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# A systematic review of internet of things-based smart farming applications with biotechnology

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## *Abstract*

### Objective

This study combines technology and software to let farmers track and change certain field parameters in real-time. Along with a quick examination of the interplay between weather station monitoring and mobile data logging, it offers a study on Smart Farming (SF) based on the Internet of Things (IoT). The Internet of Things (IoT) will play a pivotal role in the viability of the agriculture sector in the years to come. Highlighting technological, ICT, and robotics advancements, the research centers on multimedia devices, communication procedures, sensors, and systems frequently utilized in SF monitoring. In order support future researchers and provide the groundwork for the creation of automated IoT-based SF monitoring systems that incorporate biotechnology, this article describes the methodologies used in this area. This project aimed to enhance Smart Farming (SF) efficiency through IoT technologies, focusing on methods, processes, and tools for monitoring SF, integrating biotechnology for improved production and sustainability, and highlighting the role of automated processes and robots in IoT-based agricultural solutions.

### Results

This study proves that the Internet of Things (IoT) is becoming more significant in contemporary farming, outperforming conventional farming practices as a result of technological, information and communication technology (ICT), and robotics improvements. Internet of Things (IoT) integration into SF boosts productivity by allowing for condition monitoring and correction in real time. According to the results, sensors and communication systems, in conjunction with IoT technology, allow for the automated and exact administration of agricultural tasks. Data logging systems and multimedia devices work well together to gather and analyze agricultural data, which improves agricultural decision-making and yields better results.

**Conclusions**

The Internet of Things (IoT) has the potential to change the nature of farming completely by facilitating the development of methods that are more productive, accurate, and environmentally friendly. It is believed that Smart Farming will continue to surpass conventional farming practices in terms of popularity as technology progresses. More efficient and automated farming systems will be the result of the effective integration of the Internet of Things (IoT), biotechnology, and robotics. This research provides important information for future studies on the improvement of SF surveillance through the Internet of Things (IoT). There is great promise for the future of agriculture and higher productivity in the agricultural industry as a whole with the introduction of robotics and automation.

**Keywords:** Biotechnology, internet of things, monitor, smart farming

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## Introduction

The issue of water shortage, which has been exacerbated by population growth, has significantly impacted individuals. The current global population is estimated to be at 7.5 billion. It is projected to increase to nine billion by the year 2050. Most freshwater resources are primarily used in agricultural operations, with irrigation being the most water-intensive (Fountas et al.

2020). Developing nations need more state-of-the-art technologies and advanced agricultural machinery than industrialized nations, resulting in heightened water usage, particularly for irrigation purposes. It is imperative to employ state-of-the-art methods for efficient irrigation. Plant pathology is a significant challenge encountered by farmers (Uzakbaeva & Ajiev 2022). Timely identification of plant diseases enables farmers to make informed decisions and enhance crop yield (He et al. 2021). Therefore, it is necessary to observe the agricultural grounds closely. Moreover, data generation in agriculture and biotechnology has greatly increased in recent years due to the very rapid development of high-performance technologies (Mohammadabadi et al. 2024). These data are obtained from studying products, foods, and biological molecules to understand the role of different aspects of agriculture in determining the structure, function, and dynamics of living systems (Pour Hamidi et al. 2017). Artificial neural networks have been proposed to alleviate limitation of traditional methods and can be used to handle nonlinear and complex data, even when the data is imprecise and noisy (Pour Hamidi et al. 2017). Agricultural data can be too large and complex to handle through visual analysis or statistical correlations. This has encouraged the use of machine intelligence or artificial intelligence (Ghotbaldini et al. 2019). Thus, this review aimed to enhance Smart Farming (SF) efficiency through IoT technologies. Continuous monitoring of plants is necessary to detect and address any pests or diseased plants promptly. Utilizing Machine Learning (ML) (Xian & Ngadiran 2021), Deep Learning (DL) (Kotwal et al. 2023), and the Internet of Things (IoT) (Mamdapur et al. 2019) would be the optimal solution for promptly identifying plant diseases, enabling the swift implementation of efficient treatments and adequate irrigation without human participation with biotechnology (Zoran et al. 2022). The globe has been greatly influenced by technological progress, which has introduced precise crop control, sophisticated equipment, and the collection of valuable data from detectors. These automated methods can effectively solve a wide range of issues.

