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# INTEGRATED DIGITAL LITERACY, IOT DEPLOYMENT, AND DIGITAL MARKETING FOR THE COMPETITIVENESS OF SMART AGRICULTURAL VILLAGES

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**Abstrak:** Kemajuan teknologi digital menawarkan peluang baru bagi sektor pertanian; namun, petani di Desa Sukamaju, Kabupaten Bandung, terus menghadapi keterbatasan akses dan kapasitas dalam memanfaatkan perangkat Internet of Things (IoT) dan platform pemasaran digital. Inisiatif pengabdian masyarakat ini diimplementasikan menggunakan pendekatan Penelitian Aksi Partisipatif (PAR) untuk memastikan bahwa petani bertindak sebagai pencipta bersama yang aktif, bukan penerima pasif. Intervensi tersebut terdiri dari pelatihan produksi berbasis IoT yang terstruktur, peningkatan kapasitas pemasaran digital, dan pendampingan berulang yang didukung oleh evaluasi pra-uji dan pasca-uji. Hasil menunjukkan peningkatan substansial dalam literasi digital dan kemampuan operasional, dengan skor rata-rata meningkat dari 48,6 menjadi 81,3. Di luar literasi, program ini menghasilkan peningkatan pendapatan penjualan sebesar 23% dan pengurangan penggunaan air irigasi sebesar 18%, menunjukkan peningkatan baik dalam akses pasar maupun efisiensi sumber daya. Strategi partisipatif lebih lanjut mengurangi kendala infrastruktur lokal dengan mengintegrasikan penggunaan perangkat bersama, modul pelatihan offline, dan mekanisme dukungan berbasis masyarakat. Hasil ini menunjukkan bahwa integrasi aplikasi IoT dan pemasaran digital memberikan landasan yang terukur untuk keberlanjutan pedesaan jangka panjang dan daya saing di sektor pertanian.

**Kata Kunci:** Internet of Things, literasi digital, pemberdayaan masyarakat, pemasaran digital, smart farming

**Abstract:** Advances in digital technology offer new opportunities for the agricultural sector; however, farmers in Sukamaju Village, Bandung Regency, continue to face limited access and capacity in utilizing Internet of Things (IoT) devices and digital marketing platforms. This community service program was implemented using the Participatory Action Research (PAR) approach to ensure that farmers act as active co-creators rather than passive recipients. The intervention comprises structured IoT-based production training, digital marketing capacity-building, and repetitive mentoring, all supported by pre- and post-test evaluations. Results showed substantial improvements in digital literacy and operational ability, with the average score increasing from 48.6 to 81.3. Beyond literacy, the program led to a 23% increase in sales revenue and an 18% reduction in irrigation water usage, demonstrating improvements in both market access and resource efficiency. Participatory strategies further reduce local infrastructure constraints by integrating the use of shared devices, offline training modules, and community-based support mechanisms. These results demonstrate that integrating IoT applications and digital marketing provides a measurable foundation for long-term rural sustainability and competitiveness in the agricultural sector.

**Keywords:** Internet of Things, digital literacy, community empowerment, digital marketing, smart farming

## Introduction

Wonogiri Village, Magelang District, is an agricultural region with abundant natural resource potential. Fertile soil and adequate water availability make rice and horticultural commodities central to the village economy. Despite these advantages, farming practices remain largely traditional. They are often inherited across generations, leading to inefficient input use, ineffective pest control, high production costs, and limited adaptive capacity to climate variability. These structural constraints negatively affect farm productivity and reduce the competitiveness of local agricultural products in increasingly demanding markets.

The region's agricultural transformation is further constrained by limited digital infrastructure. Internet connectivity and technological devices are unevenly distributed, and digital literacy among farmers remains low. These barriers limit access to modern agricultural technologies, which have been widely recognized for enhancing productivity, resource efficiency, and market integration. Contemporary studies highlight that digital technologies—such as Internet of Things (IoT) devices, big data analytics, artificial intelligence (AI), and agricultural e-commerce platforms—enhance data-driven decision-making, expand market access, and improve production outcomes (Abiri et al., 2023; Ammar et al., 2024; Gebresenbet et al., 2023). Causal inference-based evidence further indicates that digital interventions can increase agricultural yields by 12–17 percent (Khan et al., 2024; Papadopoulos et al., 2024; Raza et al., 2023). Nonetheless, most research has focused on urban or technology-ready environments, while comprehensive implementation in rural agrarian communities with low digital literacy remains limited.

This gap highlights the need for a research-based community service model that can bridge the high agricultural potential with farmers' capacity to adopt digital technology. Previous outreach efforts in Wonogiri Village, including cultivation training and conventional agricultural extension, have not addressed digital literacy nor embedded technological tools within farm management systems. Therefore, interventions focused on technology transfer and the development of an inclusive digital agricultural ecosystem are becoming increasingly relevant.

