utilized correlation-based feature selection (CFS) and incremental back propagation network (IBPLN). Aphids can cause significant damage in wheat fields, leading to substantial yield losses. Tao Liu proposed a method based on digital image analysis for identifying and monitoring aphid populations. This method offers a user-friendly approach to accurately monitor aphid populations in wheat fields and can contribute to better pest management in wheat farming [5]. Other researchers have proposed a method to identify infested plant sections, such as roots and leaves. Using data from several cameras, they interpreted scenes and analyzed videos to help make intelligent decisions on the spot. The proposed approach has been employed for apriority detection of aphids and whiteflies. Al-Safer developed a neural network-based identification system for pecan weevils. The method is reliable and can be used to design an automated, wireless sensor network for detecting pecan weevils in the field [6]. Zhu and Zhang proposed a novel method for identifying insects [7]. They combined the dual-tree and region-matching complex wavelet transforms in their image-matching work. Images of lepidopteron insects were processed using the mean shift method and the k-means

CHAPTER 5

Weed Control for Better Crop Health Using AIoT

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Abstract: Agriculture is one of the major sources of economy in India. Quality of crops and optimal yield are possible amidst several challenges, such as climate change, water scarcity, and weeds, by means of sustainable agriculture. Modern science and technological advancements can be used to address these challenges and, hence, maximize agricultural productivity.

This chapter focuses on weed control using a combination of computer vision and IoT. Weed is an unwanted crop that affects the growth of the actual crop by absorbing soil nutrients, water, and sunlight. It is extremely important to remove the weeds. Targeted spraying to kill the weed has been the most effective solution. Such a system is cost-effective and time-saving for large farms. The major concern in this method is the identification of the weed. There are several types of weeds, and identifying them among the actual crop is critical. False identification may lead to large economic losses. An efficient product for weed removal can be designed by combining the knowledge of IoT, image processing, and artificial intelligence (AI). AI and image processing aid in identifying and classifying the weeds. AI also helps in analyzing the risk of weed and the ineffective usage of weed killer, along with the amount of pesticide to be sprayed based on the type of weed. This chapter discusses sustainable agriculture, works carried out in the field of smart farming, the significance of technologies such as IoT and AI, and the design of a weed killer bot, which mainly uses image processing.

Keywords: Agriculture, Artificial intelligence, Bot, Crop identification, Image segmentation, Internet of Things, Precise targeting, Prototype, Sustainability, Weed.

INTRODUCTION

In India, agriculture is the primary source of livelihood for millions of people. India is one of the world's largest producers of food grains, but its agriculture is

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plagued by several challenges, such as a shortage of land, water scarcity, soil degradation, and climate change. Weed infestation adds to these challenges, making it difficult for agronomists to achieve optimal yields.

Sustainability in agriculture is crucial for ensuring long-term food security and protecting the environment. Sustainable agriculture practices promote the efficient use of natural resources, minimize environmental damage, and promote social and economic well-being.

Weed control is a critical aspect of agriculture, and the adoption of sustainable practices is essential to ensure long-term agricultural productivity and environmental health. By promoting sustainable weed management practices, farmers can maximize yields and agricultural productivity while minimizing the negative impacts of weed control on the environment and human health.

The concept of targeted is a relevant solution that mainly addresses the requirement of sustainable farming and control of weeds in agriculture.

This approach involves the precise application of herbicides only where weeds are present, reducing the amount of chemicals needed and minimizing the negative impact on non-target plants and the environment. By adopting this method, farmers can improve their crop yields while promoting sustainable agriculture practices that minimize environmental damage and reduce costs. Targeted spraying is a more efficient and environmentally friendly method of weed control, and it is a practical solution for agriculturalists who seek to improve their yield while maintaining sustainability in their farming practices.

Targeted weedicide spraying is an efficient and sustainable method of weed control compared to bulk spraying. Herbicides are consistently sprayed in a field during bulk spraying, which can lead to excessive use of chemicals, damage to non-target plants, and detrimental effects on the soil, water, and public health. Targeted spraying, on the other hand, allows for precise application of herbicides only where needed, resulting in a more effective and environmentally friendly weed control approach.

The targeted weedicide spraying mechanism involves the use of advanced technologies such as GPS, sensors, and mapping systems to identify and locate weeds within a field. Once the weeds are identified, the sprayer is directed only to the areas where the weeds are present, reducing the amount of herbicide needed and minimizing the impact on non-target plants and the environment. Targeted spraying can also save time and reduce costs, as farmers do not need to apply herbicides to the entire field.