The use of IoT can play a crucial role in the adoption of Smart Farming (SF) techniques and in enhancing farming efficiency (Guo et al. 2020). By leveraging the IoT and integrating ML algorithms, monitoring agricultural operations and achieving increased crop yields efficiently is possible (Orchi et al. 2021). To tackle specific challenges encountered in the farming industry, such as water scarcity and the accessibility of arable land, it is imperative to embrace cutting-edge technologies and methodologies. By 2050, it is projected that the global population will experience a 70% growth. There is a growing demand and utilization of resources. The IoT can effectively and efficiently address these issues by utilizing resources with minimal effort. The IoT is crucial in implementing SF. It utilizes specialized sensors to accurately monitor crop growth, soil moisture, and feed for livestock levels with biotechnology (Capell et al. 2020). This data is then used to operate and manage IoT-connected harvesting and irrigation equipment effectively. The IoT minimizes human labor and effectively monitors and precisely regulates agricultural fields through sensors. IoT devices have demonstrated their indispensability in intelligent agriculture (Veerasamy & Fredrik 2023). Many technical deficiencies persisted, yet they proved crucial in resolving the primary challenges encountered in the SF industry. Smart farms have achieved lower rates of water and power use, resulting in increased agricultural yields compared to conventional farming methods (Davarpanah et al. 2016). The soil condition and plant vitality were closely tracked, resulting in the diligent upkeep of the farming fields as prompt action was taken upon identifying any problems (Mantova et al. 2021). There is a need to save agricultural areas by employing innovative procedures rather than relying on conventional methods that could be more effective and productive. Accurate detection of plant infections is crucial in agriculture. The identification of plant disease is essential for the preservation of plant health. Identifying plant diseases in an early stage can lead to a substantial increase in both the quality and quantity of crop yield. SF has successfully utilized various advanced technologies, including ML, DL image processing, and IoT, with biotechnology to achieve the desired results.

The SF project presents a technique for collecting up-to-date data from farms and then alerting agriculturalists. To guarantee soil health, the device supplies farmers with essential soil information, moisture, temperatures, and nutrient levels. It enhances agricultural yields. The study presents an SF method that utilizes sensors to collect necessary information for crop cultivation in SF. The state of the farmland is upheld according to the data provided by the detectors. The data gathered can be used to make the necessary improvements. A sophisticated smart irrigation system is constructed using IoT technologies and an ML approach with the K-Nearest Neighbors (KNN) method (Amassmir et al. 2022). The primary objective of the smart irrigation system is to ensure optimal water supply for crops by considering the soil's moisture levels and weather conditions (Surendar et al. 2024). This aims to prevent both excessive and insufficient watering without the need for human involvement (Angin et al. 2020). The throughput is significantly high, while power consumption is lower than usual. Implementing a framework for detecting plant diseases was completed (Albattah et al. 2022). The process of acquiring images, preparing them, dividing them into segments, and extracting features was included to achieve precise detection. Following the procedure, it can accurately determine if the plant is in a state of good health or if it has been impacted. A novel DL approach was suggested for detecting plant diseases (Upadhyay & Kumar 2022). Leaf images were employed for detection in SF with biotechnology. The classification was taught using crop leaf pictures to differentiate the illness correctly (Camgözlü & Kutlu 2023).



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The study introduces a sensor cloud-based intelligent irrigation system designed for SF (Jayalakshmi & Gomathi 2020). Considering environmental conditions, an IoT-based intelligent system has been developed to efficiently monitor and irrigate agricultural regions. A cloud-based automated system was presented, which sends notifications to farmers via a mobile application when soil moisture levels drop below a certain threshold, indicating the need for irrigation (Sarpal et al. 2022). The deployment of this system increased the blossoming of flowers and the size and quality of fruits and vegetables. SF necessitates the uninterrupted presence of the Internet. The rural areas of developing countries need to meet these standards. Creating a reliable internet connectivity for implementing IoT in SF practices is necessary. Malfunctioning sensors or data processing engines might result in erroneous judgments, leading to excessive water usage and squandering resources. Proficiency in the procedures and methods utilized in SF-based technology with biotechnology is necessary for farmers to operate and use such equipment effectively.

