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JPPM (Jurnal Pendidikan dan Pemberdayaan Masyarakat)
12 (1), 2025, 18-28

Agrarian Community Empowerment Model Based on Digital Technology and Environmental Sustainability: A Case Study in Enrekang District

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Received: 17 January 2025; Revised: 19 March 2025; Accepted: 12 June 2025

Abstract: The agricultural sector in Enrekang Regency faces challenges, including climate change, hilly topography, and low adoption of digital technology. These issues highlight the urgent need for research to develop a digital technology-based model to enhance productivity, economic welfare, and environmental sustainability. This study employed a mixed-methods approach, involving 500 farmers through quantitative surveys, in-depth interviews, and focus group discussions. Data analysis included t-tests and linear regression to assess model effectiveness, while thematic analysis explored social and cultural factors affecting implementation. Results showed increased onion productivity from 9 to 12 tons/hectare and coffee from 1.2 to 1.5 tons/hectare. Farmers' income rose by 50%, with a 20% reduction in production costs. Using chemical fertilizers and irrigation decreased by 18% and 25%. Digital technology adoption increased from 12% to 68%, and community participation reached 89%. This model effectively improves productivity, welfare, and sustainability, providing a foundation for inclusive agricultural policy development.
Keywords:empowerment of public agrarian, digital technology, sustainable environment

How to Cite: Suparman, et al (2025). Agrarian Community Empowerment Model Based on Digital Technology and Environmental Sustainability: A Case Study in Enrekang District. *JPPM (Jurnal Pendidikan dan Pemberdayaan Masyarakat), 12* (1), 18-28. doi: https://doi.org/10.21831/jppm.v12i1.82587

INTRODUCTION

Regency Enrekang, South Sulawesi, has a strategic position in the agrarian sector, especially in horticulture and coffee production (Fattah & Mardiyati, 2022), with onion red as one of the featured commodities (Irmayani et al., 2023; Thamrin et al., 2021). Occupying the fourth position in terms of production of red onions at the national level (Wahyuni et al., 2021). This has become the backbone of agriculture in Indonesia (Rijal et al., 2018). However, the significant blocking challenges, including impact change climate such as El Niño, which causes prolonged droughts and lower productivity (Gateau-Rey et al.,2018; Vista Uli Sihombing, 2023). The topography of hills covering 84.96% of the area increasingly makes it difficult to manage land and irrigation. This problem is aggravated by

the low adoption of digital technology among farmers, which makes it difficult for the sector to develop efficiently and sustainably (Chaudhary & Sanjeev, 2020).

This research is crucial as Enrekang Regency is strategically supporting national food security through its leading agricultural commodities, such as shallots and coffee, contributing approximately 9.4% to the total national shallot production. However, the region faces serious challenges due to climate change, limited infrastructure, and low technology adoption, with only about 15% of farmers utilizing digital technology in their agricultural activities. Without appropriate, context-based interventions, agricultural productivity in the region is at risk of continuous decline, which could ultimately affect farmers' welfare and national food security. This study is urgently needed as it offers solutions that are not only technological in nature but also focused on social empowerment and environmental sustainability, thereby fostering a more resilient, adaptive, and inclusive agricultural system. Through this approach, the research can potentially catalize real change in agrarian development, particularly in hilly areas such as Enrekang Regency.

The digitalization sector of agriculture has become a focus for many organizations, including the Food and Agriculture Organization of the United Nations (FAO)(Aliev et al., 2023; Steve Hatfield-Dodds, 2007). FAO emphasizes the importance of digital technology in increasing the efficiency of production, expanding market access, and supporting a sustainable environment in the agricultural sector (Polunina, 2024; Wu & Wen, 2023). In many developed countries, the implementation of digital agriculture based Internet of Things (IoT) technology, data analytics (Aliev et al., 2023)E-commerce has succeeded in significantly increasing the productivity and resilience of food (Mentsiev et al., 2023). Digitalization also accelerates the adoption of sustainable agricultural practices, such as the substitution of fertilizer chemistry and irrigation to save water (Shamshiri et al., 2024; Dayioğlu & Türker, 2021). However, the implementation of this technology in developing countries like Indonesia still faces significant challenges, including low literacy rates and inadequate infrastructure (Astuti et al., 2024; Rabani et al., 2023).

