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Automation of IoT-Based Microclimate Management for Traditional Medicinal Plant Cultivation as a Catalyst for Sustainable Development in the North Sulawesi Community

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ABSTRACT

This community service program implements an IoT-based automation system for environmental management in the cultivation of bio-pharmaceutical plants in North Sulawesi, adopting a Community-Based Participatory Research (CBPR) approach. Utilizing the CBPR method, all program stages were designed and executed participatorily with three farmer groups involving 9 community members over six months, encompassing problem identification, system design, installation, monitoring, and evaluation. The system implementation involved the installation of DHT11 sensors, NodeMCU ESP8266 modules, and actuators, all integrated with a cloud platform. Test results demonstrated that the system successfully stabilized the cultivation environment with high consistency, maintaining temperature at 26±1°C and humidity at 50±5%, compared to pre-intervention conditions (temperature: 23-34°C, humidity: 30-70%). These optimal conditions significantly enhanced harvest quality, evidenced by a 10% increase in average harvest weight compared to conventional cultivation methods. The active participation of the community throughout the process not only ensures the system's sustainability but also strengthens the community's technological capacity.

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INTRODUCTION

The Indonesian Ministry of Health records approximately 32,000 traditional herbal formulations spread across various regions of the archipelago, utilizing more than 2,848 species of medicinal plants. This highlights the significant potential of local biodiversity as a source of natural remedies. The Indonesian Ministry of Health records approximately 32,000 traditional herbal formulations spread across the archipelago, utilizing more than 2,848 species of medicinal plants, highlighting the immense potential of local biodiversity as a source of natural remedies. Bio-pharmaceuticals, or medicinal plants, constitute crucial biological resources that play a foundational role in modern phytochemistry and pharmacognosy. The secondary metabolites they produce—such as alkaloids, flavonoids, terpenoids, and phenolic compounds—function as natural defense mechanisms for the plant and simultaneously serve as bioactive compounds with potential pharmacological activities for human health (Solikah, 2023). The therapeutic efficacy of bio-pharmaceuticals is highly dependent on the quality and quantity of these active compounds, whose biosynthesis and accumulation are significantly influenced by abiotic environmental factors, including fluctuations in temperature, humidity, light intensity, and soil nutrient availability (Kurniawan, 2021; Salatalohy, 2023).

In North Sulawesi Province, the cultivation of traditional medicinal plants has become part of the local wisdom as well as a source of livelihood for the community (Eurika UJ 2024). The study explains that there are 40 types of bio-pharmaceutical plants cultivated in the North Sulawesi region.

TABLE 1. Data on Bio-Pharmaceutical Plants in North Sulawesi

No	Family	Genus	Common Name	Local Name	Part Use
1.	Zingiberaceae	Curcuma	Kunyit	Kuning	Rimpang
2.	Zingiberaceae	Zingiber	Jahe	Goraka	Rimpang
3.	Zingiberaceae	Curcuma	Temulawak	Temulawak	Rimpang,akar
4	Zingiberaceae	Alpinia	Lengkuas	Lingkuas	Rimpang
5.	Asteraceae	Ageratum	Bandotan	Rumpusopi	Daun
6.	Asteraceae	Pluchea	Beluntas	Belontas	Daun
7.	Lamiaceae	Phaleria	Kumis kucing	Kumis kucing	Daun
8.	Lamiaceae	Ocimum	Kemanggi	Kekuru	Daun
9.	Poaceae	Cymbopogon	Serai	Saribata	Daun
10.	Piperaceae	Piper	Daun sirih	Daun sirih	Daun
11.	Myrtaceae	Psidium	Jambu biji	Jambu biji	Daun
12.	Basellaceae	Anreder	Binahong	Pinahong	Daun
13.	Lauraceae	Persea	Alpukat	Alpokat	Daun
14.	Oxalidaceae	Avverhoa	Belimbing wuluh	Belimbing	Buah
15.	Annonaceae	Annona	Daun sirsak	Daun sirsak	Daun
16.	Xantrorrhoeaceae	Aloe	Lidah buaya	Lidah buaya	Lendir
17.	Thymelaeaceae	Phaleria	Mahkota dewa	Mahkota dewa	Buah,Daun
18.	Apiaceae	Apium	Seledri	Seledri	Daun
19.	Lamiaceae	Coleus	Miana	Mayana	Daun
20.	Balsaminaceae	Impatiens	Tungkara	Tungkara	Daun
21.	Crassulaceae	Kalanchoe	Sosor bebek	Cocor bebek	Daun
22.	Piperaceae	Peperomia	Sirih Cina	Sirih Cina	Daun
23.	Amarylli daceae	Allium	Bawang merah	Bawang Merah	Buah,
24.	Amaryllidaceae	Allium	Bawang Putih	Bawang Putih	Buah
No	Family	Genus	Common Name	Local Name	Part Use
25.	Rubiaceae	Myrmecodia	Sarang Semut	Sarang Semut	Daun
26.	Acanthaceae	Storbilanthes	Kacabeling	Kacabeling	Daun

