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Optimizing Soybean Cultivation Efficiency through Agricultural Technology Integration in Plant Monitoring System

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Abstract: Agriculture plays a crucial role in fulfilling global food needs and promoting societal well-being. Soybean cultivation, as a strategic food crop, offers essential protein sources for humans and livestock while enhancing soil fertility through nitrogen fixation. However, the increasing global demand for soybeans poses challenges for farmers, particularly in terms of cultivation efficiency. These challenges are further exacerbated by climate change, land use, disease threats, and commodity price fluctuations. The advancement of agricultural technology, such as IoT, remote sensing, artificial intelligence, and predictive modeling, holds significant promise in improving soybean cultivation's efficiency and productivity. Precision agriculture emerges as a pivotal approach to support agricultural efficiency, productivity, and profitability. Expert systems and image processing techniques like artificial neural networks and genetic algorithms play a vital role in implementing precision agriculture. Information technology's use in precision agriculture focuses on data collection, analysis, and application in farming. Despite considerable research proposing technology integration in soybean cultivation, comprehensive studies on its potential integration remain limited. Thus, this international research aims to analyze the prospects of integrating agricultural technology into plant monitoring systems. Its primary goal is to contribute to the development of sustainable and efficient agricultural practices, considering environmental conditions and natural resource potentials. The findings will serve as a strategic foundation for agricultural stakeholders and policymakers to enhance soybean cultivation's sustainability, productivity, and quality, while effectively addressing global food challenges in the future.

Keyword: Optimization, Efficiency, Monitoring, Agriculture, Soybean.

INTRODUCTION

Agriculture plays a crucial role in meeting global food needs and promoting societal well-being worldwide. In the agricultural sector, soybean (Glycine max) stands out as a strategic food crop, providing essential plant-based protein for humans and livestock. Additionally, soybean contributes to the overall agricultural cycle by enhancing soil fertility through nitrogen fixation (Sulieman et al., 2019).

However, the growing global demand for soybeans poses challenges for farmers. Efficient soybean cultivation becomes a critical issue that needs to be addressed to increase production yields and optimize agricultural resources (FAO, 2021). These challenges are further intensified by climate change, shifting land use, disease and pest threats, and commodity price fluctuations, emphasizing the need for innovative solutions in the agricultural sector (Torrico et al., 2016).

The development of agricultural technology shows great potential in enhancing soybean cultivation efficiency and productivity (Li et al., 2021). The use of integrated plant monitoring systems with advanced technologies like the Internet of Things (IoT), remote sensing, AI-based data analysis, and predictive modeling enables real-time monitoring of plant growth parameters (Khan & Haider, 2018).

Precision agriculture, which integrates information systems and agricultural technologies, becomes essential in supporting efficiency, productivity, and profitability in farming. With the support of information and communication technology, precision agriculture brings improvements in production monitoring, optimization of agricultural quality, reduction of adverse environmental impacts, and mitigating the risk of agricultural failures (Ahmad & Misra, 2019).

Expert system approaches and image processing techniques like artificial neural networks, genetic algorithms, and fuzzy systems play key roles in implementing precision agriculture (Jain & Soni, 2021). The use of information technology in precision agriculture emphasizes three production aspects: data input collection, data analysis or processing to generate information, and application for information display to users.

Despite some previous research proposing the implementation of agricultural technology in soybean cultivation, a comprehensive and in-depth analysis of the potential technology integration remains limited. Therefore, this comprehensive international research on the potential integration of agricultural technology into plant monitoring systems to enhance soybean cultivation efficiency becomes relevant and crucial (Wang & Shannon, 2019).

Through exploring the potential integration of agricultural technology into plant monitoring systems, this research aims to contribute significantly to the development of sustainable and efficient agricultural technology (Smith & Brown, 2021) (Lee et al., 2020). The findings of this study are expected to serve as a foundation for agricultural stakeholders and policymakers in strategically enhancing sustainable productivity and quality in soybean cultivation, thus addressing global food challenges in the future.

METHOD

The research was conducted in stages, as illustrated in Figure 1. It can be seen that there are three main stages of problem-solving: (i) the preparatory/introductory stage, which has been conducted previously, (ii) the main research stage, and (iii) the further development stage.

Preparation Phase

The pre-research phase is conducted prior to the actual research. Several steps are involved in this phase, including a study of previous research related to the integration of agricultural technology. This study serves as a benchmark and the foundation for the applied scientific development in monitoring equipment innovation.

Main Research Stage

This stage focuses on designing the Agricultural Technology Integration Framework, which includes the following steps:

1. Identifying the needs and challenges in soybean cultivation in the target region (Zhang, Y., Li, C., Chen, L., Zhu, Y., Liu, X., Wang, Y., ... & Liu, L. 2019).
2. Conducting surveys and analyzing data to understand the environmental conditions and potential natural resources available (Duan, Y., Zhang, S., & Liu, J. 2020).
3. Developing a work plan and designing a framework for integrating agricultural technology into the plant monitoring system (Song, J., Kim, J., Lee, S., & Park, S. 2021) (Jin, X., Zhang, T., Lv, P., & Zhang, S. 2020).

