International Research Journal of Commerce and Law
Volume 5 Issue 10, October 2018 ISSN: 2349-705X Impact Factor: 4.616
Journal Homepage: http://ijmr.net.in, Email: irjmss@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal

Innovative Approaches in Greenhouse Technology: A Critical Analysis of Spectral Data for Enhanced Plant Growth Monitoring

Prof. Takale Dattatray Gopal, Prof. Bere Sachin Sukhadeo,Prof. Rajpure Amol Subhash, Prof. Amrit Priydarshi, Prof. Dhage Shrikant Narhari,

Dattakala Shikshan Sanstha “Dattakala Group of Institution” Swami-Chincholi, Daund, Pune, Maharashtra 413130. India.*Abstract*— The Greenhouse Monitoring System, grounded in image spectral data analysis, represents a pivotal advancement in agriculture technology. This research paper undertakes an extensive review of diverse literature surveys encompassing various technologies employed in greenhouse monitoring. The system's primary objectives include enhancing plant harvest phase tracking, implementing effective plant disorder identification, and facilitating meticulous plant growth monitoring. Recognizing the pressing issues of plant diseases, harvest wastage, and costly maintenance in greenhouse operations, the proposed system aims to substantially impact the maximization of yields and minimization of operational costs. Leveraging the insights gleaned from the literature surveys, this paper highlights the evolution of technologies and methodologies employed in greenhouse monitoring, emphasizing the need for advanced, automated solutions to address the challenges in contemporary agriculture.

Keywords—Greenhouse Monitoring System, Literature Reviews, IoT,

I. Introduction

The Greenhouse Monitoring System presented in this research paper addresses critical challenges in greenhouse management, focusing on plant harvest phases, disease identification, and plant growth tracking through image spectral data analysis. The system aims to mitigate plant disorders, harvest wastage, and expensive maintenance, maximizing harvest yields and minimizing greenhouse operational costs. Given the significance of agriculture in the Indian economy, where almost 50% of the workforce is employed in the sector and contributes to 16% of the country's GDP, efficient disease detection becomes paramount to ensure crop health and productivity. Historically, plant disease detection relied on manual methods by experts in the field, leading to time-consuming processes and increased chances of misdiagnosis due to reliance on the naked eye. The introduction of chemical pesticides, while intended to protect plants, often caused harm to other beneficial organisms and posed risks to crops and human health. Recognizing the limitations of manual monitoring, the proposed Greenhouse Monitoring System utilizes image spectral data for early detection and diagnosis of plant diseases. This approach enhances accuracy and enables proactive measures to prevent losses.

The research emphasizes the importance of identifying and diagnosing diseases at their initial stages to facilitate timely intervention. The conventional types of plant diseases, including bacterial, fungal, and viral infections, are discussed. These diseases can affect various parts of the plant, ranging from leaves to fruits, based on the severity of the infection. The Greenhouse Monitoring System offers a technological solution to improve disease detection, plant health management, and overall greenhouse efficiency. By leveraging image spectral data, the system provides an automated and accurate method for monitoring and diagnosis, reducing reliance on manual efforts and minimizing the adverse effects of conventional pesticide use. The study contributes to the field by addressing the crucial need for advanced monitoring systems in agriculture, especially in greenhouse cultivation.

II. Literature Reviews

A. System based on WSN

Protecting crops from harmful surroundings effectively requires an automated system to monitor and adjust the greenhouse microclimate. Using sensing devices and actuators for manual management in large-scale greenhouse facilities may be more viable. The interconnectedness of microclimatic variables, such as humidity, temperature, and sun irradiance, creates a non-linear multivariate system. Sensors placed at a height above plants give precise data on the surrounding environment, according to studies conducted on greenhouse microclimate monitoring throughout the past six years. Both hardware and software-based sensing methods work well when it comes to controlling the microclimate in a greenhouse. The sensors' location and protection from environmental variables are of utmost importance. According to modern sensor gadgets, an intelligent, completely automated system that can be remotely accessed in real time is the future of greenhouse monitoring. [1]

Modern innovations in greenhouse technology have pushed scientific solutions forward for optimal plant production year-round by modifying internal environment-growing elements such as CO2 concentration, light intensity, humidity, and temperature. Solar greenhouses are a solution to the problem of food insecurity on a worldwide scale by improving crop yields and quality. This paper provides a synopsis of the most recent developments in building design, technology for managing greenhouse microclimates, and the different solutions that are currently available. As a first step, it breaks out the various greenhouse processes based on climate, direction, and cladding material. Additionally, this research delves into the several control techniques, sensing networks, and wireless gateways utilized in greenhouse monitoring systems. The review's last section detailed the method for controlling the greenhouse's temperature. This research shows that choosing the right greenhouse geometry, orientation, and covering material creates an ideal environment. A well-planned approach to controlling and managing the climate is crucial in obtaining high crop yield while reducing energy consumption and costs.[2]