There are several benefits of adopting targeted weedicide spraying. It reduces the amount of herbicide needed, resulting in cost savings for farmers and minimizing the negative impact on the environment. Targeted spraying also reduces the chances of survival of herbicide-resistant weeds. Additionally, it can improve crop yields by reducing the utilization of resources such as nutrients, water, and light by the weed.

Concisely, targeted weedicide spraying is an effective and sustainable method of weed control that can help farmers minimize the negative impacts of herbicides on the environment and improve crop productivity. By adopting targeted spraying mechanisms, farmers can reduce the use of chemicals, save time and money, and promote sustainable agriculture practices. The information collected from the farm using sensors can be sent to the farmer through IoT. An agricultural bot that combines IoT, image processing, and AI is the solution. It uses a camera, sensors, processor, motor, and sprayer. It effectively sprays the pesticide and kills the weed.

LITERATURE SURVEY

Precise identification of the unwanted vegetation is necessary for the development of a successful weed removal. Real-time weed detection system reconstructs a 3D model of the crop using stereo vision and machine learning to find weeds in the crop. Two manually compiled datasets of the cucumber and onion crop serve as the basis for the machine learning model's training in [1].

The machine learning models are trained using the ResNet-50 method and Convolutional Neural Networks (CNN). It was interpreted that ResNet-50 outperforms Convolution Neural Networks in terms of performance. For the dataset of cucumbers and for the dataset of onion crops the ResNet-50 model provides good accuracy.

In a study [2], authors used image processing in MATLAB to detect the area where there was the presence of weeds in an image we took from the fields. In recent years, as the world population has grown and existing land and natural resources have decreased, precision agriculture is increasingly capturing the attention of researchers. Image processing approaches can be applied to solve this problem.

The best ML algorithm to be used for achieving the said objective is a topic of discussion. The effectiveness of several machine learning methods, such as k-nearest neighbor (KNN), support vector machine (SVM), and random forest (RF), is examined in a study [3] to identify weeds using UAV photos taken from an Australian chili crop field. Accuracy, false positive rate recall, precision, and

CHAPTER 6

Origin and History of AI, IoT and Blockchain Technology and their Pertinence in Food Supply Chain Management

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Abstract: In a world where hunger and malnourishment are still a matter of concern, food loss, wastage, and its timely availability must be addressed immediately. Based on an extensive literature review and secondary data, this manuscript has tried to come up with holistic, contemporary solutions for food supply chain management. Against this backdrop, tools viz., IoT, AI, and blockchain will not only manage food loss, wastage, and timely availability but also revamp transparency, food quality and safety. IoT architecture offers tracking solutions through measurement, network, service, and application layers using various sensors and WiFi-connected devices. Artificial Intelligence (AI) and the Internet of Things are becoming significant facilitators of supply chain management (SCM) optimization. The adoption of AI technology has been associated with a 15% reduction in logistics costs, a 35% reduction in inventory levels, and a 65% increase in customer service levels. It assists in demand forecasting, enhanced safety, cost saving, boosting revenue, and chiefly on-time delivery. Block Chain Technology (BCT) system can be programmed to record and track food supply chain transactions. Chhattisgarh in India has developed the Centralized Online Real-Time Electronic Public Distribution System (CORE-PDS) and has become a model state in the 'Public Distribution System (PDS)'. Unfortunately, Chhattisgarh's model fell prey to scams viz., bogus ration cards, irregularities in rice stock, and poor quality rice and salt samples collected, which were unsuitable for human consumption because of no mid-term audit and monitoring. The chapter concludes that all these anomalies would not have happened to such an extent or have been addressed timely if the technological trinity viz., IoT, AI, and Blockchain, had been incorporated judiciously into the PDS system.

Keywords: Blockchain, Chhattisgarh's PDS Model, Food Supply Chain, Internet of Autonomous Things (IoAT), Radio Frequency Identification (RFID), Wireless Sensor Networks (WSNs).

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INTRODUCTION

In April 2023, India surpassed China as the world's most populous country. On the contrary, in the 2022 Global Hunger Index, India fell under serious categories and was ranked 107th out of 121 countries, having a score of 29.1. The irony is that India's estimated economic value of post-harvest losses of just 45 crops was Rs. 92651 crores at average annual prices of 2014. AI, IoT and BCT are ubiquitous in the present world, but conceptual clarity among all these tools is rare. AI is the expression of an artificial actuality meant for perceiving, synthesizing, and inferring information. Economic, medical, engineering, and military departments frequently use artificial intelligence systems, in addition to many common home computer software operations, strategy games, and other video games. The term AI refers to both the intelligence of machines and the area of computer science that aims to develop it. The word then officially devised by Marvin Minsky and John McCarthy in the year 1956 (Table **1**), who hosted a research project for 8 weeks called *Dartmouth Summer Research Project on Artificial Intelligence (DSRPAI)*in the United States.