Research by (2023) highlights the positive impact of digital technology on agribusiness efficiency. A study by Shafi et al. (2019) showed that implementing technology in agricultural precision IoT can increase productivity by up to 30%. In Indonesia, the study by Anugrah & Wahyuni (2021) highlighted the potential of agrarian e-commerce in expanding market access for farmers. These studies have shown the success of technology-based agrarian empowerment models. Although they are relevant, they have not yet focused on a specific highlight interaction between digital technology, the sustainability environment, and the participation of the agrarian community in the region, with the challenge of topography like Enrekang.

The novelty of this research is the holistic approach that integrates digital technology, strengthening farmer capacity, and sustainable agricultural practices to address specific challenges in Enrekang Regency (Laga et al., 2020; Ridwan et al., 2020). This model not only increases productivity through technology but also encourages environmental sustainability and strengthens farmers' social capital (Ngarawula & Wahyudi, 2023). In addition, this study adapts the application of digital technology to the local context, including the geographical conditions of the hills that require special adaptation (Nuryananda & Berlianty, 2023). This approach is different from previous studies that emphasize the technological aspect without considering the relationship with local community participation and environmentally friendly practices (Saengkaew & Roengtam, 2022; Nuryananda & Al Fitriani, 2023).

This study aims to present an innovative and comprehensive agrarian community empowerment model based on digital technology and environmental sustainability. The study focuses on Enrekang Regency as a case study. The study is expected to contribute to

the agrarian empowerment literature by offering a relevant approach to increasing productivity and farmer welfare (Abidin & Prasetyani, 2021), and environmental sustainability in Indonesia's agrarian regions (Alif et al., 2021). So that the model can become a reference for policymakers, researchers, and practitioners in supporting inclusive and sustainable agrarian sector development.

METHOD

This study uses a mixed methods approach to comprehensively understand the implementation and impact of the agrarian community empowerment model based on digital technology and environmental sustainability in Enrekang Regency. The study population consists of agrarian communities active in the agricultural sector, with a sample of 500 respondents selected using stratified random sampling. The sample was grouped based on the type of superior commodity (such as shallots and coffee), age, and education level of farmers to ensure representation that reflects the conditions of the local agrarian community.

The quantitative method was carried out through a survey using a structured questionnaire designed to measure indicators of model success, such as agricultural productivity, farmer income, technological literacy, and the application of sustainable practices. These quantitative data were analyzed using descriptive and inferential statistics, t-tests to compare results before and after model implementation, and linear regression to identify factors that most influence program effectiveness.

Qualitative methods were used to understand the social, cultural, and institutional contexts that influence the adoption of the empowerment model. Qualitative data were collected through in-depth interviews with 20 community leaders, agricultural extension workers, and local stakeholders, as well as through focus group discussions (FGDs) with farmer groups. In addition, participatory observation was conducted to directly observe the program's implementation in the field.

This research was conducted in three stages: (1) Initial identification to collect baseline data related to agrarian conditions at the research location; (2) Implementation of the empowerment model, including digital technology training and sustainable practices; and (3) Impact evaluation, using quantitative data to measure success based on indicators of productivity, welfare, and sustainability, as well as thematic analysis to explore supporting and inhibiting factors for program success. The results of these two approaches were validated through data triangulation to ensure the validity and reliability of the research findings.