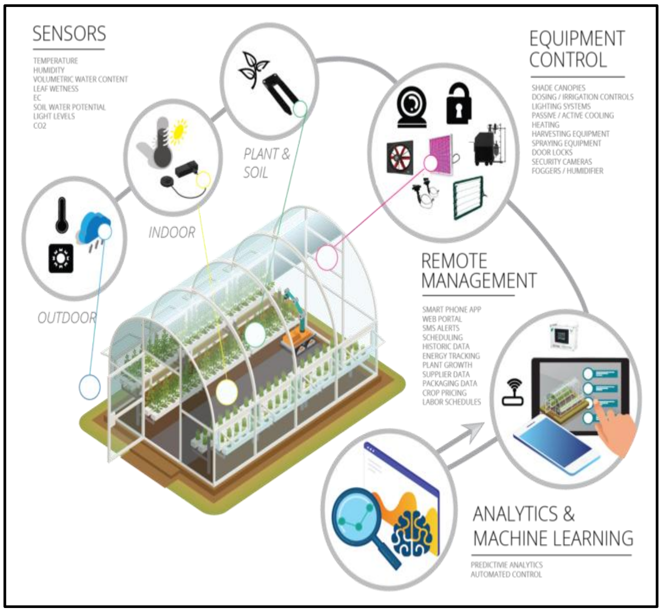

Fig.1 Smart Greenhouse

Scientists still find it unusual to use a multidisciplinary approach, particularly when studying seemingly unrelated topics like computer science and agronomy. We intend to construct a cutting-edge greenhouse with a floating ebb and flow system for future scientific investigations. The goal is to build a greenhouse that can run independently using sensors, cloud computing, and AI to interpret data and make real-time decisions. Looked at several methods and came up with a great one that could be used for future studies on how plants develop in floating ebb and flow systems. In addition, it suggests a strategy for estimating plant health using artificial intelligence instead of human knowledge based on sensor data. Estimating the state of the plants may extend the ebb periods and boost the nutrient content of the end product. Intelligent design and AI algorithms will improve the usability and reliability of plant research data while decreasing the cost of the study itself. Because of this, the research and production of plants would benefit more from the recently constructed greenhouse.[3]

Environmental monitoring with field-deployable hyperspectral imaging devices is a promising new direction that can transform many sensing applications in the next decades. This article delves into successfully miniaturizing and making hyperspectral sensors more portable. It looks at how these sensors are used in various environmental applications, both from above and below ground, and how recent developments in low-cost consumer technology have contributed to this trend. For now, these devices mostly work in tandem with other monitoring methods, but with the rapid advancement of technology, these units will soon be able to function independently. These small, lightweight, and inexpensive sensors already deliver high-quality scientific results;

now, they can make hyperspectral monitoring technology more accessible and increase the proliferation of datasets in this area.[4]

The world's food supply and ecological stability are in jeopardy due to climatic and socioeconomic crises. Smart farming (SF) that uses sensor, robotic, and ICT advancements is an encouraging strategy for more effective, long-term, and financially rewarding crop production. This article covers the background requirements for SF and the function of remote sensing. This article reviews the most recent developments in remote sensing technologies, including platforms, sensors, and algorithms, for diagnosing crops and soils by analyzing several prominent case studies. Agricultural regions with relatively small farmlands can benefit from the constellation of satellites since their operation enables timely or regular observations with a spatial resolution of 1 ~ 10 m. Utilizing high-resolution satellite sensors effectively will greatly enhance regional SF diagnosis and decision-making. With drone-based remote sensing, low-cost, high-resolution, and adaptable crop and soil studies are possible. It is possible to extract diagnostic data from thermal, optical, and video pictures related to crop development, water stress, soil fertility, weeds, diseases, lodging, and three-dimensional topography. Integrating remote sensing with drone-assisted seed, pesticide, and fertilizer application would substantially improve labor and material application efficiency and profitability.[5]

The most current developments in drone technology for precision farming are described in this research proposal. The article primarily covers two aspects of precision agriculture drone applications: crop monitoring and pesticide spraying. Specifically, focused on modifying drone designs, creating data-gathering sensors, improving pesticide-spraying drones, incorporating deep learning, and using AI for remote crop monitoring. After 2017, there was a noticeable increase in the use of drones for precision agriculture. The decrease in weight, cost, and increase in payload capabilities of UAVs are the reasons behind this. Drones with several propellers and fixed wings are the most common for agricultural and animal detection purposes. The size and price of these drones are steadily decreasing over time. The large payload capacity of unmanned helicopters makes them ideal for spraying fertilizer or pesticides. Nevertheless, multi-copters are being used more and more for spraying pesticides. Due to their greater flying stability, multi-copters are superior to single-rotor aircraft in spot spraying. The size, weight, and resolution of drone cameras have come a long way. As the need to extract additional features grows, cameras are moving away from RGB and toward multi-spectral sensors.[6]