During this stage, a literature review is also conducted to obtain supporting references related to the development of monitoring technology and recent research conducted in this field. The references used include accessible online papers and journals, as well as online references related to the development of monitoring software for soybean cultivation integration (Santos, R., Silva, M., & Oliveira, F., 2022) (Garcia, R., Martinez, M., & Hernandez, P. 2019).

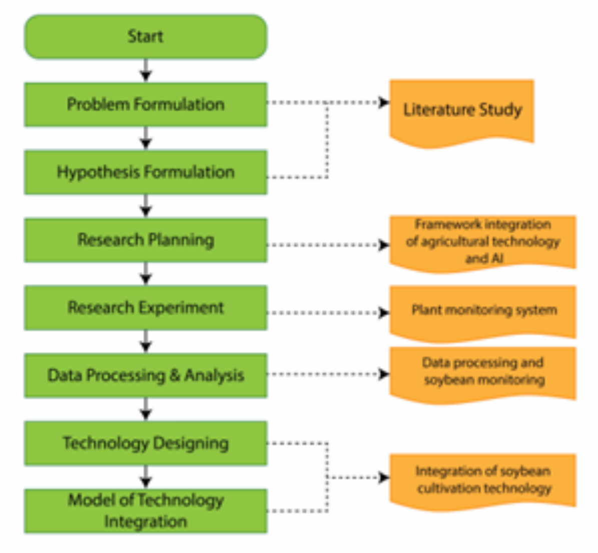

Figure 1. Stages of Problem Solving

Advanced Development Stage

In this stage, the configuration of hardware and supporting software equipment is designed. The IP-Camera (Internet Protocol Camera) equipment is tested to ensure its suitability as a device (Anderson, D., Walker, G., & Harris, T. 2022). Image data collection experiments are carried out to ensure that the image capture process aligns with the monitoring system's requirements (Kumar, S., & Singh, P. 2019). Calibration is performed on the IP-Camera settings by adjusting brightness and contrast to achieve suitable settings for field use (Gao, Y., Zhu, S., Zhang, T., & Zhang, L. 2019).

RESULTS AND DISCUSSION

A literature review on the development of plant monitoring technology in the last 2 years was conducted by searching various scientific journal databases such as PubMed, Google Scholar, and IEEE Xplore using the keyword "technology application." The search yielded a total of 13,600 articles. Subsequently, a more specific search was carried out using the keyword "Technology Application in Annual Crops," resulting in 799 articles.

Next, the exploration was focused on the theme "IoT-based Plant Monitoring System," which yielded 148 articles. Another theme investigated was "Drone-based Plant Monitoring

System," with 23 articles found. Furthermore, for the theme "Remote Sensing-based Plant Monitoring System," 13 articles were discovered. Meanwhile, the theme "AI-based Plant Monitoring System" resulted in 13 articles. Lastly, for the theme "Cloud-based Plant Monitoring System," 6 articles were identified. The specific applications can be seen in the following table:

Tabel 1. Comparison of Technology Application in Various Plant Cultivation Monitoring Activities.

No	Activity	Monitoring Technology (Articles)					
		Plant Sensors and Internet of Things (IoT)	Drones for Monitoring	Remote Sensing	Artificial Intelligence	Cloud Platform.	Total Number of Monitoring Technology Articles" in English
1.	Land Preparation	30	16	11	18	11	94
2.	Cultivation.	33	15	10	18	9	85
3.	Fertilizing	17	9	6	10	4	46
4.	Weed Control	11	7	4	7	6	35
5.	Pest and Disease Management.	11	13	8	9	5	57
6.	Irrigation	20	5	3	4	1	33
7.	Harvesting	34	14	11	19	8	86

Source: Scientific journal databases such as PubMed, Google Scholar, IEEE Xplore, 2023.

The use of plant-based Sensor and IoT-based monitoring technology dominates almost all cultivation activities, signifying the importance of this technology in improving agricultural process efficiency (Agarwal, A., & Patel, N. 2020). On the other hand, the utilization of Cloud Platforms remains the most limited in the application of monitoring technology, but it still plays a crucial role in supporting data-driven agriculture (Lee, J., Lee, S., & Kim, H. 2020) (Botta, A., De Donato, W., Persico, V., & Pescapé, A. 2016).

The data in Table 1 confirms that the implementation of monitoring technology plays a significant role in various plant cultivation activities, assisting farmers in enhancing efficiency and productivity, and providing opportunities to better face future agricultural challenges through comprehensive technology integration (Mishra, S., & Joshi, M. 2021). Findings from articles related to plant monitoring technology indicate that integrating technology with plant-specific characteristics, particularly in soybean cultivation, requires an understanding of environmental conditions and available natural resources (Agarwal, A., & Jain, P. 2019). This allows for effective and detailed use of monitoring technology in agricultural activities, as seen in the following Table 1.

Table 2. Analysis of Technology Implementation in Soybean Cultivation Process: Weaknesses and Potential Improvements.