**IoT-based Smart Farming Applications**

The suggested IoT-based smart farming model, depicted in Figure 1, has two primary modules. The proposed system consists of two fundamental components: the soil-monitoring component and the pest-detecting component. The soil monitoring component has various sensors, including the DHT11, soil moisture, and flow sensors. These sensors are used to measure the water content in the soil and assess the soil's scenario by monitoring temperatures, moisture, and humidity levels with biotechnology. It assists in determining the amount of water the soil needs for irrigation. A suggested automated irrigation method seeks to preserve water and power supplies by preventing excessive watering. This system consists of multiple modules, with the first component being the initial component. The soil surveillance component detects soil moisture content through various sensors and utilizes the ML and DLs methods to analyze the detector input information. A predictive model is constructed and trained to accurately determine the optimal amount of water needed for irrigation, considering specific needs with biotechnology. Once the algorithm calculates, the water pump is triggered, and the irrigation process is carried out accordingly. The pest detection module receives crop leaf photos as input. The system employs image processing methods and ML techniques to ascertain the presence of plant diseases in plants. The DL method is used to categorize pests to facilitate the implementation of appropriate measures to eliminate them and safeguard the health of plants with biotechnology. ML methods were utilized to identify plant illnesses precisely. The ML method was employed for categorization, while the ML method served as the decision boundary to ascertain the presence of plant infection. The input photos



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underwent preprocessing, followed by the extraction of appropriate characteristics. The methods were implemented to diagnose the disorders accurately.