A well-designed and constructed smart greenhouse control system should result in faster, more abundant harvests of healthier crops. This equipment is perfect for amateurs and small-scale farmers, so it is easy to see how it may be commercialized. With this project, effortlessly cultivate plants in a greenhouse, as the system automatically performs parameter checking. For those who prefer to grow their food on a smaller scale, a smart greenhouse project can serve as an indoor plantation for residences or a tiny nursery. It can also be utilized for growing medicinal herbs, necessitating meticulous eco-culture monitoring because of their delicate nature. Plant species in danger of extinction can also benefit from this technology by having an artificial habitat built specifically for them.[7]

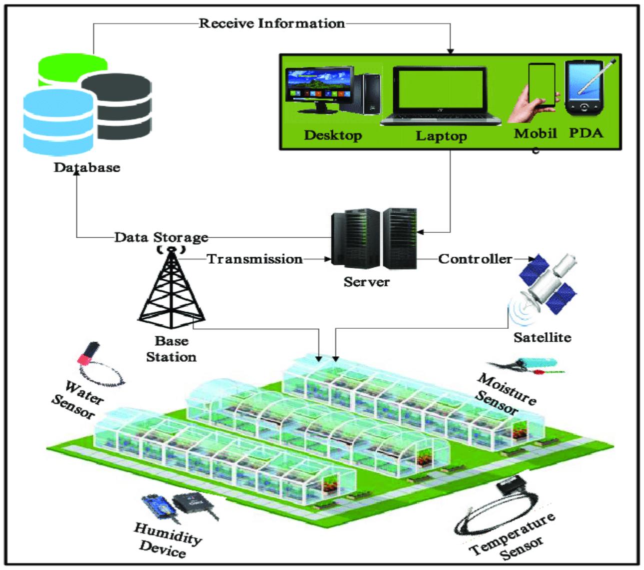

Fig.2 WSN Monitoring Greenhouse

Recent advancements in precision agriculture have significantly enhanced the efficiency of agronomic inputs through spatially variable applications. This progress is primarily attributed to innovations leveraging technologies like remote sensing, IoT, robotic systems, weather forecasting, and GPS. Integrating remotely sensed multisource data, including HSI and LiDAR, allows detailed monitoring, even at the level of individual plant sections. Despite the wealth of agricultural remote-sensing technologies, few comprehensive overviews are available, particularly for students and researchers. This article serves as a valuable resource by providing a discipline-specific introduction to remote sensing methods for field crop monitoring using spectrum imaging. The content offers a detailed exploration of various technologies, emphasizing benefits and drawbacks to aid readers in selecting optimal solutions based on specific needs.[8]

The purpose of this research is to provide a comprehensive review of the algorithms that have been suggested for using proximate pictures of cereal crops to estimate five important growth indicators. Crop growth monitoring might be made faster and more accurate using high-resolution in-field digital imagery. Nevertheless, LAI estimation still needs additional study. Little research has focused on development stage estimation using photos up until now. Literature reviews reveal numerous unresolved issues, such as a need for more resilience to changes in picture capture or cropping parameters. In addition, expanding the range of growth stages covered by all metric estimate methodologies is essential. These problems may be amenable to new developments in image processing. However, the optimal application of these methodologies to agricultural growth monitoring is still much debated.[9]

As a proof of concept, provide a case study that shows how a PA system based on WSN was implemented. This proposed smart system for crop health monitoring is built around the IoT and consists of two modules. The main component is a system that monitors crop health in real time using a network of wireless sensors. The second module requires collecting multi-spectral images using a remote sensing platform at a low height. Then, they are processed to identify healthy and unhealthy crops. This work typically includes a summary of the case study's findings, a discussion of the difficulties encountered, and recommendations for moving forward.[10]

B. System Based on Deep Learning

Scientists have recently focused on the problem of automatically identifying diseases using hyperspectral pictures as a major obstacle to sustainable farming. So far, the extent of the technologies and methodologies that have been accepted is limited, and they are completely dependent on deep learning models. Convolutional neural networks quickly become the gold standard for crop image-based infection diagnosis and prediction. This article briefly overviews several current neural network approaches to processing picture data, focusing on detecting crop diseases. To begin, look back at the various imaging data sources, deep learning models and architectures, and image processing methods that went into processing the data. Secondly, the study emphasized the outcomes of evaluating several deep learning models that are already available. Lastly, it touched on the potential future applications of hyperspectral data processing. By enhancing system performance and accuracy, this survey will pave the way for future studies to understand more about the deeper potential of deep learning in plant disease detection.[11]