The novelty of this program lies in its participatory and context-sensitive design, which empowers farmers to adopt and utilize digital technologies tailored to their local conditions. To mitigate infrastructural constraints, the program integrates low-connectivity IoT solutions (e.g., LoRa-based field monitoring), village-level shared infrastructure (digital hubs), and offline-first learning modules adapted to local capacities. These design elements ensure that digital innovations remain feasible even in low-connectivity rural environments, while simultaneously facilitating capacity building and technological adaptation at the community level.

Based on these considerations, the objectives of the program are formulated as follows: (1) strengthening farmers' digital literacy through training and mentoring on modern agricultural applications; (2) promoting the integration of precision agriculture technologies such as field monitoring systems and real-time irrigation management; (3) establishing collaborative networks between farmers, extension agents, academics, and local stakeholders to foster a sustainable digital agricultural ecosystem; and (4) expanding access to market information and digital distribution channels to increase added value and market reach of Wonogiri Village's agricultural products. Collectively, these objectives position Wonogiri Village as a potential model of digitally adaptive and competitive agrarian development in Indonesia.

## Method

This community service program uses a Participatory Action Research (PAR) approach and an Asset-Based Community Development (ABCD) framework. The PAR approach was chosen because it positions the community as an active participant in every stage of the activity, from planning and implementation to reflection and evaluation. Thus, the results of the community service are not top-down, but rather emerge from the real needs of the farming community itself, making them more relevant, contextual, and likely to be adopted sustainably (Bisht et al., 2020; Sulistyowati et al., 2023). Meanwhile, the ABCD approach provides a conceptual framework for optimizing various local village potentials and assets, whether in the form of natural resources, local wisdom traditions, or social networks, so that the development of digital literacy-based agricultural smart villages can take place sustainably (Langford et al., 2021; Nel, 2018). The collaboration of these two approaches is believed to produce intervention patterns that are more humane, effective, and in accordance with the characteristics of rural communities.

The community service subjects were a farmer group in Wonogiri Village, Magelang District, consisting of 45 active farmers aged 25–65. Participants were selected through purposive sampling, based on their involvement in rice farming and horticulture, as well as their willingness to participate in the digital literacy program. In addition to farmers, the program involved agricultural extension workers, academics, and village officials, all of whom play a crucial role in supporting the development of a digital agricultural ecosystem. The presence of these various stakeholders was intended to ensure that the community service activities were not solely individual in nature but also built collaborative networks capable of supporting the program's sustainability.

The presented methodological flowchart demonstrates the integration of Participatory Action Research (PAR) with Asset-Based Community Development (ABCD) in designing a digital agricultural literacy-based community service program. This flow systematically depicts the process of socio-economic transformation of farmers through five main stages (see Figure 1): problem identification and asset mapping, collaborative planning, program implementation, participatory reflection, and final evaluation and sustainability strategies. The relationship between the stages is cyclical, so the program does not stop at solving immediate problems but fosters community capacity to continue the initiative independently. The integration of PAR and ABCD is clearly visible in this diagram: PAR provides a participatory mechanism through the action-reflection cycle, while ABCD provides a conceptual framework to ensure each intervention is rooted in local potential. The collaboration between the two forms a dual approach that is adaptive, humanistic, and oriented towards sustainable empowerment.

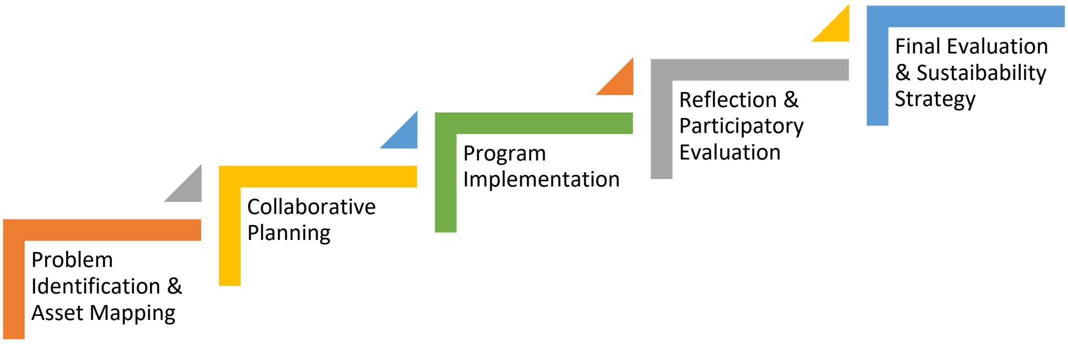


**Figure 1.** Community Service Flow Chart

The first stage, problem identification and village asset mapping, as illustrated in the diagram's initial node, focuses on developing a shared understanding of farmers' conditions. This stage was conducted through interviews, focus group discussions, field observations, and asset mapping guided by ABCD principles. Farmers actively contributed by identifying their own agricultural assets—such as irrigation networks, seed varieties, cultivation knowledge, and social labor-sharing practices—and by articulating existing gaps related to digital literacy and precision technology. In this framing, low digital literacy and limited technology adoption were not treated as deficits, but rather as entry points for collective capacity-building supported by existing resources, local knowledge, and community networks.