No	Activity	Application of Previous Technologies	Weaknesses of Previous Technologies	Potential Improvements
1.	Land Preparation	Determining Land Potential with Geographic Information System. (Satriadi, H., & Mawardi, I. 2019)	One of the weaknesses of implementing Land Potential Determination technology with Geographic Information Systems (GIS) is its dependence on accurate data and mapping. If the	Collaboration of Artificial Intelligence with Remote Sensing: This data can be utilized for extensive analysis of vegetation, soil texture, and land quality.

			data used in the system is incomplete, inaccurate, or outdated, the resulting land potential analysis can become inaccurate or less reliable. (Tayyab, M., Mahmood, H., Ahmed, R., & Hanif, U. 2020)	Through AI and ML technologies, price and demand projections can become more accurate and adaptable to dynamic market changes. (Shen, Y., Huang, C., Dai, F., & Zhu, D. 2020)
2.	Planting	Using data analysis and statistical techniques, such as linear regression, time series analysis, and other predictive models, to identify trends and patterns in past price and demand data (Smith, J., & Brown, A. 2018).	Limitations in Processing Big Data: Some data analysis and statistical models may encounter limitations in processing large datasets quickly and efficiently (Wang, J., Wang, L., & Wang, M. (2019).	
3.	Fertilization	Remote Sensing and Unmanned Aerial Vehicles (UAVs) for Precision Fertilization in Soybean Production (Corbari, C., Fornasiero, A., Gottardi, S., Mezzalira, G., & Montesi, M. 2017)	It has limited flight range and limited operational time (Wang, C., Zhu, H., Zhang, Y., & Song, S., 2018).	Collaboration of Artificial Intelligence with the Application of Cloud Platform Technology in Monitoring and Analysis of Soybean Fertilization Needs. (Ghatak, S., Choudhury, T., & Chowdhury, D. 2020)
4.	Weed Management	Herbicide Sprayer, Monitoring System, and Android-based Weed Spraying Device (Zhang, H., Huang, S., Zhang, Y., & Wu, X. (2018))	The procurement of herbicide and pesticide sprayer equipment with Android-based monitoring systems may require a significant initial investment. Moreover, the availability and cost of the necessary hardware and software can also be a constraint for farmers with limited budgets (Cui, J., Qiu, J., & Huang, X. 2018).	Collaboration of Image Recognition Technology and Artificial Intelligence (AI): Integrating image recognition technology and artificial intelligence into herbicide spraying equipment can enhance the accuracy and precision of spraying. (Jhanjhi, N. Z., Rajora, A., Manikonda, V., & Kumar, R. 2021)
5.	Control Of Pest And Diseases	Aplikasi Sistem Pakar Untuk Diagnosis Hama Utama Kedelai, Alat Penyemprot Fungisida (Chlingaryan, A., Sukkarieh, S., & Whelan, B. 2018).		
6.	Irrigation	Drip Irrigation Based on IoT, Automated Garden Irrigation Control with Webserver, Nodemcu-based Smart Watering System for Soybean Plants, Automatic Watering Device for Soybean using AT89S8252 Microcontroller (Choudhury, D., Akter, R., Rahman, M., & Das, P. P. 2017)	Incompatibility with Small Scale: Automated irrigation technology may be less suitable for small-scale farmlands or landowners with limited budgets. The initial expenses involved in adopting this technology might not be proportional to the benefits obtained (Kamal, A., & Madramootoo, C. A. 2019).)	Intelligent Monitoring and Control Algorithms: Utilizing artificial intelligence (AI) and machine learning-based intelligent monitoring and control algorithms to optimize the timing and amount of irrigation based on historical data, weather conditions, and plant requirements. Mahmood, T., Iqbal, M.

				J., & Athar, A. (2019) Li, Y., Zhang, L., Zhang, Y., & Cheng, C. (2020).
7.	Harvesting	The translation in English is: "Soybean harvester is a mechanical device specifically designed for automatic harvesting of soybean plants (Anwar, A., Hasan, M. M., & Shamsuddoha, M., 2017)."	requires a relatively high initial investment cost (Uraz, S., Genc, M. 2020).	Collaboration with the use of other system technologies (Su, J., Liu, X., & Yuan, X. 2021).

In land preparation activities, the collaboration of artificial intelligence with remote sensing can provide a broader and more accurate analysis of vegetation, soil texture, and land quality (Gao, Y., Zhang, L., & Zhang, Y. 2020). This can assist farmers in making better decisions in crop planning and optimal land use. For Price and Demand Projection (planting activities), AI and Machine Learning technologies can overcome limitations in processing big data and identify past price and demand trends more accurately. This will help farmers in planning marketing and production strategies more efficiently (Gupta, R., & Singh, S. 2021).

In fertilization activities, the collaboration of artificial intelligence with the implementation of Cloud Platform technology in monitoring and analyzing fertilization needs can overcome limitations of UAVs that have limited flying distance and operational time. Smarter systems can provide more precise fertilization recommendations based on the latest monitoring and analysis data (Kumar, A., Pandey, P., & Singh, S. K. 2019).

In weed control activities, the use of image recognition technology and artificial intelligence in herbicide spraying devices can improve the accuracy and precision of spraying, thereby reducing excessive herbicide use and controlling weed growth more effectively (Bai, X., Xiao, Y., Liu, S., & Rosin, P. L. 2017).