Worldwide, greenhouses have been a game-changer for farmers. Maps of greenhouses created using high spatial resolution (HSR) satellite imagery are crucial for estimating vegetable production. Despite the existence of automatic greenhouse mapping tools, their use is mostly restricted to small-scale regions. The challenges of large-scale greenhouse mapping, on a national level, include the distribution of greenhouses in dense locations, the difficulty of extracting both the number and area of greenhouses simultaneously, and the diversity of greenhouses in different places. The dual-task learning module takes two branches—one for extracting the area of greenhouses and another for extracting their numbers—and employs them both simultaneously. To improve the trained model's performance in dense greenhouse extraction. The six regions of China that were tested out outperformed Faster R-CNN by 1.8% in terms of mean average precision (mAP). Lastly, gathered 1-meter spatial resolution remote sensing image tiles from all over China and used the entire country as a research area. A separate sensor took each picture and then either bought or downloaded from an open-source website. According to the findings of the experiments, China harvested about 13 million greenhouses.[12]

Chinese cities often have plastic greenhouses (PGs) constructed to grow fruits and vegetables. Many remote sensing techniques can detect and track the spread of PGs; many of these techniques use spectral responses and geometric forms to map PGs, which can help with sustainable agriculture, rural landscape development, and water resource management. Here are the main points from the results of a pilot region study that used this approach: One finding from a time-series study of Sentinel-2 pictures is that greenhouse reflectance changes as crops mature. Specifically, the red-edge and near-infrared bands show a marked increase followed by a reduction over the whole crop growth cycle. Therefore, to achieve a precise and efficient mapping result, just two photos from the critical period, which showed a significant variation in greenhouse reflectance, were needed. (2) By capturing both the broad trend of the spectra and more nuanced information, the 1D-CNN classifier was employed to map greenhouses. On average, the method outperformed alternatives that used random forests or support vector machines (SVMs) for classification (RF). Furthermore, the kappa coefficient of 0.81 indicates that the detected greenhouse area is congruent with the surfaces shown in extremely high-resolution photos. The narrow band feature variations greatly aided high-precision greenhouse mapping in the two-temporal Sentinel-2 images, namely in the red-edge and near-infrared narrow bands. Compared to maps generated without narrow band features, the categorization accuracy using these features was substantially higher. To facilitate enhanced decision support in agricultural management, this program offered a means of accurately digitizing greenhouses and making their statistics publicly available at no cost. [13]

Provide a structure for spatial convolutional long short-term memory that considers the ground objects' spatial continuity in comprehensive detail. Employ multitask learning to enhance the network's capability to detect picture borders and encourage convergence using auxiliary loss. To improve the main-branch outcomes of network semantic segmentation, provide a superpixel optimization module that uses the more accurate bounds acquired by sophisticated superpixel segmentation methods. This suggested structure can consider geographical information and produce more precise results than other popular methods. Using remote sensing photos taken by the Gaofen-1 satellite, a novel greenhouse dataset was constructed and focused on research on Shandong Province in China. This approach outperformed state-of-the-art semantic segmentation networks with an F1 score of 77% and could extract greenhouse data with more accurate borders. These suggested modules demonstrate promising greenhouse extraction results and a large-scale greenhouse mapping project for Shandong Province was finished.[14]

C. **System based on the Internet of Things**

Internet of Things (IoT) devices can gather massive volumes of data on soil, crop performance, and the surrounding environment. This data can be used to create time series models, which can then be used to make predictions, calculate recommendations, and provide real-time critical information to farmers. Concurrently, a working model of an electric valve (coordinator), an interface app, and a robotic greenhouse control system based on the Internet of Things (IoT) were developed. The device is called a cable box. After the system's functionality was tested, it is now being put in a greenhouse that belongs to the University of Patras's Agriculture Department. Automated smart irrigation is just one of many autonomous activities that this system can perform, and it can also gather a variety of data sensitive to crops.[15]

An intelligent greenhouse monitoring system is the target of this paper's systematic review through identifying, listing, and further explaining greenhouse environmental parameters and examining the system's overall design. Data transport and server processing subsystems will also benefit from it. This article provides a synopsis of the intelligent monitoring system's current and future popular technologies. Supports research on greenhouse monitoring systems by comparing and contrasting the system's components depending on their features. Effective greenhouse control is achieved through multi-parameter monitoring, and wireless technology is progressively replacing cable mode for data transfer in indoor and outdoor environments. It is worth mentioning that cutting-edge technologies such as deep learning and big data have been integrated into greenhouse monitoring systems. These advancements have proven valuable, as they have helped refine unmanned greenhouse management and enhance the energy efficiency of greenhouse construction. [16]