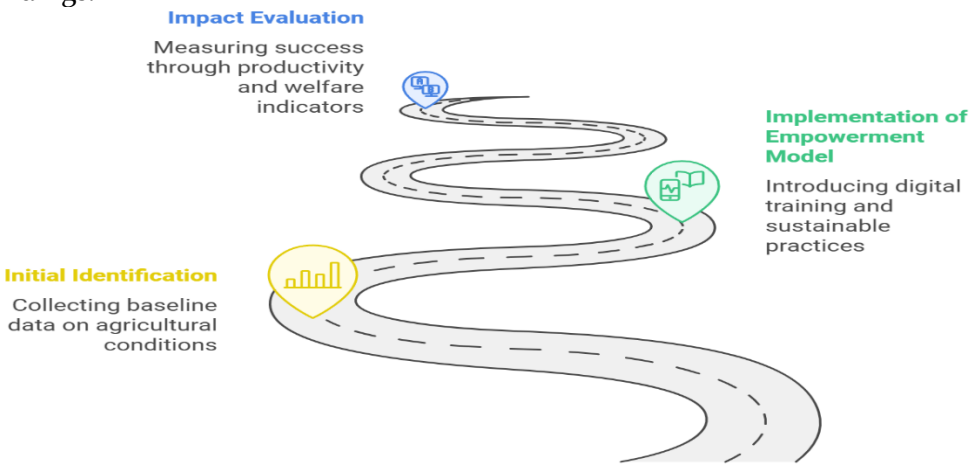

Figure 1.1 Research Stages

RESULTS AND DISCUSSION

The research findings demonstrate that implementing a community empowerment model for agrarian societies based on digital technology and environmental sustainability has significantly positively impacted agricultural productivity in Enrekang Regency. Data from 500 farmer respondents indicated substantial increases in key commodities such as shallots and coffee. Before the program intervention, shallot productivity averaged around 9 tons per hectare; however, after applying the empowerment model, this figure rose to 12 tons per hectare. Similarly, coffee production increased from 1.2 tons per hectare to 1.5 tons per hectare. This improvement did not occur spontaneously but resulted from intensive facilitation and the application of appropriate digital technologies, including weather-monitoring applications and structured crop scheduling tools. Farmers could better anticipate climatic conditions and select optimal planting times by gaining access to more accurate meteorological data, thereby minimizing losses due to extreme weather events.

The increase in productivity directly contributed to the improved welfare of local farmers. The average monthly income of farmers rose from approximately IDR 2,500,000 to IDR 3,750,000 following the implementation of the program. Beyond the income boost, a notable 20% reduction in production costs was recorded, attributed to adopting Internet of Things (IoT)-based irrigation systems. These systems enabled automated watering based on real-time soil moisture data, replacing traditional manual irrigation practices. This data-driven approach minimized water waste and reduced labor needs, leading to more cost-efficient operations without compromising yield. Moreover, distribution and marketing costs were also reduced due to local e-commerce platforms that shortened the supply chain and improved farmers' profit margins by enabling direct sales to buyers.

Digital transformation emerged as a crucial pillar of the model's success. Before the intervention, only 12% of farmers in Enrekang had adopted digital technologies. However, after the program's implementation, this number rose significantly to 68%, reflecting a clear shift in both mindset and behavior regarding the use of technology in agriculture. Among the most widely used tools were weather forecasting applications, which helped farmers determine optimal planting and harvesting times. Additionally, digital marketing platforms enabled farmers to sell their products directly to consumers or wholesalers, bypassing mediators. This digital shift led to a 15% increase in the selling value of agricultural products, as farmers could market their goods more broadly, consistently, and with added value through better quality control and branding strategies.

A central focus of the model was environmental sustainability. The study found that following the program's implementation, the use of chemical fertilizers declined by 18%. This reduction was made possible through training and education on producing and applying organic fertilizers, alongside increased awareness of the importance of maintaining long-term soil health. Moreover, irrigation water usage dropped by 25% due to the efficiency of sensor-based innovative irrigation systems. In addition to resource efficiency, 34% of respondents adopted agroforestry practices, integrating food crops with protective shade trees. This approach supports soil and water conservation and enhances biodiversity in agricultural landscapes. The combination of resource efficiency and ecological conservation underscores the program's alignment with environmentally sustainable farming principles.

The program's success extended beyond technical and economic dimensions to include significant social impacts, particularly in strengthening social capital. Approximately 72% of respondents reported improved collaboration among farmers following the program's implementation. This was primarily facilitated by establishing digital farmer cooperatives and discussion forums using social media and communication

apps such as WhatsApp and Telegram. Collective activities—such as joint seed purchases, shared equipment usage, and cooperative harvest management—became easier to coordinate via digital platforms. Participation in community activities also rose sharply, with 89% of farmers actively engaging in training sessions, group discussions, and communal work projects. These developments indicate that digital-based empowerment enhances productivity, reinforces social cohesion, and expands collaborative networks among previously isolated farmers.