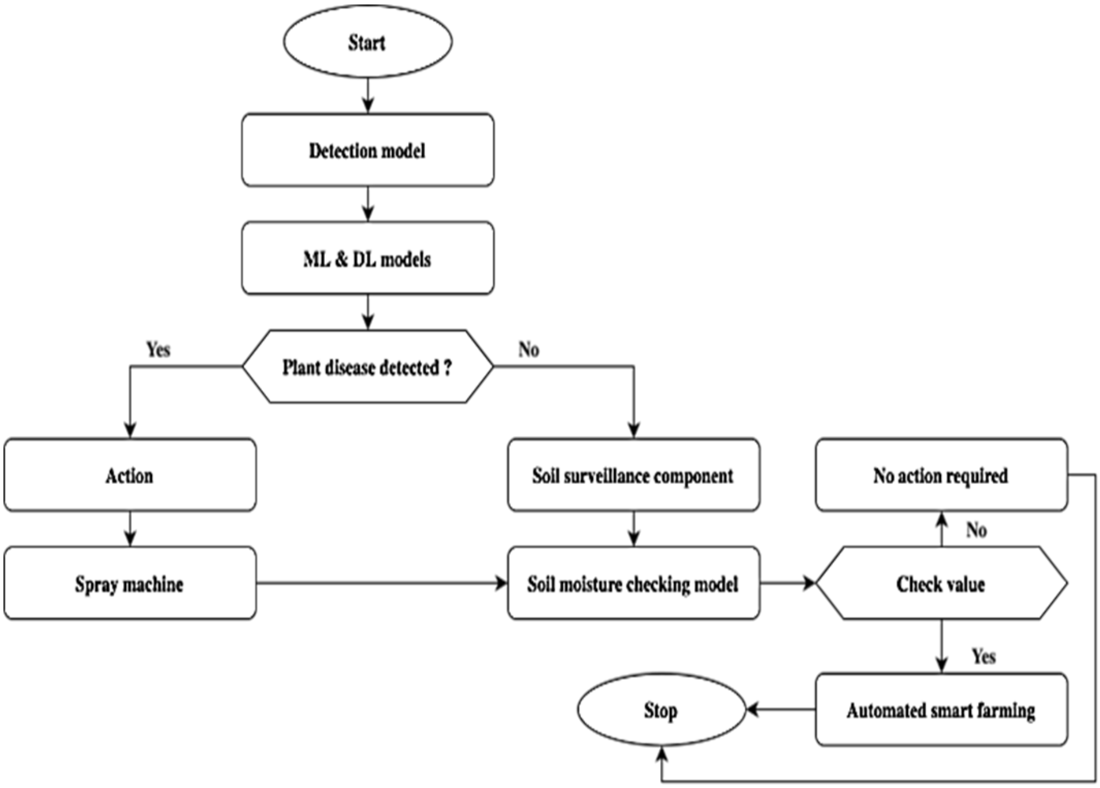


**Figure 1. Workflow of the proposed smart farming research**

The soil monitoring component is equipped with various sensors, including the DHT11 detector, soil moisture detector, and flow detector, as depicted in Figure 2. These sensors are used to measure the water content in the soil and assess the soil's scenario by tracking temperature, moistness, and moisture levels with biotechnology. It aids in determining the amount of water the land needs for agriculture. The suggested system is comprised of two primary components in its design. The proposed system consists of two fundamental components: the soil surveillance component and the pest-detecting component. The initial component of the system provides a sustainable method for effectively irrigating the lands by utilizing the ML method to accurately forecast the precise amount of water needed. It automatically supplies the appropriate amount of water to the fields at the proper time without human involvement. The component distributes water based on the specific water needs of the crops. A predictive model is constructed using the sensor data collected from the detectors. This model is utilized with biotechnology to determine the crop's optimal water needs accurately. Irrigation is carried out at the appropriate moment, a task that cannot be accomplished manually. Deploying this automatic irrigation method can



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significantly minimize water consumption compared to manual farming. The soil surveillance component detects soil moisture content through various sensors and utilizes the ML method to analyze the sensor input information. A model is constructed and trained to forecast the optimal quantity of water needed for agriculture accurately. The water pump is triggered, and irrigation is performed according to the specified needs with biotechnology. The system is coded utilizing an Arduino microcontroller, minimizing power usage.

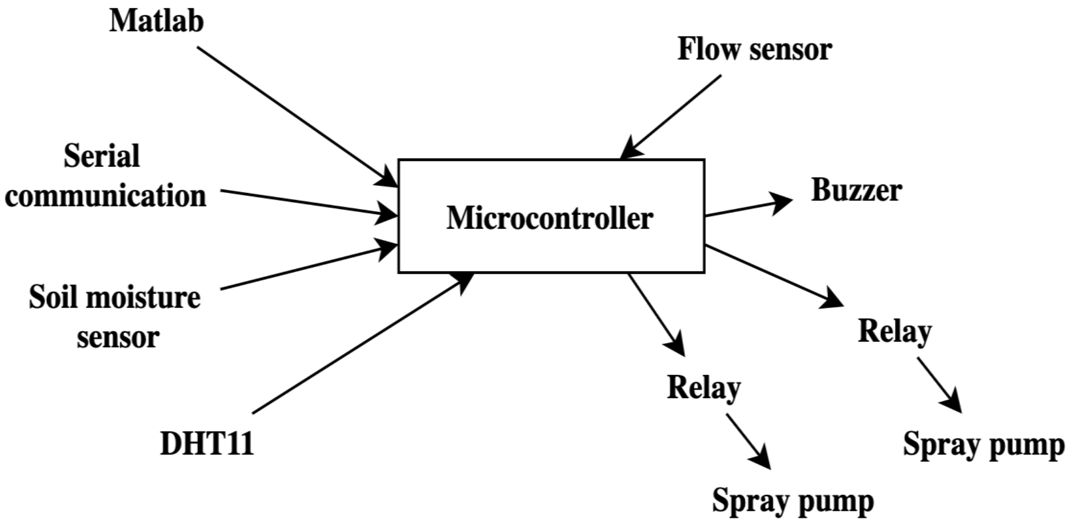


**Figure 2. Block diagram of the smart farming algorithm**

The soil surveillance component in the system suggested consists of a sensor network used to acquire the soil moisture content. The data acquired from the detectors were utilized to estimate the variables that controlled the requirement for irrigation. The ML method is applied to the sample data acquired from the sensors for the intent of training. With biotechnology, it can correctly forecast the precise amount of water needed. The input information is categorized into highly unnecessary, moderate, and essential. Automatic irrigation is implemented when required, taking into account the water needs. It made a reasonable choice for a sufficient level of agriculture, thus preventing excess watering that cannot be accomplished manually.

## Analysis and Outcomes

This section examines the ML and DL algorithms employed by different investigators in the SF system. The global agriculture business is encountering numerous obstacles. Implementing a knowledge-based agricultural system enables farmers to utilize resources sustainably and maximize agrarian output from the available land. SF consists of two fundamental phases: the pre-processing step and the manufacturing stage with biotechnology. During the pre-processing stage, an analysis of market developments is conducted to choose the most suitable seeds depending on geographical circumstances and soil attributes.

The field is set up to accommodate the SF system. During the post-processing phase, machine vision methods are employed to identify diseases and weeds, while intelligent approaches are utilized for irrigation and harvests. The research conducted a survey and analysis of 70 articles that present various ML methods used to optimize the efficiency of the SF process with biotechnology. Figure 3 depicts the categorization of articles according to multiple uses of SF.