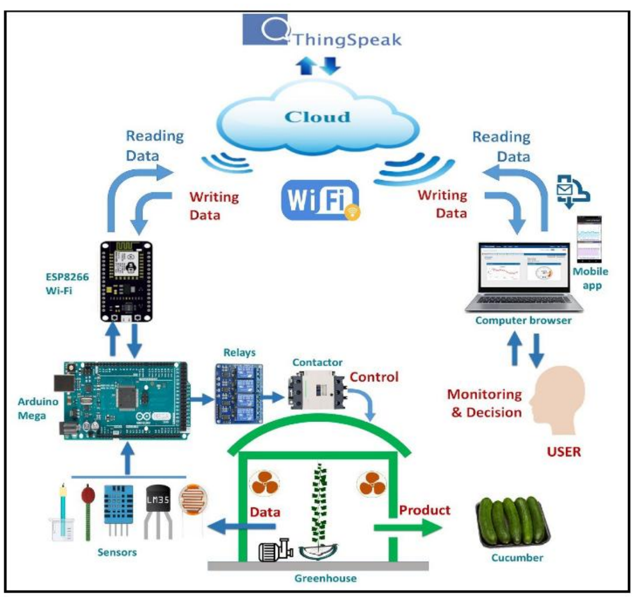

Fig.3 IoT-Based Greenhouse

Increased harvest yields are possible with the use of greenhouse technology. Optimal and maximal plant growth is still within reach, thanks to the fast-moving technological developments in food production and agriculture. Even in this day and age of Android smartphone apps, a precise method would cause a shift. One recent development in the realm of information and communication technology is the Internet of Things (IoT), which enables the worldwide communication and management of devices, sensors, and users through the provision of data. This paper proposes an IoT system for controlling and monitoring greenhouses. An LCD module, a 12-volt DC fan, an electric bulb, the water pump motor, a servo motor, air quality sensors, soil moisture sensors, Light Dependent Resistors (LDR) sensors, and an electric bulb are also part of it. Online data collection from environmental parameters can be sent to farmers' cell phones through the IoT platform. This allows them to make informed decisions even when not physically present in the field.[17]

This study applies the concept of monitoring environmental conditions and irrigation systems within a greenhouse setting to detect leaf diseases. Both the prototype and the analysis of the experiment are behaving as predicted. The outcomes were achieved by the predictions made throughout the analysis and experiment. More features can be added to this system in the future, and these suggestions for enhancement will be considered for upcoming updates. [18]

Fig.4 WIFI Greenhouse Monitoring System

. Intelligent systems and remote access technologies, including green infrastructure, are made possible by the Internet of Things (IoT). Utilizing AI and ML-based information systems for efficient real-time training and creating intelligent systems and predictive models inside an organization (AI). As a result, a recommendation for enhancing the needs of greenhouse farming has been made: the Remote Sensing Assisted Control System (RSCS). This approach suggests utilizing AI and ML technologies to improve the potential for green development in the industry's resource management and agricultural product innovation patterns. Therefore, simple recommendations for creating an efficient marketing plan are the essential prerequisites for expanding access to healthy food options and supporting the potential growth of organic farmers on a local and worldwide scale. When compared to other methods, the experimental results show that RSCS achieves the best results in terms of precision (95.1%), performance (96.35%), data transmission rate (92.3%), agricultural production (94.2%), irrigation control (94.7%), lowest moisture content (18.7%), and CO2 emission (21.5%). [19]

This paper presents an intelligent soil management system that utilizes the Internet of Things (IoT) to keep soil in optimum condition for farming and crop production. This is where the integrated IoT platform comes in handy, reading the sensor values regularly. About the energy consumption of the nodes, the longevity and functionality of the IoT platform will differ for every sensor node. As part of this process, the greenhouse's temperature, humidity, and moisture level and take corrective action as needed. As a solution, this methodology allows the agricultural and food industries to obtain information and monitor crop growth. [20]

Greenhouse designs frequently make use of networked wireless sensors. This study presents a concept for two greenhouses based on a Networked Control System. Constructed on top of Wi-Fi and switched Ethernet, this design is based on the Internet of Things. Some require a real-time deadline of one second for the sensors in the proposed design. According to riverbed simulations, there is no packet loss or over-delayed packets. This work contributes significantly to avoiding interference in this big Greenhouse system by designing a channel allocation scheme. The addition of controller-level fault tolerance is another contribution of this study. If one of the greenhouse controllers stops working, the other controller will immediately take over and run the complete system. Riverbed simulations confirm that this fault-tolerant system is completely free of packet loss and over-delay issues. The two-greenhouse system's steady-state availability and dependability are then calculated using Continuous Time Markov Chains. Consideration is given to the Coverage parameter. Last but not least, a case study is offered to statistically evaluate the benefit of fault tolerance in reducing downtime; this is anticipated to be particularly appealing in developing nations. [21]

D. System Based on Imaging Technology

By capturing RGB photos of grapes at different growthphases, a Phenofix plant phenotype-monitoring technology could forecast when grapes will be ready to be picked in solar greenhouses. This study used PCP indicators to determine the different phases of grape ripening using a back-propagation neural network algorithm (BPNN) and skin color data. With 79.3% recognition accuracy for Drunk Incense, 78.2% for Muscat Hamburg, and 79.4% for Xiang Yue grapes, the combination of color values, horizontal diameter, and compactness produced good prediction accuracy. The two-factor combination strategy has proven the most effective when predicting when grapes will be ready to harvest in a greenhouse.[22]