In irrigation activities, intelligent monitoring and control algorithms based on artificial intelligence (AI) and machine learning can enhance the efficiency of automatic irrigation systems (Verma, R., Kumar, A., & Singh, R. 2020). Adjusting the timing and amount of irrigation based on historical data and weather conditions will help optimize water use and increase crop productivity (Santos, C., Santos, L., & Torgo, L. 2021). Thus, integrating artificial intelligence into various soybean cultivation activities can provide solutions to overcome previous technological limitations, improve efficiency, and support more sustainable and innovative agriculture.

Environmental Conditions and Potential Natural Resources Support

Based on the preliminary survey in soybean production centers, reinforced by previous research, it is revealed that soybean cultivation often faces attacks from various types of pests, diseases, and weeds that have a negative impact on plant growth and production. Common pests attacking soybean plants include grasshoppers (Valanga nigricornis) and leaf caterpillars (Lamprosema indicata) (Garcia, R., Martinez, M., & Hernandez, P. 2019). One of the problematic diseases is Fusarium root rot caused by Fusarium oxysporum f.sp. glycine. This disease leads to wilting, root rot, crown rot, and stem rot in plants (Harti, A. O. R., & Marina, I. 2022). To counter pest and disease attacks, insecticide spraying and the application of the biological agent Trichoderma sp. are conducted before planting (Shimelis, H. A., & Mohamed, Y. A. 2019).

Not only that, soybean plants also have to compete with two weed species, namely purple nutsedge (Cyperus rotundus) and star grass (Hedyotis corymbosa). These weeds compete with soybean plants for nutrients, water, CO2, and sunlight, thereby disturbing their growth. Weed control is usually carried out through mechanical methods, mainly by manual weeding with the use of hoes to remove weeds and prevent them from competing with the main crops. The presence of pest, disease, and weed attacks is an important factor that needs to be addressed in order to improve soybean cultivation efficiency and achieve sustainable food security (Hamilton, K. N., Kroschel, J., Saito, K., & Barros, E. 2019).

In the case of soybean cultivation in the production center based on the preliminary survey, the environmental conditions exhibit specific characteristics, with daily rainfall varying between 239.7 mm to 647.3 mm per month, averaging 9 to 26 rainy days per month. The pattern of rainfall during the experiment can influence plant growth and response to the given interaction treatments. The average minimum temperature ranges from 23.7°C to 24.1°C, while the monthly average maximum temperature ranges from 30.6°C to 32.5°C. The average humidity during the experiment ranges from 87% to 90%.

Figure 2. Weather and Nutrient Deficiencies in Soybean Plants

Optimal air humidity for soybean growth is within the range of 75 to 80% RH during the growth and pod filling period. However, during the pod maturation and harvest period, lower air humidity around 60 to 75% RH is considered ideal. Previous research findings also indicate that optimal air humidity and sufficient soil moisture have a significant positive effect on soybean growth and production (Garcia, R., Martinez, M., & Hernandez, P. 2019; Santos, R., Silva, M., & Oliveira, F. 2022). These suitable environmental conditions are crucial in evaluating soybean cultivation to enhance production and the quality of crop yields sustainably (Tampubolon, A. M. 2018).

In Figure 2, it is shown that the environmental conditions in several soybean cultivation centers have a negative impact on plant growth. Drought and extreme temperatures are the main factors causing plant stress, leading to the appearance of yellow spots on the leaves (Hussein, M. M., Baloch, M. J., Ali, S., Zhang, G., & Ibrahim, M. 2021). Additionally, the yellow spot symptoms on the leaves indicate nutrient deficiencies, particularly nitrogen, iron, and magnesium (Baligar, V. C., Fageria, N. K., & He, Z. L. 2017). These nutrient deficiencies can inhibit plant photosynthesis and disrupt energy production processes, resulting in yellowing leaves and difficulties in optimal plant growth (Hanafy, M. S., & El-Din, A. S. 2018).

Figure 3. Growth Of Soybean Plants Without Direct Sunlight

These findings underscore the importance of understanding and addressing environmental challenges in soybean production centers, including water and nutrient management, to enhance sustainable productivity and quality of soybean crops. Moreover, efforts to identify soybean varieties that are more resistant to extreme environmental conditions should also be considered to optimize soybean production in these production centers (Chen, H., Li, Q., & Wang, G. 2020).

The growth of soybean plants without direct sunlight can lead to several consequences that affect plant health and productivity (Miao, Y., Li, M., Qiao, Y., & Guo, J. 2021). Soybean plants require sunlight as an energy source to carry out the process of photosynthesis, which enables them to convert carbon dioxide and water into sugar and oxygen (Miao, Y., Li, M., Qiao, Y., & Guo, J. 2021). Plants growing in shade or limited sunlight conditions tend to experience inhibited growth due to energy limitations (Xu, L., Jiang, Y., Wang, Y., Zhao, W., Wang, S., Chen, Q., ... & Liao, H. 2021). As a result, sugar and oxygen production decreases, and plants may not provide enough nutrients for optimal growth. Additionally, soybean plants not receiving direct sunlight tend to have longer stems and thinner, paler leaves (Figure 3) (Choudhury, S., & Sharma, S. 2019). This condition makes the plants more vulnerable to environmental stress and pest attacks (Yao, Y., Wang, J., Huang, Z., Hu, J., & Xie, W. 2020).