Table 1. Fathers/Pioneers of AI, IoT, BCT and ChatGPT.

S. No.	Particulars	Year	Father/Pioneer	Source
1.	AI	1955	John McCarthy	Encyclopedia Britannica (2023) [1]
2.	Godfather of AI	2012	Geoffrey Hinton	Taylor & Hern (2023) [2]
3.	IoT	1999	Kevin Ashton	History of Information (2023) [3]
4.	Blockchain	2008	Satoshi Nakamoto	Robb Report (2023) [4]
5.	ChatGPT	2022	Sam Altman	Technical University of Munich (2023) [5]

AI concentrates on the advancements of intelligent machines that are proficient in performing tasks that require the use of human intellect. By developing algorithms and models, computers and systems are able to simulate cognitive functions such as learning, reasoning, problem solving and making decisions. As a result of artificial intelligence, large amounts of data can be analyzed, patterns can be recognized, predictions can be made, and actions can be taken based on the information gained. Advances in artificial intelligence, such as improved algorithms, autonomous vehicles, virtual assistants, fraud detection systems, personalized medicine and smart homes, have been developed. Besides, recent years have seen a significant increase in attention and popularity for Blockchain Technology (BCT). Using this system, multiple parties can record and transact securely and transparently across multiple ledgers without an intermediary being necessary. By creating the first cryptocurrency, Bitcoin, Satoshi Nakamoto introduced the concept of Blockchain in 2008. It is important to note that at its core, a Blockchain is a chain of blocks containing a list of transactions within each block. A chain of immutable and tamper-proof blocks is formed by linking these blocks using cryptographic hashes. A Blockchain is a decentralized network that cannot be controlled by any single entity, which makes it resistant to censorship and manipulation. While the Internet of Things (IoT) denotes a network of interconnected devices, such as machines, appliances, and cars, which can collect and exchange data through the use of sensors, software, and network connectivity (Table **1**). By enabling these devices to communicate and interact with one another and with humans, IoT creates an intelligent and seamless ecosystem. Sensors in IoT devices are capable of capturing data such as temperature, humidity, light, motion, and location. As a result of the transmission of this information through networks, either locally or via the Internet, the data is then stored, analyzed, and further processed on centralized servers or cloud-based platforms.

In Table **2**, varied widely accepted definitions of artificial intelligence (AI) have been compiled. As these definitions are from the pioneer workers, they are consequently widely cited.

Table 2. Definition of Artificial Intelligence (AI).

S. No.	Definition	Given by	Source
1	"The science and engineering of making intelligent machines".	McCarthy, 1956	(Dartmouth, 1956) [6]
2	"Capability of machines to communicate with and imitate the capabilities of humans".	Schutzer, 1990	(Schutzer, 1990) [7]
3	"A program which, in an arbitrary world, will cope not worse than a human".	Dobrev, 2004	(Dobrev, 2004) [8]
4	"A system's ability to interpret external data correctly, to learn from such data, and to use those learnings to achieve specific goals and tasks through flexible adaptation".	Haenlein and Kaplan, 2019	(Haenlein & Kaplan, 2019) [9]

The phrase "4 seasons of AI" has a widely recognized or standardized meaning in the field of artificial intelligence (AI). It refers to a specific framework, concept, or model that was introduced in 1942 (Table **3**). AI is a rapidly evolving field, and new frameworks and ideas are constantly emerging.

CHAPTER 7

Food Supply Chain Management by Leveraging AI, IoT, and Blockchain Technologies

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Abstract: Traceability is an important component of food supply chain management because it allows businesses to track food products from their origin to the point of consumption. However, the current food supply chain system frequently lacks proper traceability methods, making it difficult to pinpoint the source of food safety concerns, monitor product quality, and assure regulatory compliance. As a result, there is a growing need to rethink food supply chain management to assure traceability. Artificial intelligence (AI), the Internet of Things (IoT), and blockchain are contributing to the resolution of these issues by increasing accountability, traceability, and efficiency. The application of blockchain, IoT, and AI to food supply chain management is examined in this book chapter. It highlights the possible advantages of incorporating these technologies into the food industry, including improved food safety, real-time food quality monitoring, and increased supply chain visibility. It looks at other uses as well, such as decentralized food traceability systems, smart packaging, and predictive analytics. The chapter also discusses the obstacles and restrictions that come with implementing these technologies in the food supply chain, as well as potential solutions and effectiveness.