This article outlines the standard operating procedure (SOP) for analyzing hyperspectral plant data using examples from indoor and outdoor settings. A thorough literature analysis of potential solutions to these errors and influences is presented to describe the sources of these problems fully. This article describes in detail the process of processing hyperspectral data from plants, beginning with hardware sensor calibration and continuing through software processing processes to overcome sensor flaws and prepare for machine learning. A standardized vocabulary for describing hyperspectral properties in plant phenotyping is also established by grouping plant features acquired from spectral hypercubes. Data from spectral and 3D measurement equipment and information on individual organs, plant development, and the canopy as a whole 37 are presented from a scientific data perspective.[23]

This study demonstrates that the proposed methodology can be applied to Sentinel-2 images to detect greenhouses. As a result, this dataset is highly suitable for creating a greenhouse coverage map in the chosen Mediterranean area of Turkey. Using an object-based classification technique, was able to identify greenhouses in Sentinel-2 images correctly. When the proposed method was applied to the case of Anamur District, Mersin, Turkey, a kappa coefficient of 0.64 and an overall accuracy of 74% were reached. Limiting one's attention to greenhouses in a certain area yields encouraging results. Future research can use diverse datasets and classification techniques in various test regions to further enhance the accuracy of greenhouse and surrounding land cover classifications.[24]

E. Based on Different Technologies

This system utilized the WIFI module to carry out software and hardware design for collecting environmental data from greenhouses. The findings show that the sensor module kept working without issues or crashes during the 7-day test, the server software kept running without interruptions or other strange occurrences, the network connection between the two devices was stable, and the transmission performance was good. As a natural occurrence, the shadows cast by buildings during the day could generate unexpected shifts in lighting, particularly in the amount of light available. Another typical occurrence on days without precipitation is the observed inverse relationship between humidity and temperature, as seen in the results. Consequently, this system offers a practical, affordable, dependable option for managing greenhouse production. It allows for the remote wireless dynamic monitoring of environmental variables such as temperature, humidity, light intensity, etc. [25]

Fig. 5 Automated Greenhouse System

In this big data age, intelligent greenhouses are defined in terms of their development trajectory and objectives. Simultaneously, suggest analyzing and designing the greenhouse's intelligent control system using data from both the inside and outdoor environments since there has been little research on the combined effects of current intelligent greenhouses on these two settings. To provide a more stable and appropriate greenhouse environment, the system has the advantage of pre-regulating environmental parameters before they alter beyond the threshold. Meanwhile, to make the program more accessible to farmers, the anticipated values are transformed into grading indicators that are easy to interpret. This study aims to examine the system's potential and build its implementation.[26]

Greenhouses are a significant land use since they enhance agricultural production conditions and boost crop yields. To ensure food security and regional agricultural production, it is crucial to acquire precise and timely data on the geographical distribution of greenhouses. For the most accurate regional greenhouse extraction, it is best to combine spectral, texture, and terrain information; however, these three factors alone are insufficient. Regarding greenhouse remote sensing mapping, spectral features are key, but texture and landscape features can also help with classification accuracy. (3) There is a lot of spatial aggregation and differentiation in the Jiangsu Province greenhouse. Areas with a strong agricultural economy. [27]

This research introduces a novel approach to plastic greenhouse mapping using GF-2 satellite photos in a three-stage process. Even in challenging real-world scenarios, the suggested approach maintains competitive mapping accuracies. The method's stability and universal applicability are demonstrated by transferring it to a different GF-2 image, to a different seasonality and phenological stage, and varied combinations of land use patterns surrounding plastic greenhouses. This technology should thus work well with better spatial resolution photos and in regions with even bigger plastic greenhouses. Using a GF-2 satellite image, the method demonstrates its viability. Spatial inventories of plastic greenhouses for large areas can be conducted using these data despite the need for historical availability. This is made possible by the present method's excellent accuracies, reduced costs relative to the best resolution satellite data, and a wider swath width of 45 × 45 km. [28]

An intelligent control system is developed to regulate the greenhouse's temperature and other environmental variables to increase cultivation efficiency while decreasing management expenses. Using LabVIEW software, connected devices, and peripheral circuits allows growers to monitor crop growth on computers remotely. Just plug the crop species and their corresponding growth stages into the front panel, and the system will figure out how to set up the greenhouse. The system pre-set the buttons on the front panel to switch between automatic and manual control. The results were shown under controlled laboratory conditions. According to the findings, the effect is less than perfect, and the highest parameter error is 8.7 percent. However, it retains some reference value for fields with minimal control accuracy requirements, such as greenhouses, cold chain logistics, aquaculture, etc. [29]