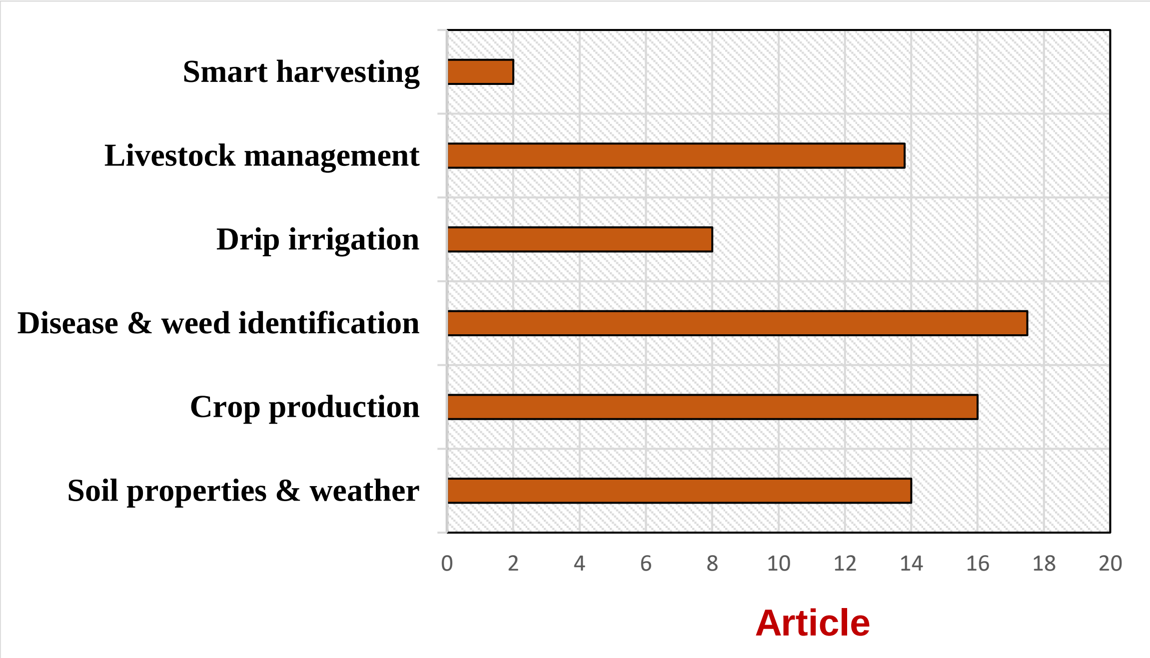


**Figure 3. SF cycle categorization analysis**

Figure 4 illustrates the cumulative distribution of ML algorithms employed by research in SF. The result represents the general classification of techniques and their specific applications throughout farming. A common trend in the literature is using numerous methods for categorization and variable prediction. Researchers commonly utilize regression equations and Artificial Neural Networks (ANN) in approximately 65% of their applications of Artificial Intelligence (AI) approaches. Examining the methods employed and contrasting them is crucial. Figure 8 illustrates how the different ML and DL frameworks are distributed in the literature. The Ensemble Learning Method (ELM) is extensively studied for predicting soil variables, including soil moisture, temperatures, surface humidity, and more. The hybrid model effectively forecasts the precipitation and agricultural output in various geographical areas worldwide. A DL-based

Convolutional Neural Network (CNN) model is widely used to accurately classify diseases and weeds in crops.