Keywords: Consumer trust, Donsumption, Data analytics, Distribution, Efficiency, Food safety risks, Inventory management, Market dynamics, Quality control, Real-time monitoring, Regulatory compliance, Traceability, Transparency, Transportation, Visibility.

INTRODUCTION

Food supply chain management [1] refers to the process of overseeing and managing the flow of food products from the point of origin to the consumer. It encompasses all the activities involved in the production, processing, storage, transportation, and distribution of food items [2]. The food supply chain shown in Fig. (**1**) consists of several interconnected stages.

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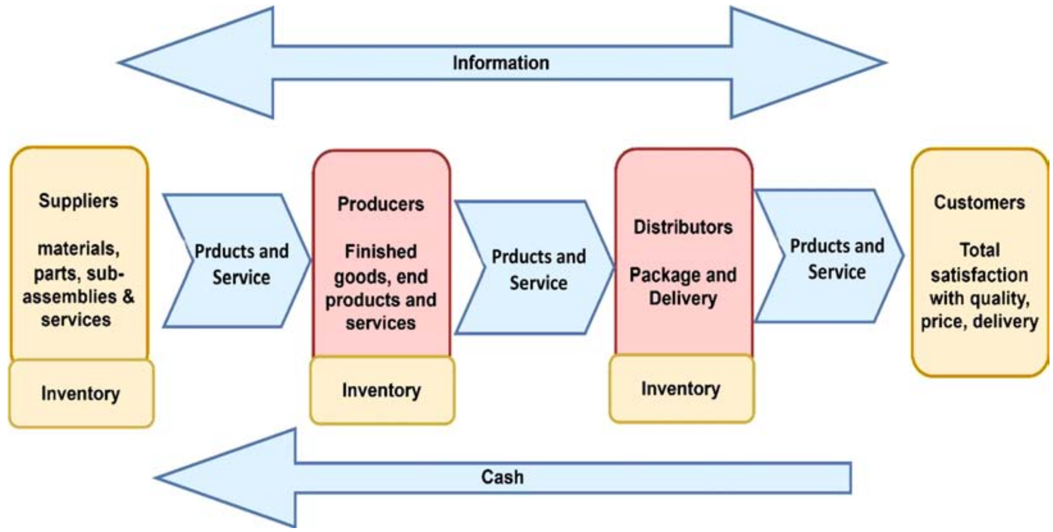

Fig. (1). Supply chain management.

Procurement: This involves sourcing raw materials, such as agricultural produce, ingredients, and packaging materials, from suppliers, farmers, or other sources.

Processing: Raw materials are transformed into finished food products through various manufacturing and processing operations. This stage may include cleaning, sorting, cutting, cooking, packaging, and labeling.

Storage: Processed food products are stored in warehouses or distribution centers before they are transported to retailers or consumers. Proper storage conditions, such as temperature control, are crucial to maintain product quality and safety.

Transportation: Food products are moved from storage facilities to distribution centers, retailers, or directly to consumers. This stage requires efficient logistics management, including route optimization, vehicle selection, and compliance with food safety and transportation regulations.

Distribution: Food products are distributed to various points of sale, such as grocery stores, restaurants, and institutions. This may involve working with wholesalers, distributors, or direct delivery to retailers. Inventory management, order fulfillment, and demand forecasting are essential aspects of distribution.

Retail: Food products are made available to consumers through retail outlets, both physical stores and online platforms. Retailers play a significant role in product placement, pricing, marketing, and ensuring a positive consumer experience.

Consumption: The final stage occurs when consumers purchase and consume the food products. Consumer feedback and preferences play a crucial role in shaping the supply chain and product development.

Food supply chain management involves coordinating and managing activities across all these stages to ensure the efficient and timely delivery of safe and quality food products [3]. It requires collaboration and information sharing among various stakeholders, including suppliers, manufacturers, distributors, retailers, and consumers.

Effective food supply chain management is crucial for meeting the demands of a growing population, ensuring food security, minimizing waste, and promoting sustainability. It involves addressing challenges such as food safety risks, quality control, inventory management, traceability, regulatory compliance, and responding to market dynamics.