The next stage, collaborative planning, represents the second node in the diagram and embodies PAR's core philosophy: the co-creation of solutions through shared decision-making. Farmers, extension workers, academics, and village officials deliberated through participatory mechanisms to formulate relevant strategies, including enhancing digital literacy, adopting precision agriculture, and developing digital market access. At this stage, farmers' inputs were essential in determining the training content, selecting IoT tools suitable for their local environment, and identifying market channels relevant to their existing production. The planning was not implemented through a top-down design, but aligned with local aspirations, constraints, and capabilities.

The subsequent implementation and reflection stages functioned as iterative cycles in which farmers were positioned as active experimenters rather than passive recipients. During implementation, farmers directly tested IoT-based monitoring tools, engaged in data interpretation during field demonstrations, and participated in the application of digital marketing platforms. The reflection phase was conducted through periodic review meetings, during which farmers evaluated outcomes, identified bottlenecks, and proposed adjustments to improve subsequent cycles. These iterative reflections contributed to a growing sense of ownership as the community not only adopted the interventions but also actively shaped their evolution.

The program implementation stage, which constitutes the core of the diagram, was carried out through digital literacy training, precision agriculture technology trials, and real-time data-based irrigation management. Implementation did not focus solely on technology transfer but also on capacity building through continued mentorship. Farmers were positioned as active experimenters who learned, tested, and adapted technologies directly on their fields, rather than as passive recipients.

IoT mentoring was conducted in a multi-layered manner that went beyond operational use. After an initial demonstration phase, farmers practiced deploying sensors, configuring LoRa-based data transmission, and interpreting field data to make irrigation decisions. A subsequent technical mentoring cycle enabled farmers to perform basic device maintenance, troubleshoot connectivity issues, and replace modular components provided by the team. This approach ensured that technological adoption extended beyond the ability to operate ready-made devices and fostered a level of technical independence that supports long-term sustainability.

The following stage, participatory reflection and evaluation, is depicted as the fourth node in the diagram. Reflection occurred through joint evaluation forums, where farmers assessed program achievements and emerging challenges. These forums facilitated the articulation of both technical and socio-cultural dimensions of digital adoption, including group solidarity, leadership, and collective motivation, all of which significantly influence the success of technology adoption in rural settings.

The final stage, the evaluation and sustainability strategy, is represented at the closing node of the diagram. Evaluation employed a mixed-methods approach, combining quantitative and qualitative methods. Quantitatively, paired-sample t-tests were used to measure significant differences in digital literacy before and after the intervention. Qualitatively, thematic analysis was employed to identify key patterns, obstacles, and opportunities for ongoing implementation. The consolidated into a sustainability roadmap designed to guide the community in replicating, scaling, and independently reinforcing the program. At this stage, the program's effectiveness can be empirically demonstrated not only through improved digital literacy and enhanced agricultural productivity, but also through strengthened community independence in managing digital technologies that are aligned with local conditions.

## Results and Discussion

The implementation of the Community Service (PkM) Program demonstrated the role of farmers as active agents of digital transformation within a participatory framework. The quantitative evaluation, using pre- and post-tests with 45 participants, showed a substantial improvement in digital literacy competencies. As shown in Table 1, the total average score increased from 48.6 to 81.4 (32.8% improvement), with the most significant gains observed in the use of e-commerce platforms, followed by device operation and mastery of agricultural applications. These results indicate that structured training and mentoring effectively enhance farmers' digital readiness, forming a crucial foundation for the adoption of more advanced technologies in agricultural settings.

**Table 1.** Comparison of Farmers' Digital Literacy Scores Before and After the Program

| Digital Literacy Indicators | Before (Average) | After (Average) | Increase (%) |
|---|---|---|---|
| Use of digital devices | 50,2 | 82,5 | 32,3 |
| Understanding agricultural applications | 47,8 | 79,6 | 31.8 |
| Utilization of e-commerce platforms | 47,0 | 82,1 | 35.1 |
| Total average score | 48,6 | 81,4 | 32.8 |

From a theoretical perspective, increased digital literacy does not immediately translate into higher competitiveness; however, it serves as a critical enabling prerequisite that facilitates digital participation in the agricultural value chain. This interpretation aligns with findings that emphasize the enhancement of farmers' access to information, market linkages, and innovation pathways through digital competence (Ji & Zhuang, 2023; Zhang & Zhang, 2024; Zhou et al., 2024). Therefore, the primary contribution of this PkM intervention is establishing a literacy-based entry point that supports long-term digital transformation within agrarian communities.