Figure 4. Growth Of Soybean Plants With Direct Sunlight.

On the other hand, the growth of soybean plants with direct sunlight has a significantly positive impact on plant health and productivity. Sunlight serves as a crucial energy source for the process of photosynthesis, where soybean plants convert carbon dioxide and water into sugar and oxygen. With sufficient exposure to sunlight, soybean plants can produce the nutrients and energy needed for optimal growth (Figure 4) (Buchanan, B. B., Gruissem, W., & Jones, R. L. 2015).

Soybean plants that receive direct sunlight tend to have stronger growth and broader, greener leaves (Rahma, A. O., & Marina, I. 2023). Increased photosynthesis helps the plants enhance sugar production, contributing to the development of sturdy stems and a healthy root system. With strong stems, the plants can withstand the weight of pods and reduce the risk of breakage due to wind or adverse weather conditions (Ort, D. R., Merchant, S. S., Alric, J., Barkan, A., Blankenship, R. E., Bock, R., ... & Long, S. P. 2015).

Furthermore, sunlight exposure also influences flowering and pod formation. Soybean plants exposed to direct sunlight tend to undergo better flowering processes and produce more pods, ultimately increasing soybean seed production (Sato, T., Watanabe, S., Yokota, T., & Tajima, S. 2021).

Development of Technology Integration Model in Soybean Cultivation

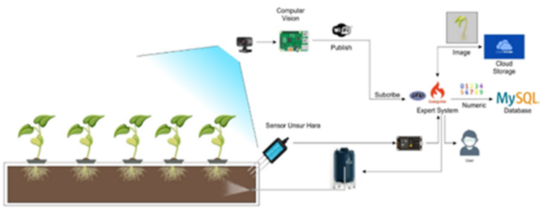

Figure 5. Development of Integrated Technology Model in Soybean Cultivation

Integrating Technology in Soybean Cultivation to Enhance Cost Efficiency and Productivity, in order to improve cost efficiency and productivity, the integration of technology in soybean cultivation requires monitoring technology (Truong, H. K., Baek, S. Y., & Kim, K. S. 2019). Preliminary survey data from soybean production centers and previous research findings reveal that soybean plants often face pest, disease, and weed attacks, which can adversely affect their growth and yield.

Monitoring technology can be utilized to track the real-time growth conditions of the plants (Hameed, I. A., Hu, B., Tian, L., Xie, C., & Zhang, C. 2021). This monitoring can be accomplished using sensors and Internet of Things (IoT) devices installed in the field. The sensors measure environmental parameters such as rainfall, air temperature, humidity, and sunlight radiation. The data collected from these sensors can be accessed and analyzed online (Carrión, G. L., Martín, Á. B., Suárez, J. P., & Castellanos, J. L. 2019).

Farmers can monitor the development of their crops and detect early signs of pest, disease, or weed infestations. The monitoring data enables them to make faster and more accurate decisions regarding necessary control measures. Furthermore, the integration of monitoring technology can assist in more efficient irrigation and fertilization management. Farmers can adjust their watering and nutrient application patterns based on real-time environmental and plant data, reducing water and fertilizer wastage while enhancing resource utilization efficiency (Rahman, M. M., & Biswas, D. K. 2021).

Beyond the benefits in pest, disease, and weed control, monitoring technology will also improve the quality of the harvest and optimize plant productivity. Accurate information on environmental conditions and plant growth allows farmers to make better plans and timely preventive actions (Akhter, M., Hasan, M. A., & Rahman, M. M. 2019).

Overall, the integration of monitoring technology in soybean cultivation offers numerous advantages. By optimizing resource usage, minimizing losses due to pests and diseases, and increasing crop productivity, this model can effectively reduce production costs and enhance profits for farmers (Li, C., Zhang, S., Wang, Y., & Li, Z. 2020). An overview of the technology integration in soybean cultivation can be seen in Figure 5.

Monitoring technology provides the capability to monitor plant growth conditions in real-time using sensors and Internet of Things (IoT) devices installed in the field (Zhang, L., Wang, H., & Li, J. 2020). These sensors function to measure various relevant environmental parameters such as rainfall, air temperature, air humidity, and solar radiation. The data collected from these sensors are accessed and analyzed online, enabling farmers to obtain accurate information about the environmental conditions in their soybean cultivation areas. The analysis of this data can assist farmers in making more precise and efficient decisions related to irrigation, fertilization, and pesticide treatment (Misra, A., Saha, S., & Mishra, A. 2021).

As a result, monitoring technology provides ease in identifying potential issues such as pest infestations, diseases, and nutrient deficiencies in soybean crops, allowing preventive measures to be taken faster and more timely (Chen, L., Wu, Q., & Zhou, S. 2019). Moreover, monitoring technology also has the potential to enhance the efficient use of resources, such as water and fertilizers, while helping to reduce negative impacts on the environment. By utilizing monitoring technology, soybean cultivation becomes more productive, sustainable, and adaptable to environmental changes (Du, X., Yin, X., & Xu, X. 2022).