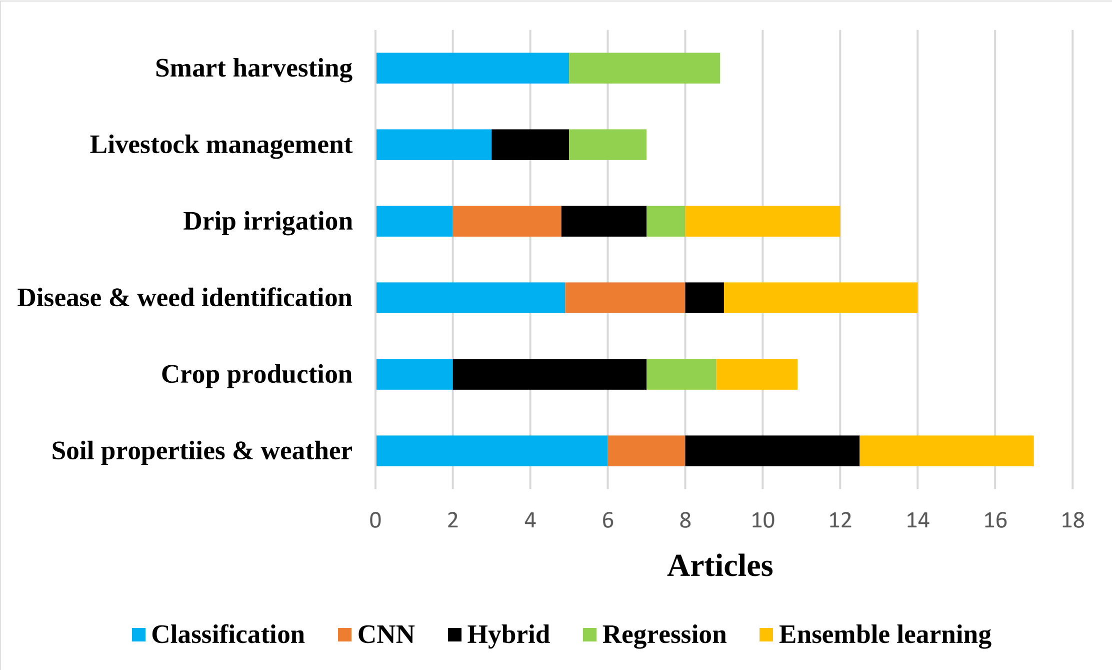


**Figure 4. ML model analysis**

The regression model accurately predicts the nitrate level and water needs in a drip irrigation scheme. The SVM (Support Vector Machine) technique predicts the emission outflow discharge based on different temperatures and pressure circumstances with biotechnology. The Decision Tree (DT) method effectively identifies chewing behaviors and predicts Subclinical Mastitis (SCM) in dairy animals. CNN has extensively investigated the use of livestock detection. Research in SF investigates the utilization of metaheuristic-enhanced ML techniques.

The examined studies have employed around 22 distinct techniques for prediction. Table 1 shows the identification of the five most frequently utilized methods (Random Forest (RF), Artificial Neural Network (ANN), K-nearest neighbors (kNN), Support Vector Machine (SVM), and Extreme Gradient Boosting (XGB)) with biotechnology. The other 17 methods, used solely for comparison or deployed as support methods, have been categorized as "others."

DL models have made substantial contributions and have surpassed ML categorization methods in accurately classifying crop illnesses, weed presence, and livestock illnesses. Table 2, depicts the utilization of CNN, ANN, Backpropagation Neural Network (BPNN), and Recurrent Neural Network (RNN) techniques in SF. The studies have employed around ten distinct ML/DL techniques for prediction and categorization. Table 2 highlights the nine most frequently utilized methods. These methods are used solely for comparison or serve as supporting methods.

**Table 1. Regression analysis**

| Methods | Regression (%) |
|---|---|
| RF | 18% |
| ANN | 5% |
| KNN | 11% |
| SVM | 18% |
| XGB | 12% |
| Others | 36% |

**Table 2. ML/DL analysis**

| Methods | Usage (%) |
|---|---|
| RNN | 8% |
| BPNN | 5% |
| CNN | 9% |
| ANN | 17% |
| Resnet | 15% |
| Densenet | 12% |
| Googlenet | 16% |
| Alxenet | 5% |
| others | 13% |

**Conclusions:** Farmers and agricultural firms are adopting the IoT for data analysis and enhanced production capacities to fulfill this requirement. The field of smart controlled farms is a prominent topic of study, with great potential due to the outcomes of several technological advancements in SF with biotechnology. The study examines the typical survey of SF initiatives and their diverse specifications. This research analyzes the advantages and disadvantages of implementing SF. The categorization of gadgets, communication techniques, media, computations, services, and security provide a comprehensive and efficient analysis of related technology. This research acknowledges many prospective approaches and addresses problems with analyzing SF with biotechnology. Progress in agricultural technology will lead to the standardization of smart machinery, enabling the seamless integration of diverse devices and add-ons. This framework will be beneficial for other domains. The variables and information acquired will be highly valuable for agricultural research experts, soil investigators, and food technology study academics. In the future, multiple vendors will support Smart Farms in streamlining and



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maximizing farming operations and obtaining necessary services. With biotechnology, incorporating an SF can enable government agencies to address farmers' worries and ensure crop sustainability. The future prominence of SF is expected to soar because of the advanced infrastructure and amenities it offers to benefit farmers and the advancements in agriculture.