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27.	Solanaceae	Lycopersicum	Tomat	Tomat	Daun
28.	Malvacea	Abelmoschus	Gedi Merah	Gedi Merah	Daun
29.	Graminae	Saccharum	Tebu Merah	Tebu	Batang
30.	Palmae	Cocos L.	Kelapa	Kelapa	Buah, Isi
31.	Rutaceae	Citrus	Jeruk Nipis	Lemon nipis	Buah
32.	Rutaceae	Citrus	Lemon	Lemon	Buah
33	Loranthaceae	Loranthus Linnaeus	Benalu	Benalu	Akar
34	Musaceae	Musa	Pisang	Pisang	Batang, Tunas Muda
35	Asteraceae	Lactuca	Selada	Selada	Daun
36	Amaryllidaceae	Allium	Kucai	Rampa-rampa	Daun
37	Sterculiaceae	Theobroma	Coklat	Coklat	Kulit
38	Amaranthaceae	Achyranthes	Sangketan	Daun Sangketan	Daun
39	Clusiaceae	Garcinia	Manggis	Manggis	Kulit
40	Myrtaceae	Syzygium	Daun Salam	Daun Salam	Daun

Table 1 identifies 40 existing bio-pharmaceutical plants in North Sulawesi. However, the sustainability of medicinal plant cultivation faces serious challenges, including climate change, limited land availability, and the increasing market demand for high-quality raw medicinal plant materials.

The conventional cultivation methods, which are still predominantly used by local communities, have proven ineffective in responding to environmental dynamics such as fluctuations in temperature, humidity, and light intensity. These factors directly impact the decline in plant productivity and quality (Sirajuddin Z, 2021; El-Ghamry, 2023; Sharma, 2022; Aburasain, 2024). This situation is exacerbated by a shortage of productive labor, as most cultivators are elderly farmers with limited access to training and mastery of digital technology. The lack of involvement of the younger generation in the traditional agricultural sector also results in low regeneration of a workforce that is adaptive to the development of precision agriculture technology (Novisma, 2023; Martiarena, 2024; Hyeyoung K. Park, 2023).

This situation demands the adoption of a new approach that is not only capable of increasing production efficiency but is also responsive to environmental changes. One strategic solution is the utilization of automation technology based on the Internet of Things (IoT) (Zulhajji Z, 2022), (Heri A, 2024; Dhanaraju, 2022; Idoje, 2021; Doshi, 2019). IoT enables real-time monitoring and control of environmental variables, which can enhance the accuracy of cultivation decision-making, reduce reliance on manual labor, and promote farming that is more adaptive, precise, and sustainable (Faizah A, 2019; Suherman, 2024; Firdaus, 2023), (Mohamed, 2021), (Gowda, 2021).

METHOD

The approach used to carry out the community service program for the community in North Sulawesi employs the Community-Based Participatory Research (CBPR) method. CBPR is a collaborative method between the community and higher education institutions, oriented toward action and service learning to support social movements for achieving social justice (Ahmad Fauzi, 2023), (al., 2025). CBPR involves students and lecturers working together with organizations or communities in a research activity to achieve common goals. The objective of CBPR is to address research questions and real problems currently faced by the community, as well as to meet needs defined by the community itself. Ultimately, the outcome of CBPR aims to offer solutions or contribute to resolving real-world issues within the

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community (Salimi, 2012; Brush, 2020). The stages of the community service program adopting the CBPR method are outlined in the following mindmap:

FIGURE 1. Community Service Flow

Based on the community service flow referring to CBPR in Figure 1, it is further elaborated in the following table:

TABLE 2. Stages of Implementation

No	Stage of Activity Implementation		
1.	Contex	1. Analyzing Recent Issued	Discussion activities with partners
		2. Analyzing Field Conditions	Direct on-site survey accompanied by partners
			Literature review activities
2.	Partnership Process	1. Analyzing Partner's Problems	Discussing with partners
		2. Helping to Find Solutions	Discussing with partners
3.	Intervention & Research	1. Developing the Application	Development activities in the laboratory with the team and students
		2. Conducting Counseling and Training	Activities for socializing the tool and training on its use.
		3. Evaluation and Monitoring	This activity is carried out after the technology is implemented, aiming to determine whether the technology is running well or not.
		4. Periodic Mentoring	Ongoing mentoring activities for partners
4.	Outcomes	Improving the quality and quantity of the traditional medicinal plant (bio-pharmaceutical) harves	Implementing monitoring technology and management of the cultivation environment for traditional medicinal plants (bio-pharmaceuticals)

The stages of the program will involve the community under the auspices of the BLKK Bina Lentera Insan, with approximately 60 community members participating from the initial to the final stage. Nine individuals will be directly involved in the cultivation development, while the rest will participate in extension activities.

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RESULT AND DISCUSSION

Overview of the Technology

The technology developed is a cultivation house system for bio-pharmaceutical plants, integrated with microcontroller technology for temperature and humidity management. Temperature and humidity are monitored by a DHT11 sensor and subsequently transmitted to an Arduino as the control center, ensuring the temperature remains within the range of 24-28°C and humidity is maintained at an average of 50%.

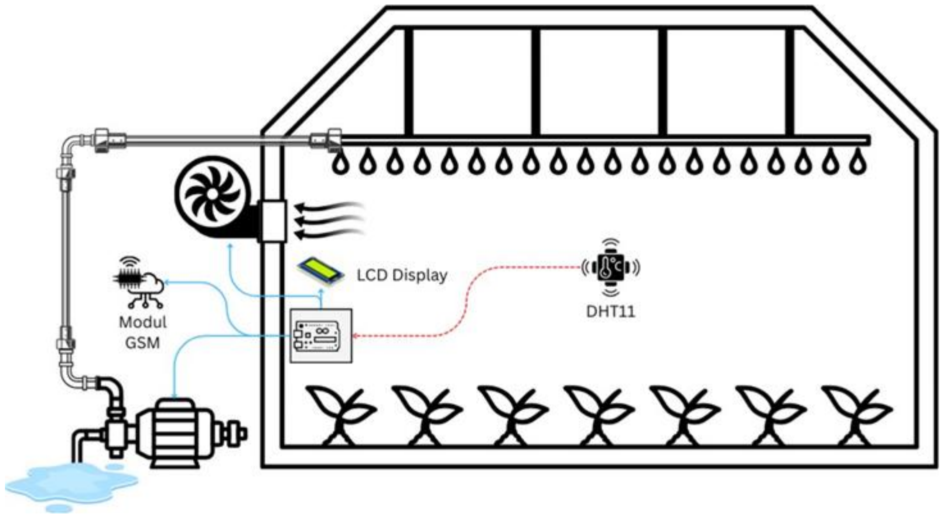

FIGURE 2. Technology Design

When the temperature exceeds the threshold (too hot), the microcontroller will command the relay to activate the electrical current and turn on the water pump to spray water inside the cultivation house. Once the temperature returns to the specified range, the microcontroller will command the relay to cut off the electrical current to the water pump. Furthermore, if the humidity exceeds the predetermined threshold, the microcontroller will command the relay to activate the electrical current connected to the fan. This aims to remove excess humidity from the cultivation house and replace it with fresh air. The temperature and humidity conditions can be monitored on the provided LED display as well as on the IoT application connected to the internet.