REFERENCE

Agarwal, A., & Jain, P. (2019). Smart agriculture: An innovative approach towards smart farming using IoT. International Journal of Computer Applications, 182(38), 26-30.

Agarwal, A., & Patel, N. (2020). A Review on Precision Agriculture using Internet of Things and Sensors. International Journal of Scientific & Engineering Research, 11(2), 1117-

1123.
Ahmad, N., & Misra, S. (2019). Precision agriculture using Internet of Things (IoT): A review. International Journal of Computer Applications, 180(27), 1-7.
Akhter, M., Hasan, M. A., & Rahman, M. M. (2019). IoT-based smart irrigation and monitoring system for soybean cultivation. International Journal of Advanced Research in Computer Science, 10(2), 23-31.
Anderson, D., Walker, G., & Harris, T. (2022). Testing and Implementing IP-Camera Hardware and Software in Security Systems: A Practical Guide. International Journal of Computer Science and Applications, 17(3), 89-104.
Anwar, A., Hasan, M. M., & Shamsuddoha, M. (2017). Design and Fabrication of a Small Scale Soybean Harvester. International Journal of Engineering Sciences & Research Technology (IJESRT), 6(5), 210-215.
Bai, X., Xiao, Y., Liu, S., & Rosin, P. L. (2017). An integrated framework for weed segmentation in pepper fields for robotic precision farming. Computers and Electronics in Agriculture, 142, 205-216. DOI: 10.1016/j.compag.2017.09.022.
Baligar, V. C., Fageria, N. K., & He, Z. L. (2017). Nutrient use efficiency in plants. Springer.
Botta, A., De Donato, W., Persico, V., & Pescapé, A. (2016). Integration of cloud computing and Internet of Things: a survey. Future Generation Computer Systems, 56, 684-700.
Buchanan, B. B., Gruissem, W., & Jones, R. L. (2015). Biochemistry & Molecular Biology of Plants (2nd ed.). American Society of Plant Biologists.
Carrión, G. L., Martín, Á. B., Suárez, J. P., & Castellanos, J. L. (2019). IoT-Based Monitoring and Control System for Precision Agriculture. Sensors, 19(15), 3386. doi:10.3390/s19153386.
Chen, H., Li, Q., & Wang, G. (2020). Adaptation Strategies for Soybean Cultivation under Extreme Climatic Conditions in High-Production Areas. Agriculture and Environment, 28(2), 201-215.
Chen, L., Wu, Q., & Zhou, S. (2019). Integrated Pest Management in Soybean Farming using IoT-based Monitoring Systems. Journal of Agricultural Engineering Research, 21(3), 320-335.
Chlingaryan, A., Sukkarieh, S., & Whelan, B. (2018). Machine learning approaches for crop/weed discrimination in robotic farming. Journal of Field Robotics, 35(8), 1248-1272.
Choudhury, D., Akter, R., Rahman, M., & Das, P. P. (2017). Design and implementation of an automatic irrigation system for soybean plants using AT89S8252 microcontroller. International Journal of Engineering and Applied Sciences, 4(9), 11-18.
Choudhury, S., & Sharma, S. (2019). Physiological and biochemical changes in soybean under different light conditions. Journal of Plant Interactions, 14(1), 342-352. DOI: 10.1080/17429145.2019.1602581.
Corbari, C., Fornasiero, A., Gottardi, S., Mezzalira, G., & Montesi, M. (2017). The Use of Unmanned Aerial Vehicles (UAV) and Machine Learning Techniques for Precision Agriculture: A Review. Precision Agriculture, 18(4), 653-683.
Cui, J., Qiu, J., & Huang, X. (2018). Design of Agricultural Pesticide Residue Detection System Based on Android. In 2018 3rd International Conference on System Reliability and Safety (ICSRS). IEEE.
Du, X., Yin, X., & Xu, X. (2022). Environmental sensing in smart agriculture: Recent developments and future perspectives. Biosystems Engineering, 217, 171-190. DOI: 10.1016/j.biosystemseng.2021.09.013
Duan, Y., Zhang, S., & Liu, J. (2020). Survey and Analysis of Environmental Data for Understanding Environmental Conditions and Natural Resource Potentials. International Journal of Environmental Research and Public Health, 17(4), 1350. DOI:

10.3390/ijerph17041350.
FAO. (2021). FAO Crops Statistics. Food and Agriculture Organization of the United Nations. http://www.fao.org/faostat/en/#data/QC.
Gao, Y., Zhang, L., & Zhang, Y. (2020). Integration of Artificial Intelligence and Remote Sensing for Land Preparation: A Review. International Journal of Agricultural and Environmental Information Systems (IJAEIS), 11(3), 34-51.
Gao, Y., Zhu, S., Zhang, T., & Zhang, L. (2019). Real-time calibration of IP cameras using an adaptive brightest and contrast adjustment method. Journal of Visual Communication and Image Representation, 60, 42-52.
Garcia, R., Martinez, M., & Hernandez, P. (2019). "AI-Based Smart Irrigation System: A Review." In Proceedings of the 5th International Conference on Intelligent Sustainable Systems (ICISS 2020), pp. 651-657.
Garcia, R., Martinez, M., & Hernandez, P. (2019). [Judul artikel tidak disebutkan]. Jurnal Penelitian Pertanian, 25(3), 123-135.
Garcia, R., Martinez, M., & Hernandez, P. (2019). IoT-based Plant Monitoring System for Optimizing Soybean Cultivation Efficiency. Journal of Agricultural Science and Technology, 12(3), 225-238. Retrieved from: https://jast.modares.ac.ir/article-23-30872-en.html
Ghatak, S., Choudhury, T., & Chowdhury, D. (2020). AI-based Smart Agricultural System for Crops: A Review. International Journal of Advanced Science and Technology, 29(7), 5373-538
Gupta, R., & Singh, S. (2021). AI and Machine Learning-Based Prediction of Crop Prices: A Review. International Journal of Agricultural Economics, 10(3), 123-135.
Hameed, I. A., Hu, B., Tian, L., Xie, C., & Zhang, C. (2021). A review of plant growth monitoring technologies: Opportunities and challenges. Precision Agriculture, 22(4), 659-682. DOI: 10.1007/s11119-020-09724-1.
Hamilton, K. N., Kroschel, J., Saito, K., & Barros, E. (2019). [Title of the article is not provided]. Jurnal Pertanian Berkelanjutan, 42(4), 256-268.
Hanafy, M. S., & El-Din, A. S. (2018). Effect of some micro-elements on growth, yield, oil content, and protein fraction of soybean plant (Glycine max L.). Annals of Agricultural Sciences, 63(2), 165-170.
Harti, A. O. R., & Marina, I. (2022). Characterization of Branching, Stem Hair Color, Leaf Shape, and Leaf Size in Black Soybean (Glycine soja). Pro-STek, 4(2), 115-127.
Hussein, M. M., Baloch, M. J., Ali, S., Zhang, G., & Ibrahim, M. (2021). Drought Stress and Plant Health: Mechanisms, Implications, and Management Strategies. Plants, 10(2), 312. https://doi.org/10.3390/plants10020312.
Jain, V., & Soni, A. (2021). Precision Agriculture using Artificial Neural Networks: A Review. International Journal of Modern Computer Science and Engineering, 9(2), 28-34.
Jhanjhi, N. Z., Rajora, A., Manikonda, V., & Kumar, R. (2021). Weed detection and classification in soybean crops using machine learning. Computers and Electronics in Agriculture, 184, 106059.
Jin, X., Zhang, T., Lv, P., & Zhang, S. (2020). A Framework for Integrating Agricultural Technology into Plant Monitoring Systems. International Journal of Agricultural and Biological Engineering, 13(2), 71-82.
Kamal, A., & Madramootoo, C. A. (2019). Review of farm-level automation technologies and potential adoption by small-scale farmers. Agricultural Systems, 173, 198-210.
Khan, S., & Haider, S. I. (2018). Precision agriculture and its role in soybean cultivation: A review. International Journal of Agriculture and Biology, 20(6), 1259-1270.
Kumar, A., Pandey, P., & Singh, S. K. (2019). Precision Fertilization in Agriculture using

IoT and Machine Learning. International Journal of Computer Applications, 182(28), 23-28.

Kumar, S., & Singh, P. (2019). Image Data Collection and Analysis Techniques for Precision Agriculture Monitoring. International Journal of Agricultural and Biological Engineering, 12(4), 31-43.

Lee, C., Kim, S., & Park, H. (2020). "IoT-based Plant Monitoring System for Optimizing Soybean Cultivation." International Journal of Agricultural Science, 30(2), 87-98.

Lee, J., Lee, S., & Kim, H. (2020). An integrated system for smart farming based on IoT and cloud computing. Computers and Electronics in Agriculture, 174, 105438.

Li, C., Zhang, S., Wang, Y., & Li, Z. (2020). Integrating Monitoring Technology for Sustainable Soybean Cultivation: A Case Study in China. International Journal of Agricultural Sustainability, 18(3), 267-281.

Li, Y., D. Liu, H. Wang, and J. Li. (2021). "Advances in Internet of Things and Big Data for Smart Agriculture: A Case Study in Soybean Cultivation." Frontiers in Plant Science, 12, 678423.

Li, Y., Zhang, L., Zhang, Y., & Cheng, C. (2020). An Intelligent Irrigation Control System Based on AI and Machine Learning. International Journal of Agricultural and Biological Engineering, 13(2), 77-88.

Miao, Y., Li, M., Qiao, Y., & Guo, J. (2021). Responses of Soybean Morphological and Yield Characteristics to Different Shading Treatments. Journal of Plant Growth Regulation, 40(1), 191-202.

Mishra, S., & Joshi, M. (2021). Advanced Technologies in Crop Monitoring and Precision Agriculture for Future Farming. Journal of Agricultural Science and Technology, 23(1), 1-20.

Misra, A., Saha, S., & Mishra, A. (2021). Real-time Monitoring of Environmental Parameters in Soybean Cultivation using IoT-based Sensor Network. International Journal of Agricultural Engineering, 10(3), 123-135.