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**Conflict of Interest:** There is no conflict of Interest.

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انجمن بیوتکنولوژی ایران

# بررسی سیستماتیک کاربردهای کشاورزی هوشمند مبتنی بر اینترنت اشیا با بیوتکنولوژی

**کاملش کومار یاداو**

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## چکیده

**هدف:** این مطالعه فناوری و نرم افزار را ترکیب می‌کند تا به کشاورزان اجازه دهد پارامترهای مزرعه خاصی را در زمان واقعی ردیابی و تغییر دهند. همراه با بررسی سریع تعامل بین پایش ایستگاه های هواشناسی و ثبت داده های تلفن همراه، مطالعه‌ای در مورد کشاورزی هوشمند (SF) بر اساس اینترنت اشیا (IoT) ارائه می‌دهد. اینترنت اشیا (IoT)، با برجسته کردن پیشرفت‌های فن‌آوری، فناوری اطلاعات و ارتباطات و روباتیک، مراکز تحقیقاتی بر روی دستگاه‌های چند رسانه‌ای، روش‌های ارتباطی، حسگرها و سیستم‌هایی که اغلب در نظارت بر SF استفاده می‌شوند نقشی اساسی در دوام بخش کشاورزی در سال‌های آینده ایفا خواهد کرد. به منظور حمایت از محققان آینده و ایجاد زمینه برای ایجاد سیستم‌های نظارت خودکار SF مبتنی بر اینترنت اشیا که بیوتکنولوژی را در بر می‌گیرد، این مقاله روش‌های مورد استفاده در این زمینه را شرح می‌دهد. این پروژه با هدف افزایش کارایی کشاورزی هوشمند (SF) از طریق فناوری‌های اینترنت اشیا، تمرکز بر روش‌ها، فرآیندها و ابزارهای نظارت برSF، ادغام بیوتکنولوژی برای بهبود تولید و پایداری، و برجسته کردن نقش فرآیندهای خودکار و روبات‌ها در راه‌حل‌های کشاورزی مبتنی بر اینترنت اشیا انجام شد.

**نتایج:** این مطالعه ثابت می‌کند که اینترنت اشیا (IoT) در کشاورزی معاصر بسیار مهم‌تر می‌شود و در نتیجه پیشرفت‌های فن‌آوری، فناوری اطلاعات و ارتباطات (ICT) و روباتیک از شیوه‌های کشاورزی مرسوم بهتر عمل می‌کند. ادغام اینترنت اشیا (IoT) در SF با امکان نظارت بر شرایط و اصلاح در زمان واقعی، بهره وری را افزایش می‌دهد. با توجه به نتایج، حسگرها و سیستم‌های ارتباطی، در ارتباط با فناوری اینترنت اشیا، امکان مدیریت خودکار و دقیق وظایف کشاورزی را فراهم می‌کنند. سیستم‌های ثبت داده‌ها و

دستگاه‌های چند رسانه‌ای برای جمع‌آوری و تجزیه و تحلیل داده‌های کشاورزی به خوبی با هم کار می‌کنند، که تصمیم‌گیری کشاورزی را بهبود می‌بخشد و نتایج بهتری را به همراه دارد.

**نتیجه‌گیری:** اینترنت اشیا (IoT) این پتانسیل را دارد که ماهیت کشاورزی را با تسهیل توسعه روش‌هایی که سازنده‌تر، دقیق‌تر و سازگار با محیط زیست هستند، به طور کامل تغییر دهد. اعتقاد بر این است که کشاورزی هوشمند همچنان به پیشی گرفتن از شیوه های کشاورزی مرسوم از نظر محبوبیت با پیشرفت فناوری ادامه خواهد داد. سیستم‌های کشاورزی کارآمدتر و خودکار نتیجه ادغام مؤثر اینترنت اشیا (IoT)، بیوتکنولوژی و روباتیک خواهد بود. این تحقیق اطلاعات مهمی را برای مطالعات آینده در مورد بهبود نظارت SF از طریق اینترنت اشیا (IoT) فراهم می‌کند. به طور کلی با معرفی روباتیک و اتوماسیون نویدهای زیادی برای آینده کشاورزی و بهره وری بالاتر در صنعت کشاورزی وجود دارد.

**واژه‌های کلیدی:** اینترنت اشیا، بیوتکنولوژی، کشاورزی هوشمند، مانیتور

**نوع مقاله**: مروری.

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