Advancements in technology, such as AI, IoT, and blockchain, have the potential to optimize and streamline food supply chain management by improving visibility, traceability, efficiency, and transparency [4]. These technologies enable real-time monitoring, data analytics, automation, and secure data sharing, leading to enhanced operational effectiveness and consumer trust [5].

ARTIFICIAL INTELLIGENCE IN FOOD SUPPLY CHAIN MANAGEMENT

Artificial intelligence is the imitation of human intellect in computers that have been designed to do tasks that would ordinarily require human intelligence. It comprises developing computer systems capable of performing activities such as speech recognition, decision-making, problem-solving, and learning, among others. Machine learning, neural networks, natural language processing, and expert systems are some of the approaches employed by AI technology. Machine learning, a subtype of AI, feeds large amounts of data to algorithms in order for them to learn patterns, make predictions, and improve performance over time. Neural networks, which mimic the structure of the human brain, are used to process and analyze massive volumes of data. AI has found applications in a wide range of industries, including healthcare, banking, transportation, manufacturing, and others [6].

Role of AI in Food Supply Chain Management

Artificial intelligence has the capability of processing and analyzing massive volumes of data, generating correct forecasts, and automating decision-making processes, considerably improving efficiency, quality control, and overall

CHAPTER 8

Framework Based on IoT, AI, and Blockchain for Smart Access to Government Agricultural Schemes

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Abstract: Agriculture plays an important part in most countries, such as India. A survey says that 54.6% of the total labor force of India is engaged in agriculture and its connected activities. The government is announcing many schemes to facilitate agriculture and support farmers. But most of the farmers are from poor families and are not able to reach the government schemes when they are really in need. Also, it is required to observe and measure the inter and intra-field variability in crops to enjoy the complete benefits of government schemes. This can be done with the advancements in the field of the Internet of Things. Information related to the impact of natural calamities on the agricultural field, malfunctions in the machinery used for cropping, yielding level, and health status of crops can be measured using the technology of IoT (Internet of Things) and analyzed using AI (Artificial Intelligence). Blockchain plays a critical role in replacing traditional means of data storage and exchanging agricultural data with a more trustworthy, immutable, transparent, and decentralized approach. By keeping all the transactions related to government schemes in blockchain, the possible crimes in the form of false data by the intermediate dealers acting between the farmers and the government can be addressed. This, in turn, allows useful government schemes to reach the farmer in time. We propose to develop a theoretical model using IoT, AI, and blockchain, which can assist the farmers in benefitting from the appropriate schemes announced by the government in time and achieving precise agriculture.

Keywords: Artificial intelligence, Blockchain, Drone monitoring system, Internet of Things, Learning model, Multispectral imaging sensors, Precision agriculture, Unmanned aerial vehicles.

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INTRODUCTION

Recently, concerns over food production have increased drastically. It is due to the surge in the world population and the decrease in agricultural resources. Many governments and private organizations are trying to find ways to improve agricultural efficiency. This results in increased research and spending on farming. Nowadays, drones and robots are used for agricultural automation in all stages, from soil preparation to harvesting, to increase productivity and quality. Researchers focus on introducing new approaches to increase yield with fewer agricultural resources. Traditional agriculture uses basic methods of cultivation with primitive knowledge and standard tools. More than half of the world's population uses this method for food production. Even though the cost of production is less in conventional agriculture, it has many cons like low productivity, nutrition depletion, compromise in quality, increase in pollution, *etc.* Hence, there is a need for some modern techniques in agriculture to improve crop productivity without compromising the quality of the crops.

Precision agriculture uses more accurate ways of cultivation to increase productivity with high quality. It gathers, analyzes, and manages information based on the soil, crops, and other parameters to yield high productivity [1]. It is also known as satellite agriculture. It uses sensors to acquire information about the soil. Real-time images of the crops, farm fields, weather conditions, *etc.*, are acquired using satellites, drones, and robots [2, 3]. Captured images are analyzed further with the sensor data to obtain the necessary information for better cultivation of crops. Agriculture involves many stages, like crop selection, land preparation, seed selection, seed sowing, irrigation, crop growth, fertilizing, and harvesting. Each stage can be automated using drones and robots, which helps in increasing productivity. It also reduces the dependency on weather conditions by creating the best environmental conditions suitable for different crop production. Even though precision farming has many advantages, it is expensive and requires huge capital. It is the main reason that most farmers continue with traditional farming methods. Since over 80% of the farmers are poor, implementing such expensive infrastructure in their small portion of land will be unthinkable for them. In rural areas, there is a difference in the land portions owned by the farmers. Because of the land differences, adapting modern infrastructure is tedious. It also requires prior knowledge to operate the tools, which the farmers must learn. Since they are comfortable with the conventional method, there is a lack of interest in adapting to modern technologies. If they are adopted, understanding and implementing them in the farmlands consume more time and capital. To overcome the drawbacks of precision agriculture mentioned above, the government proposed many schemes to benefit the farmers. To better understand the proposed government schemes, a friendly handbook explaining them and their benefits has also been issued to the farmers by the Department of Agriculture, Cooperation and Farmers Welfare (DAC&FW) and the Ministry of Agriculture and Farmers Welfare. It includes the details of the assistance provided to the farmers to increase productivity. A few details are listed below.