A greenhouse is a structure that houses plants and other organisms under a protective covering, such as a glass or plastic roof or, more commonly, a canopy of verdant nets. The structure grows extremely hot because the plants, bacteria, soil, and other elements within absorb the sun's visible radiation beams. Consequently, the levels of greenhouse gases within the structure rise. The inability to manage two crucial aspects—productivity and plant growth—is why many farmers fail to reap substantial profits from greenhouses. To help farmers overcome these issues, a smart greenhouse monitoring system. The Arduino and Atmega328 microcontrollers provide electricity to the greenhouse monitoring equipment. Automated environmental tracking and management in greenhouses through the use of a Wireless Sensor Network is detailed in this study, along with its design, installation, and operation.[30]

III. Conclusion

In conclusion, the Greenhouse Monitoring System based on Image Spectral Data emerges as a promising solution to the complex challenges of modern agriculture. The literature surveys provided a comprehensive understanding of the varied technologies applied in greenhouse monitoring, revealing a paradigm shift towards more advanced and automated systems. The system's emphasis on early detection and diagnosis of plant diseases and its ability to track plant growth phases positions it as a vital tool for greenhouse management. The integration of image spectral data not only enhances the accuracy of disease detection but also contributes to reducing the reliance on manual monitoring and the potential risks associated with chemical pesticides.

This research underscores the critical role of technological advancements in addressing the intricate interplay of factors affecting plant health and greenhouse productivity. By reviewing and synthesizing existing literature, this paper informs the design and implementation of the Greenhouse Monitoring System, providing a foundation for future research and development in the field. As agriculture continues to evolve, embracing innovative solutions like the proposed monitoring system becomes imperative for sustainable and efficient greenhouse cultivation. The insights from this research contribute to the ongoing discourse on technological interventions in agriculture and pave the way for further advancements in greenhouse management systems.

References

[1] Anil Bhujel, Jayanta Kumar Basak, Fawad Khan, Elanchezhian Arulmozhi, Mustafa Jaihuni, Thavisack Sihalath, Deoghyun Lee, Jaesung Park & Hyeon Tae Kim, "Sensor Systems For Greenhouse Microclimate Monitoring And Control: A Review," Journal Of Biosystems Engineering, 2020

[2] Badji, A. Benseddik, H. Bensaha, A. Boukhelifa, I. Hasrane, "Design, Technology, And Management Of Greenhouse: A Review," Journal Of Cleaner Production, 2022

[3] Davor Cafuta, Ivica Dodig, Ivan Cesar, And Tin Kramberger, "Developing A Modern Greenhouse Scientific Research Facility—A Case Study", Mdpi Sensors, 2021

[4] Mary B. Stuart,1 Andrew J. S. Mcgonigle,2,3,4 And Jon R. Willmott, "Hyperspectral Imaging In Environmental Monitoring: A Review Of Recent Developments And Technological Advances In Compact Field Deployable Systems", Mdpi, Sensors, 2019

[5] Yoshio Inoue, "Satellite- And Drone-Based Remote Sensing Of Crops And Soils For Smart Farming – A Review," Soil Science And Plant Nutrition 2020

[6] Abdul Hafeez, Mohammed Aslam Husain A, S.P. Singh, Anurag Chauhan, Mohd. Tauseef Khan, Navneet Kumar, Abhishek Chauhan, S.K. Soni, "Implementation Of Drone Technology For Farm Monitoring & Pesticide Spraying: A Review," Information Processing In Agriculture 10 (2023)

[7] Muhammad Faizan Siddiqui, Asim Ur Rehman Khan, Neel Kanwal, Haider Mehdi, Aqib Noor, M. Asad Khan, "Automation And Monitoring Of Greenhouse," Ieee, 2017

[8] Emmanuel Omia, Hyungjin Bae, Eunsung Park, Moon Sung Kim, Insuck Baek, Isa Kabenge And Byoung-Kwan Cho, "Remote Sensing In Field Crop Monitoring: A Comprehensive Review Of Sensor Systems, Data Analyses, And Recent Advances," Mdpi Remote Sens. 2023

[9] Sanaz Rasti, Chris J. Bleakley, N.M. Holden, Rebecca Whetton, David Langton, Gregory O'hare, "A Survey Of High Resolution Image Processing Techniques For Cereal Crop Growth Monitoring," Information Processing In Agriculture 9, 2022

[10] Uferah Shafi, Rafia Mumtaz, José García-Nieto, Syed Ali Hassan, Syed Ali Raza Zaidi, And Naveed Iqbal, "Precision Agriculture Techniques And Practices: From Considerations To Applications", Mdpi Sensors, 2019

[11] M. Nagaraju & Priyanka Chawla, "Systematic Review Of Deep Learning Techniques In Plant Disease Detection," International Journal Of System Assurance Engineering And Management, 2020

[12] Ailong Ma, Dingyuan Chen, Yanfei Zhong, Zhuo Zheng, Liangpei Zhang, "National-Scale Greenhouse Mapping For High Spatial Resolution Remote Sensing Imagery Using A Dense Object Dual-Task Deep Learning Framework: A Case Study Of China," Isprs Journal Of Photogrammetry And Remote Sensing, 2021