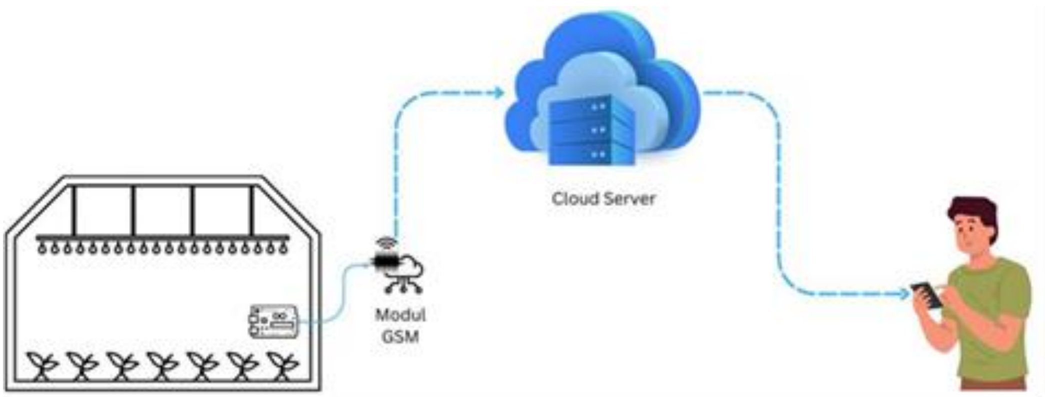

FIGURE 3. Topology

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Overview of the Technology

This community service initiative was carried out in collaboration with the Community Training Center (Balai Latihan Kerja Komunitas/BLKK) Bina Lentera Insan. BLKK oversees 275 community groups. The program was implemented in several communities willing to be mentored, enabling them to develop cultivation practices integrated with microcontroller and IoT technologies to simplify the cultivation process. This community service activity consists of three main programs: counseling on bio-pharmaceutical plant cultivation and technology integration, technology development, and sustainable mentoring.

FIGURE 4. Outreach / Counseling Activity on Bio-Pharmaceutical Cultivation and Technology Implementation

The counseling session was conducted at the Bina Lentera Insan Community Training Center (BLKK) building, inviting several community members. During the session, the prospects of bio-pharmaceutical cultivation were presented as a potential opportunity to generate income for the community. The next program involved the development of technology in the form of an Arduino-based microcontroller device and sensor modules designed for temperature management in the cultivation house.

FIGURE 5. Microcontroller Technology Development

The microcontroller device will be integrated with Internet of Things (IoT) technology to control the conditions inside the cultivation house. The application can be accessed via computer devices as well as Android devices. A comparison of the conditions before and after the technology was implemented can be seen in the following Table 3.

TABLE 3. Comparison of Environmental Conditions Before and After Technology Implementation

Parameter	Before	After
Temperature Consistency	22-34°C	25±1°C
Humidity Consistency	30-70%).	50±5%

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FIGURE 6. Cultivation House Construction Activity

The construction of the cultivation house is one of the most important aspects of this community service initiative. The cultivation house serves to protect the medicinal plants (bio-pharmaceuticals) from pests and viruses. However, the conditions inside the cultivation house are highly fluctuating, as temperature and humidity levels can change very easily. The size of the cultivation house built is approximately 10 x 20 meters. It will be planted with several bio-pharmaceutical plants, such as turmeric, ginger, mint, lemongrass, etc.

DISCUSSION

Implementation and Discussion of the IoT System for Bio-Pharmaceutical Plant Cultivation.

The implementation of an IoT-based automation system in bio-pharmaceutical plant cultivation houses in North Sulawesi has successfully addressed the main challenge of microclimatic instability. Data obtained shows that the system consistently maintained temperature at 25±1°C and humidity at 50±5%, a significant achievement compared to pre-intervention conditions which experienced wide fluctuations (temperature: 22-34°C, humidity: 30-70%). This stability directly correlated with improved visual plant quality (greener and thicker leaves, absence of chlorosis) and a 10% increase in average harvest weight, providing quantitative evidence of the system's effectiveness.

Technical Performance and Comparative Analysis

From a technical perspective, the system built using DHT11 sensors and NodeMCU ESP8266 modules demonstrated adequate reliability for low-cost community-scale applications. However, the lower accuracy of the DHT11 sensors (±5% for humidity) compared to industrial-grade sensors (such as the SHT series with ±1.8% accuracy) is acknowledged as a trade-off for achieving affordability. This system is simpler and significantly cheaper than commercial precision agriculture solutions (such as platforms from Bosch or Philips), which offer tighter control but require much higher initial investment and complexity, unsuitable for community contexts. The performance of the actuators (water pumps and fans) in responding to parameter changes based on setpoints proved to be fast and effective, reducing environmental fluctuations to below 2% of the target conditions.

Sustainability through the Participatory Approach (CBPR)

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The key success of this program lies in the Community-Based Participatory Research (CBPR) approach. The active involvement of three farmer groups in all stages—from problem identification, design, installation, to monitoring—ensured that the technological solution was appropriate for the local context and created a strong sense of ownership. Technical training focused on simple troubleshooting (such as reading data on the application interface and resetting devices) successfully enhanced the community's technological capacity. The establishment of a local technician cadre from the younger generation ensures post-implementation operational sustainability and system maintenance, reducing dependence on external parties.