• Assistance to improve soil conditions by distributing micronutrients and soil ameliorants and supplying gypsum/pyrite/lime/dolomite, lime/liming materials, and bio-fertilizers, which are proposed with affordable prices for the benefit of the farmers.

• Water management methods under the Mission for Sustainable Agriculture (MSA) include drip irrigation, sprinkler irrigation, water harvesting systems for individuals, construction of tube wells/bore wells (shallow/medium), *etc.*

• E-marketing of agriculture commodities.

• Assistance with organic farming with bio-chemicals, bio-pesticides, and bio-fertilizers.

• Assistance in the cultivation of horticulture crops.

Though the government has proposed many schemes to help the farmers achieve high productivity, they have not been well received by the farmers. On the other hand, because of the intermediate dealers, the farmers are not getting their actual share for their contribution, which in turn reduces the farmers' trust in government schemes, which may also lead to conflicts, protests, and other severe consequences. Thus, a secure system is needed to exchange the information directly with the farmers rather than through the intermediate dealer. With the system, the farmers can acquire benefits and productivity can be increased. Hence, this paper proposes a model with recent technologies to assist the farmers in getting benefits from the schemes. The paper is organized as follows: Section 2 explicates the existing precision agriculture methods with their merits and demerits. Section 3 describes the technologies used in various stages of farming to increase productivity. A framework of smart access model for accessing government schemes is proposed in Section 4, and Section 5 concludes this paper.

EXISTING SYSTEMS

With rising population, the problem pertaining to food production has attracted focus. Population with diverse needs is expected to increase to between 9.4 and 10.1 billion by 2050, increasing the need for designated areas for food production [4]. Human-induced environmental changes may result in circumstances where the growth of new crops is impossible. In the same way, increasing urbanization

CHAPTER 9

Transforming Agriculture with IoT for Precision Agriculture and Sustainable Crop Management

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Abstract: The Internet of Things (IoT) technology is making a radical transition in the agricultural business, resulting in the creation of precision agriculture and sustainable crop management practices. This study inspects how Internet of Things (IoT) technology is revolutionizing agriculture, with a particular emphasis on sustainable crop management techniques and precision agriculture. The study explores the extent and significance of using sensors, IoT devices, and data analytics for improved crop monitoring and management, empowering farmers to make data-driven choices. Farmers are able to allocate resources more efficiently and produce less waste due to the real-time data collecting on soil moisture, temperature, humidity, and crop health. We go into great detail on the essential elements of IoT-based precision agriculture, such as decision support systems, data collecting, analytics, and sensor technology. The study also looks at the benefits of using IoT in agriculture, highlighting how technology might completely transform farming methods for more sustainability and efficiency. A thorough literature study adds to our understanding of the status of research in Internet of Things applications for sustainable crop management and precision agriculture.

Keywords: Artificial intelligence (AI), Internet of things (IoT), IoT in agriculture, Precision agriculture, Sustainable crop management.

INTRODUCTION TO IOT IN AGRICULTURE

The interconnection of physical things, automobiles, structures, and other items that are merged with software, sensors, electronics, and connections to networks, allowing them to collect and transmit data, is referred to as the Internet of Things

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(IoT). The purpose of IoT is to build a seamless communication network between items and systems, allowing the development of smart arrangements capable of collecting, treating, and analyzing data in order to make choices and conduct actions [1, 2].

The Internet of Things (IoT) idea goes back to the late 1980s when academics first began investigating the possibility of linking common things to the internet. However, the technology and infrastructure required to execute IoT did not become accessible until the 2000s. IoT has become a fast-developing industry, with applications in a variety of businesses, such as agriculture, as a result of broad internet usage and the growth of low-cost devices and wireless communication technologies [3].