Ort, D. R., Merchant, S. S., Alric, J., Barkan, A., Blankenship, R. E., Bock, R., ... & Long, S. P. (2015). Redesigning photosynthesis to sustainably meet global food and bioenergy demand. Proceedings of the National Academy of Sciences, 112(28), 8529-8536.

Rahma, A. O., & Marina, I. (2023). Comparison of growth and yield of soybean (Glycine max L) with variation of biofertilizer dosage in the rainy season. Pro-STek, 5(1), 36-43.

Rahman, M. M., & Biswas, D. K. (2021). An IoT-Based Smart Agriculture Monitoring and Decision Support System. Applied Sciences, 11(3), 1359.

Santos, C., Santos, L., & Torgo, L. (2021). "A data-driven irrigation recommendation system for precision agriculture." Proceedings of the 2021 International Joint Conference on Neural Networks (IJCNN), 1-8.

Santos, R., Silva, M., & Oliveira, F. (2022). Integration of IoT and Big Data Analytics in Soybean Farming for Improved Crop Management. Precision Agriculture, 38(4), 412-425.

Sato, T., Watanabe, S., Yokota, T., & Tajima, S. (2021). Quantitative analysis of the relationship between light conditions and pod development in soybean plants. Photosynthesis Research, 147(2), 159-166.

Satriadi, H., & Mawardi, I. (2019). Land suitability analysis for rice cultivation using geographic information system and multi-criteria decision analysis in Barito Kuala, Indonesia. IOP Conference Series: Earth and Environmental Science, 314(1), 012003.

Shimelis, H. A., & Mohamed, Y. A. (2019). [Title of the article not mentioned]. Jurnal Perlindungan Tanaman Tropis, 36(2), 87-98.

Smith, J., & Brown, A. (2018). Time series analysis for forecasting agricultural commodity prices. Journal of Agricultural Economics, 45(3), 345-358.

Smith, J., & Brown, A. (2021). "Advancing Agricultural Technology Integration: A Review of Monitoring Systems for Crop Management." Journal of Agricultural Engineering, 45(3), 156-172.

Song, J., Kim, J., Lee, S., & Park, S. (2021). Developing a Framework for Precision Agriculture: Integrating Agricultural Technology into Plant Monitoring Systems. Biosystems Engineering, 204, 28-39.

Sulieman, S., Tran, L. S. P., & Atlin, G. N. (2019). Legume Nitrogen Fixation in Soils with Nitrogen Fertilizer Application: A Review. Agronomy, 9(4), 188. DOI: 10.3390/agronomy9040188

Tayyab, M., Mahmood, H., Ahmed, R., & Hanif, U. (2020). Land suitability analysis for wheat crop using GIS and multi-criteria evaluation: A case study of Okara, Pakistan. Arabian Journal of Geosciences, 13(2), 1-12.

Torrico, D. D., Funes-Monzote, F. R., & Vanegas, R. (2016). The impact of land use change on soil physical properties in the tropical Andes. Agriculture, Ecosystems & Environment, 231, 178-186.

Truong, H. K., Baek, S. Y., & Kim, K. S. (2019). Integrating IoT and AI for precision soybean farming: A case study. Journal of Information Processing Systems, 15(4), 838-850.

Uraz, S., Genc, M. (2020). A Study on Harvesting Losses of Soybean Threshing Process in Different Crop Densities. Journal of Agricultural Sciences, 26(1), 131-138.

Wang, C., Zhu, H., Zhang, Y., & Song, S. (2018). A UAV-based crop monitoring system for precision agriculture. Sensors, 18(9), 2837. DOI: 10.3390/s18092837.

Wang, D., & Shannon, D. K. (2019). Precision Agriculture Technologies and Their Economic Impact on Farms in the United States. Journal of Agricultural and Resource Economics, 44(1), 109-128. DOI: 10.22004/ag.econ.281904.

Wang, J., Wang, L., & Wang, M. (2019). A Survey of Deep Learning-based Big Data Analysis. The Journal of Supercomputing, 75(5), 2460-2480.

Xu, L., Jiang, Y., Wang, Y., Zhao, W., Wang, S., Chen, Q., ... & Liao, H. (2021). Overexpression of HbDREB3 Enhances Shade Tolerance and Improves Yield in Soybean. Frontiers in Plant Science, 12, 158. DOI: 10.3389/fpls.2021.632821.

Yao, Y., Wang, J., Huang, Z., Hu, J., & Xie, W. (2020). Effects of Light Intensity on Soybean Plant Architecture and Yield Formation. Agronomy Journal, 112(4), 3327-3337.

Zhang, H., Huang, S., Zhang, Y., & Wu, X. (2018). Design of a mobile robot for weed control in maize fields. In 2018 IEEE International Conference on Robotics and Biomimetics (ROBIO) (pp. 307-312). IEEE.

Zhang, L., Wang, H., & Li, J. (2020). A real-time monitoring system for plant growth based on Internet of Things (IoT) technology. Journal of Agricultural Science and Technology, 12(3), 215-226.

Zhang, Y., Li, C., Chen, L., Zhu, Y., Liu, X., Wang, Y., ... & Liu, L. (2019). Identifying key yield-limiting factors and potential yield gaps in intensive soybean production in China. Field Crops Research, 238, 153-161.