Economic Analysis and Impact

From an economic perspective, a cost-effectiveness analysis indicates that this system is a viable investment. The implementation cost, minimized through the use of open-source technology, resulted in a 10% productivity increase, which is estimated to reach the break-even point within 2-3 growing seasons, depending on the scale and value of the commodity. Automation also reduced dependence on manual labor by up to 30%, addressing the shortage of productive workers. Resource efficiency was achieved as actuators were activated only based on need; data showed water savings of up to 20% compared to routine manual watering. The results of the pre-harvest and post-harvest analysis for the bio-pharmaceutical plants can be seen in the following Table 4.

TABLE 4. Harvest Comparison

Name	Before (kg)	After (kg)	Percentage Increase
Turmeric	2.5	2,7	8%
Ginger	3,5	3,9	11,43%
Galangal	3,5	3,9	11,43%
Lemongrass	1,5	1,6	6,67%
Temulawak	2,8	3,1	10,71%

The data above was collected on a per-square-meter basis, both before and after the implementation of the technology. The data used were harvest data with a three-month growing period. This was done considering the short time frame, which made it impossible to conduct the study optimally, as the optimal harvest time for each bio-pharmaceutical plant generally falls within a growing period of around 4-8 months. Temporarily, only five variants were planted due to limitations in time and funding required. As shown in Table 4, turmeric increased by 8.5%, ginger by 11.43%, galangal by 11.43%, lemongrass by 6.67%, and temulawak by 10.71%. After three months of implementation, it was observed that the harvest yield experienced a positive increase in quantity, with an overall average of 9.7%, which can be rounded to 10%.

Limitations and Scalability Challenges

Despite its success, this program has several critical limitations that must be acknowledged for future replication:

- Technical Limitations: The system relies on stable internet connectivity, which remains a challenge in many rural areas of Indonesia. Offline solutions or the use of local mesh networks need to be explored.

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- Testing Duration: The six-month implementation period was insufficient to evaluate the long-term impact on soil health and yield consistency across different seasons.
- Scalability: Replication to other communities faces challenges such as varying land conditions, human resource capacity, and component availability. The development of a more modular system and clear adaptation guidelines is necessary.
- In-Depth Impact Analysis: Claims of ecological impact (such as reduced fertilizer/pesticide use) are still based on preliminary observations and require verification through further research with soil-test analysis and more rigorous data.

CONCLUSION

Based on the implementation results and discussion, it can be concluded that the integration of IoT technology with the Community-Based Participatory Research (CBPR) approach has proven effective in creating a precise and sustainable bio-pharmaceutical cultivation system in North Sulawesi. The automation system, utilizing DHT11 sensors, NodeMCU ESP8266 modules, and a cloud platform, successfully stabilized the microclimatic environment within the optimal range of 25±1°C temperature and 50±5% humidity. This stability directly resulted in a 10% average increase in harvest weight compared to conventional methods, demonstrating the practical significance of environmental control even within a relatively short three-month growing period—less than the optimal 4-8 month cycle for such crops. The participatory approach, engaging three farmer groups across all program stages, ensured the technology's suitability to the local context while building community capacity and fostering a strong sense of ownership. However, the study acknowledges limitations, including the six-month implementation duration, restricted geographical coverage, and reliance on stable internet connectivity.

For long-term sustainability, clear business models and supportive policies from local governments are recommended. Wider replication requires the development of more modular, cost-effective systems, coupled with specialized training to address digital infrastructure challenges in remote areas. Further research is needed to test the system's effectiveness on a larger scale, over longer periods, and with diverse bio-pharmaceutical plant species. Future studies should also investigate whether the 10% productivity increase can be sustained or enhanced under optimal growing cycles and analyze its economic impact on farmers' incomes. Overall, this IoT-based empowerment model synergizes ecological benefits through environmentally friendly cultivation, economic advantages via enhanced product value, and social gains through strengthened community resilience and youth engagement.

REFERENCES

Aburasain, R. (2024). Enhanced black widow optimization with hybrid deep learning enabled intrusion detection in Internet of Things-based smart farming. IEEE Access, 16621-16631.

Ahmad Fauzi, e. a. (2023). Penguatan masyarakat literasi melalui komunitas literasi “karsa” dengan pendekatan community based participatory research (CBPR). As-Sidanah: Jurnal Pengabdian Masyarakat, 5(1), 163-176.

https://doi.org/10.35568/abdimas.v8i4.7143

al, D. P. (2025). Pelatihan Desain Berbasis Software untuk Membantu UMKM Lokal di Desa Cadassari Kabupaten Purwakarta. Jurnal Kemitraan Masyarakat, 2(2), 87-95.