A key outcome of the program is the successful use of Internet of Things (IoT) devices in precision agriculture practices. Seventy-two percent of participating farmers reported being able to operate soil moisture sensors and the associated Android monitoring application following mentoring activities. To address the initial infrastructural constraints—namely, limited internet access and uneven device availability—specific mitigation strategies were implemented. These included establishing a village digital hub equipped with signal boosters, localized offline-to-online gateways for data synchronization, and shared device clusters to reduce barriers to entry. These mechanisms enabled IoT devices to operate effectively despite environmental constraints, ensuring that the transformation could be sustained beyond the intervention period.

The application of IoT technology produced measurable field impacts. An average 18% reduction in irrigation water use was recorded during a single planting cycle, with no yield reductions. Water volume was measured using inline flow meters installed on irrigation channels, while yield stability was determined through weight-based post-harvest measurements per unit plot across comparable parcels. These results reinforce previous studies demonstrating that IoT-based precision agriculture improves input efficiency and reduces operational costs (Duguma & Bai, 2024; Sharma & Shivandu, 2024; Soussi et al., 2024). The empirical evidence strengthens the scientific relevance of the intervention by demonstrating that digital empowerment is not merely theoretical but produces tangible agronomic outcomes.

The program also influenced agricultural marketing behavior by increasing the adoption of digital commerce. Prior to intervention, only 15% of respondents had used online platforms to sell agricultural products. Following the program, this percentage increased to 68%, accompanied by a 23% rise in sales revenue during a single harvest cycle. These findings show that digital literacy not only improves farmers' operational capabilities but also expands their participation in broader economic networks. This result is consistent with studies highlighting the role of agricultural e-commerce in shortening distribution chains and enhancing profit margins for smallholder farmers (Guan et al., 2024; Liu et al., 2023).

Overall, the integrated model applied in this program—combining digital literacy strengthening, IoT utilization, and digital market access—proved effective in enhancing farmers' digital readiness, production efficiency, and economic outreach. Compared with previous implementations documented in the literature, the distinctive contribution of this study lies in its participatory and asset-based community development (ABCD) approach, which positions farmers not as passive beneficiaries but as primary stakeholders in the transformation process. This approach enhances sustainability by embedding knowledge, competencies, and motivation within the community rather than importing them externally.

From a theoretical standpoint, the findings enrich current discussions in the field of digital empowerment and community capacity-building in rural economies. The integration of technological literacy, precision agriculture, and digital commerce demonstrates a complementary relationship that accelerates rural socio-economic transformation. The participatory development perspective emphasizes that technological interventions are most effective when communities actively contribute to planning, decision-making, and implementation (Li et al., 2021; Rostami & Salehi, 2024). The novelty introduced by this PkM program lies in demonstrating that the digital transformation of agricultural villages can be achieved through a literacy-first participatory framework supported by infrastructural mitigation strategies, making it replicable for other agrarian regions facing similar digital constraints. Thus, it can be confirmed that the program objectives were successfully achieved, and the intervention contributes not only to practical field outcomes but also to the broader academic discourse on technology-based community empowerment and sustainable digitalization of agriculture.

## Conclusion

The implementation of the Community Service Program in Wonogiri Village produced measurable improvements in digital readiness and agricultural performance among farmers. The intervention increased farmers' digital literacy scores from an average of 48.6 to 81.4 (equivalent to a 32.8% improvement), enabled 72% of participants to operate IoT-based soil moisture monitoring systems, reduced irrigation water use by 18% without reducing yields, and increased the proportion of farmers utilizing e-commerce platforms from 15% to 68%, resulting in a 23% increase in sales revenue within a single harvest cycle. These outcomes demonstrate that the literacy-based participatory approach successfully translated into tangible benefits for production efficiency, resource management, and market access. The results also show that community independence and technological adaptability are achievable despite initial infrastructural limitations. It was made possible through mitigation strategies embedded in the program, such as the establishment of a shared village digital hub, the installation of signal boosters, shared device clusters, and offline-to-online data synchronization mechanisms, which collectively enabled sustained digital interaction under low-connectivity conditions. These strategies ensured that digital technology adoption did not rely solely on ideal infrastructure, but instead adapted to local realities and resource constraints.

To maintain progress beyond the formal program period, several actionable steps are recommended for the local community and village stakeholders: (1) institutionalizing periodic peer-to-peer mentoring to retain and distribute technical competencies within farmer groups, (2) integrating device maintenance and troubleshooting responsibilities into existing farmer cooperatives to support technological continuity, (3) formalizing access to the digital hub as a shared service for production data management and market transactions, and (4) expanding partnerships with local buyers and logistics actors to stabilize digital market linkages.

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