[13] Haoran Sun, Lei Wang, Rencai Lin, Zhen Zhang, And Baozhong Zhang, "Mapping Plastic Greenhouses With Two-Temporal Sentinel-2 Images And 1d-Cnn Deep Learning", Mdpi Remote Sens. 2021

[14] Zhengchao Chen, Zhaoming Wu, Jixi Gao, Mingyong Cai, Xuan Yang, Pan Chen And Qingting Li, "A Convolutional Neural Network For Large-Scale Greenhouse Extraction From Satellite Images Considering Spatial Features", Mdpi Remote Sens. 2022

[15] Thomopoulos, V.; Bitas, D.; Papastavros, K.-N.; Tsipianitis, D.; Kavga, A. "Development Of An Integrated Iot-Based Greenhouse Control Three-Device Robotic System." Agronomy 2021

[16] Haixia Li, Yu Guo, Huajian Zhao, Yang Wang, "Towards Automated Greenhouse: A State Of The Art Review On Greenhouse Monitoring Methods And Technologies Based On Internet Of Things," Computers And Electronics In Agriculture, 2021

[17] M. Dharani, M. Bharathi, "Intelligent Iot-Based Greenhouse Monitoring And Control System," I-Manager's Journal On Electronics Engineering, Environmental Science, Computer Science, Agricultural And Food Sciences, 2022

[18] Fazeel Ahmed Khan, Adamu Abubakar Ibrahim, And Akram M Zeki, "Environmental Monitoring And Disease Detection Of Plants In Smart Greenhouse Using Internet Of Things," J. Phys. Commun. 4, 2020

[19] Yuanyuan Zhoua, Qing Xia, Zichen Zhang, Mengqi Quana, and Haoran Li, "Artificial Intelligence And Machine Learning For The Green Development Of Agriculture In The Emerging Manufacturing Industry In The IoT Platform," Acta Agriculturae Scandinavica, Section B — Soil & Plant Science 2022

[20] B. Lanitha, E. Poornima, R. Sudha, D. Beulah David, K. Kannan, R. Jegan, Vijayakumar Peroumal, R. Kirubagharan, And Meroda Tesfaye, "Iot Enabled Sustainable Automated Greenhouse Architecture With Machine Learning Module," Hindawi Journal Of Nanomaterials Volume 2022

[21] Hassan Ibrahim, Norhan Mostafa, Hassan Halawa, Malak Elsalamouny, Ramez Daoud, Hassanein Amer, Yasmine Adel, Amr Shaarawi, Ahmed Khattab, Hany Elsayed, "A Layered Iot Architecture For Greenhouse Monitoring And Remote Control," Sn Applied Sciences, 2019

[22] Xinguang Wei, Linlin Wu, Dong Ge, "Prediction Of The Maturity Of Greenhouse Grapes Based On Imaging Technology," Plant Phenomics, 2022

[23] Stefan Paulus And Anne-Katrin Mahlein, "Technical Workflows For Hyperspectral Plant Image Assessment And Processing On The Greenhouse And Laboratory Scale," Gigascience. 2020

[24] Filiz Bektas Balcik, Gizem Senel, Cigdem Goksel, "Greenhouse Mapping Using Object-Based Classification And Sentinel-2 Satellite Imagery", Ieee, 2019

[25] Mei-Hui Liang, Yao-Feng He, Li-Jun Chen, Shang-Feng Du, "Greenhouse Environment Dynamic Monitoring System Based On Wi-Fi," Ifac Papers online, 2018

[26] Wei Sun, Fantao Kong, Jianhua Zhang, Jianzhai Wu, Xin Chai, and Shanshan Cao, "Greenhouse Intelligent Control System Based On Indoor And Outdoor Environmental Data Fusion," IOP Conf. Series: Earth And Environmental Science 440, 2020

[27] Jinhuang Lin, Xiaobin Jin, Jie Ren, Jingping Liu, Xinyuan Liang, and Yinkang Zhou, "Rapid Mapping Of Large-Scale Greenhouse Based On Integrated Learning Algorithm And Google Earth Engine," Remote Sens. 2021

[28] Lifeng Shi, Xianjin Huang, Taiyang Zhong, and Hannes Taubenböck, "Mapping Plastic Greenhouses Using Spectral Metrics Derived From Gaofen-2 Satellite Data", Ieee Journal Of Selected Topics In Applied Earth Observations And Remote Sensing, Vol. 13, 2020

[29] Xiaoyong Bo, "Design Of Remote Intelligence Monitoring System Based On Labview For The Greenhouse," Tenth International Conference On Applications And Techniques In Cyber Intelligence (ICATCI), 2022

[30] C Visvesvaran; S Kamalakannan; K Niresh Kumar; K Meenakshi Sundaram; S Murugananda Sri Sabari Vasan; S Jafrrin, "Smart Greenhouse Monitoring System Using Wireless Sensor Networks," 2nd International Conference On Smart Electronics And Communication (ICOSEC), 2021