Brush, B. L. (2020). Success in long-standing community-based participatory research (CBPR) partnerships: A scoping literature review. Health Education & Behavior, 47(4), 556-568.

Dhanaraju, M. (2022). Smart farming: Internet of Things (IoT)-based sustainable agriculture. Agriculture, 12(10), 1745.

Doshi, J. P. (2019). Smart Farming using IoT, a solution for optimally monitoring farming conditions.

Procedia Computer Science, 746-751.

El-Ghamry, A. A. (2023). An optimized CNN-based intrusion detection system for reducing risks in smart farming. Internet of Things, 100709.

Eurika UJ, N. O. (2024). Studi Etnobotani Tumbuhan Obat Di Masyarakat Kelurahan Tounsaru Kecamatan Tondano Selatan Kabupaten Minahasa. Innovative: Journal Of Social Science Research, 17884- 17902.

Faizah A, S. P. (2019). Pemanfaatan Microcontroller Arduino Uno Untuk Sistem Monitoring Suhu Dan Kelembaban Kumbung Jamur Tiram. Jurnal Ilmiah Inovasi Teknologi Informasi, 1-8.

Firdaus, S. T. (2023). Sistem Manajemen Pengairan Pada Budidaya Tanaman Anggur Berbasis Internet of Things (Iot). Jurnal Informatika dan Teknik Elektro Terapan, 11(3s1).

Gowda, V. D. (2021). Smart agriculture and smart farming using IoT technology. Journal of Physics: Conference Series, 012038.

Heri A, I. C. (2024). Penerapan Teknologi IoT Pada Tanaman Hidroponik Untuk Monitoring Pertumbuhan Tanaman di Desa Puccadi. Journal Of Computer Science Contributions (JUCOSCO), 4(1), 37-46.

Hyeyoung K. Park, J. C. (2023). Acceptance of technology related to healthcare among older Korean adults in rural areas: A mixed-method study. Technology in Society, 72, 102182.

Idoje, G. D. (2021). Survey for smart farming technologies: Challenges and issues. Computers & Electrical Engineering, 92, 107.

Kurniawan, H. M. (2021). Persepsi Masyarakat Tani Terhadap Penanaman Biofarmaka Di Kecamatan Pontianak Utara. Jurnal Equilibrium Manajemen Fakultas Ekonomi Universitas Panca Bhakti, 4(2), 13-24.

Martiarena, M. L. (2024). Endogenous learning and innovation in African smallholder agriculture: lessons from Guinea-Bissau. The journal of agricultural education and extension, 30(2), 161-179.

Mohamed, E. S. (2021). Smart farming for improving agricultural management. The Egyptian Journal of Remote Sensing and Space Science, 24(3), 971-981.

Novisma, A. A. (2023). The study of millennial farmers' behavior in agricultural production. IOP Conference Series: Earth and Environmental Science. 1183. IOP Publishing, Salatalohy, A. M. (2023). Optimalisasi Pemberdayaan Masyarakat Melalui Pembibitan Tanaman Obat (Biofarmaka). Jurnal Pengabdian Masyarakat Hutan, 67-74.

Salimi, Y. E. (2012). Is community-based participatory research (CBPR) useful? A systematic review on papers in a decade. International journal of preventive medicine, 386.

https://doi.org/10.35568/abdimas.v8i4.7143

Sharma, V. A. (2022). Technological revolutions in smart farming: Current trends, challenges & future directions. Computers and Electronics in Agriculture, 107217.

Sirajuddin Z, K. P. (2021). Persepsi petani terhadap implementasi teknologi informasi dan komunikasi dalam penyuluhan pertanian. Jurnal Penyuluhan, 17(2), 136-144.

Solikah, W. Y. (2023). Pengembangan biofarmaka menjadi produk olahan, pengemasan serta strategi pemasarannya. Jurnal ABDI: Media Pengabdian Kepada Masyarakat, 8(2), 209-216.

Suherman, A. A. (2024). Implementasi fuzzy Tsukamoto pada sistem internet of things budidaya tanaman bayam. SMATIKA JURNAL: STIKI Informatika Jurnal, 14(1), 195-204.

Zulhajji Z, M. R. (2022). Penerapan Teknologi Internet of Thing (IoT) Pada Bisnis Budidaya Tanaman Hidroponik. Jurnal Media Elektrik, 30(19), 102-115.

https://doi.org/10.35568/abdimas.v8i4.7143