The usage of IoT in agriculture has developed quickly in the past few years as farmers seek ways to enhance efficiency, lower costs, and raise yields. IoT-based agriculture systems have been utilized to automate operations such as crop and soil health monitoring, irrigation system control, and animal tracking. IoT in agriculture has also enabled the assembly and examination of vast sizes of data, giving farmers useful insights into their operations [4]. The application of IoT technology and systems to improve agricultural practices and boost efficiency is referred to as IoT in agriculture. This may be accomplished by collecting data on soil health, crop growth, weather patterns, and other elements that affect agricultural operations using sensors, cloud computing, and other IoT-based skills. This data may then be evaluated to help farmers make better decisions and improve agricultural practices, resulting in higher yields, lower costs, and a more sustainable agriculture business [5, 6].

This research attempts to highlight the most recent trends and scientific findings in the fields of IoT and agriculture. According to Google Trends, there has been a significant increase in searches for the terms precision agriculture and sustainable crop management. Precision agriculture and sustainable crop management have had varying degrees of popularity. The chart below depicts the web search prevalence for the aforementioned terms as determined by Google search trends since 2024.

This chapter provides a widespread outline of the Internet of Things (IoT) in agriculture. The chapter begins with an introduction to IoT, outlining the concept and underlining its many agricultural applications. The chapter goes on to discuss the advantages of installing IoT-based agricultural systems. It then looks into the many types of IoT sensors used in agricultural, including soil moisture sensors, crop sensors, weather sensors, animal sensors, and irrigation sensors. The sections that follow go into further depth on IoT-based data collection and management systems, covering both centralized and decentralized approaches. It talks about cloud-based data management systems as well as the emerging trend of edge computing in IoT-based agriculture, underlining the need of real-time data processing and localized decision making. The chapter focuses on IoT-based precision agriculture, providing both an explanation and a summary of the advantages of employing precision agricultural practices. The chapter then goes into IoT-based sustainable agriculture management, such as crop monitoring, automated irrigation systems, and pest and disease management using IoT technologies. Finally, the chapter reviews the key findings and examines the importance of IoT in transforming agriculture into more efficient, sustainable, and technologically driven agricultural practices. The references section includes a comprehensive list of all sources and publications cited throughout the chapter, making it an invaluable resource for agricultural researchers, practitioners, and policymakers interested in the possibilities of IoT.

Definition of IoT

The Internet of Things (IoT) is a collection of physical objects, including automobiles, buildings, and other items, that are connected to the internet and equipped with software, hardware, sensors, and network connections. The purpose of IoT is to build a seamless communication network between items and systems, allowing the development of smart organizations capable of collecting, processing, and analyzing data in order to make choices and conduct actions [7, 8]. The Internet of Things (IoT) is the convergence of a number of technologies, including artificial intelligence (AI), ubiquitous computing, inexpensive sensors, and increasingly potent embedded systems [9]. Several instances include healthcare delivery systems, cameras, fixtures for lighting, heating and cooling systems, security systems for homes, and other products [10].

Applications of IoT in Agriculture

According to current estimates, 9.6 billion people will populate the world by 2050. In order to feed this massive population, agriculture is being compelled to use the Internet of Things. IoT is eradicating concerns such as harsh weather, climatic shifts, and environmental degradation while also supporting us in addressing the growing need for food [11]. Previously, mechanical innovations such as tractors were introduced for managing the ever-growing food demand. Many more sophisticated sensors are being used in agriculture as a result of the development of industrial IoT. A mobile or satellite communication network currently connects the sensors to the cloud. It enables us to get sensor data instantly and make defensible decisions.

CHAPTER 10

Scientific Integrated Solid Waste Management System to Minimize Adverse Effects on Agriculture

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Abstract: The management of solid waste is a major issue everywhere in the world. It is an undesirable material produced from industrial and business activities andfrom residential areas in a given region, which leads to adverse impacts on agriculture. Decentralized municipal solid waste is one of the causes of the harmful environment in India and all over the world. Decentralized waste management causes significant problems, including hazardous diseases and environmental pollution. To tackle these problems, scientific management of waste disposal is needed. Few methods are used to find the solution to these problems, but they do not give precise and accurate results. Moreover, there is uncertainty in data, so there is an immediate need to establish a reliable way to find a place where solid waste can be disposed of. A scientific, integrated solid waste management system must be immediately designed to reduce the effects on agriculture. Geospatial tools like Remote Sensing and GIS, which can help in appropriate site choice for Municipal Solid Waste (MSW) disposal in an additional scientific manner, might result in economically supported concrete proof. The study provides the suitable places in the city and the best algorithms in the field of Site Suitability Analysis (SSA).

Keywords: Composition, Human excreta, Integrated solid waste management system, Nutrient recovery, Recycling, Site suitability analysis, Waste disposal.

INTRODUCTION

Most urban regions in the nation are tormented by intense issues identified with solid waste because of the constant movement of individuals from provincial and semi-urban territories to towns and urban areas.

The world population is increasing rapidly with the rise of economic growth, and a high standard of living increases solid waste all over the world. Because of the lack of information, it is recorded that a high quantity of solid waste is dumped in

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water bodies in open ground areas, which is the most common practice of the municipalities [1].

The drainage system is the pattern formed by streams and rivers over the landform. It is also known as the river system. Most of the daily water requirements are fulfilled by these river systems of an area, so it is very necessary to avoid these patterns from the waste management sites [2].

This decentralized waste then causes environmental degradation. Non-scientific disposal of waste leads to hazardous diseases in society and at the community level. Mismanagement and improper planning by the authorities lead to the non-scientific disposal of waste. For sustainable agriculture in a country, it is vital to employ a management strategy regarding modern approaches to solid waste disposal. Scientific ways of waste disposal will affect in a way that there will be no harm to any agriculture field or the environment [3].

A methodology and an appropriate location for disposing of solid waste are suggested in this research study [4]. This methodology will help to centralize all the solid trash in a good scientific manner without harming agriculture, and it is also one of the more affordable options. Satellite remotely sensed data and geospatial technology are used to solve the solid waste disposal location suitability problem [5].

The article has six sections. The related work on integrated solid waste management is studied. After that, we define the problem and find the solution to solve the solid waste disposal location suitability problem, and then we explain the methodology to design a scientifically integrated solid waste management system. This article summarizes the technical hurdles in results and implementation. Lastly, it compares and concludes the article.

RELATED STUDY

The multi-criteria decision-making approach for site appropriateness analysis in a fuzzy environment is the main emphasis of this study. Waste disposal practices cause the decline of agricultural land. A scientifically integrated solid waste management system must be studied to reduce adverse environmental effects.

García *et al.* explainedthat the chemicals in wastewater have a significant impact on the agricultural reuse of municipal wastewater. Additionally, due to the presence of pathogens, environmental risk and the influence on human health are the main issues with municipal wastewater reuse [6].

Akram *Qazi et al.*explained that traditional wastewater systems are made up of a combination of chemical and biological processes that remove organic matter and nutrients from wastewater, resulting in a high removal efficiency of BOD, total nitrogen, and phosphorus [7].

Aquino *et al.*found that instead of being dumped into the environment, both treated and untreated wastewater can be used to irrigate crops. Pathogen threats, on the other hand, must be completely addressed to maintain food safety because agriculture consumes over 70% of the world's water [8].

Cherif *et al.* suggested that pollutant removal procedures in hydroponic systems use a combination of physical, biological, and chemical activities with microorganisms, plants, and media-based interactions [9].

C. Namasivayam and K. Kadirvelu suggested that field-grown plants get the majority of their nutrients from the earth, and nutrient formulations for field cultivation are considerably different from those used for hydroponic crop production [10].

Vaverková *et al*. explained that agricultural reuse of wastewater primarily occurrs following the use of several types of technology, including primary treatment and biological treatment systems. Primarily processed home wastewater was used [11]

Increases in crop growth have been observed in the literature when crops are irrigated with treated municipal wastewater. In this regard, various studies have shown that treated effluents can boost crop growth and yield, such as wheat [12].

PROBLEM STATEMENT

In the literature survey, few methods are used to find the solution to this problem, but they do not give precise and accurate results. Also, there is uncertainty in data, so there is an immediate need to find a suitable method to find the place for the disposal of waste. Decentralized municipal solid waste is one of India's agricultural problems, and decentralized waste management causes environmental pollution. To tackle this problem, waste management must be carried out scientifically. Geospatial tools like Remote Sensing and GIS can help in appropriate site choice for solid waste disposal. Remote Sensing and GIS techniques can efficiently find suitable sites for waste disposal with effective low cost.

METHODOLOGY

Studies reveal that these open dumps of solid waste cause a harmful impact on agriculture. A non-scientific disposal system of solid waste leads to a downturn in

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