From a quantitative perspective, the model's effectiveness was validated through statistical analysis. A paired sample *t*-test comparing productivity before and after the program revealed a highly significant difference ($p < 0.001$), indicating that the observed improvements were not coincidental but directly linked to the program intervention. Further, linear regression analysis identified three key success factors: access to digital technology ($\beta = 0.42$, $p < 0.001$), strengthening of social capital ($\beta = 0.36$, $p < 0.01$), and training in sustainable farming practices ($\beta = 0.30$, $p < 0.05$). These results highlight that a multidimensional intervention—combining technology, social engagement, and education—generates more substantial impacts than a single-focus approach.

Qualitative data obtained through in-depth interviews and focus group discussions (FGDs) provided additional insights into the challenges and dynamics encountered in the field. One of the primary obstacles was farmers' limited understanding of digital technology, particularly among older farmers and those with lower education levels. Furthermore, uneven internet infrastructure in mountainous and remote areas of Enrekang hindered access to digital applications. Despite these challenges, the presence of local facilitators and strong support from local government—including training programs and subsidies for technology tools, played a pivotal role in overcoming barriers. Farmers expressed greater confidence in adopting technology when they felt supported and guided, rather than left to navigate changes alone. This finding underscores that success was not solely due to the availability of technology, but also to the participatory and human-centered implementation approach.

In summary, implementing a digital and environmentally sustainable community empowerment model in Enrekang Regency has delivered positive outcomes. The model not only boosted productivity and farmers' incomes but also promoted more ecologically friendly farming practices and strengthened social cohesion at the community level. Robust quantitative data, supported by qualitative evidence, confirms that a holistic approach integrating digital tools, capacity building, and social engagement is an effective strategy for sustainable rural development. The success of this model in Enrekang suggests that it holds strong potential for replication in other agrarian regions facing similar challenges, provided it is adapted to local contexts. Consequently, this model may serve as a national reference in advancing sustainable digital villages across Indonesia.

DISCUSSION

This research describes the importance of developing empowerment models that are oriented to economic aspects and include social, technological, and environmental transformation. In the context of Enrekang Regency, the majority of people depend on the agricultural sector, the traditional approach that has been implemented has been proven to have not been able to provide significant changes to the welfare of farmers. Therefore, the empowerment model that integrates digital technology and the principles of environmental sustainability is present as a strategic and contextual solution (Ehnert, 2025; Makkonen et al., 2022). The application of this model does not stand alone, but rather strengthens the idea of participatory and sustainable development that places the

community as the subject of change. This approach aligns with empowerment theories (Anand et al., 2024; Gopalakrishnan et al., 2025), which emphasize the importance of strengthening local capacity, access to information, and control over the development process by the community itself.

Digital transformation is a central driver of this model's success, as evidenced by the significant increase in productivity for key commodities such as shallots and coffee. The rise in yields from 9 to 12 tons per hectare for shallots and from 1.2 to 1.5 tons per hectare for coffee reflects technical improvements and a shift in farmers' decision-making processes toward data-informed practices. Weather apps and digital crop scheduling systems enabled farmers to anticipate climate risks and maximize planting opportunities (Mba et al., 2025; Mwikamba et al., 2024). Furthermore, production efficiency improved with the introduction of smart irrigation systems, which significantly reduced water usage (Abdelhaleem et al., 2025). The 20% decrease in production costs illustrates that technology increases output and optimizes inputs, confirming that digitalization in agriculture is not merely a trend but a necessity that must be mainstreamed in future development agendas.

The ripple effects of increased productivity and efficiency are evident in farmers' improved economic and social well-being. The rise in monthly income—from IDR 2,500,000 to IDR 3,750,000—is a substantial achievement, especially considering the long-standing disadvantages smallholder farmers face in traditional supply chains. With access to local e-commerce platforms, farmers can now sell directly to end consumers or bulk buyers at more competitive prices. Digitalization has also enabled them to engage in product branding and expand their market reach beyond regional boundaries (Liu & Li, 2024). This indicates that digital empowerment not only enhances agricultural output but also opens new economic spaces for farmers (MacPherson et al., 2025). In the long run, this transformation could be a cornerstone for building village-based economies rooted in local innovation.

The model has also succeeded in internalizing principles of environmental sustainability into community farming practices. Reducing chemical fertilizer use by 18% and irrigation water consumption by 25% signals a growing ecological consciousness among farmers. Moreover, the adoption of agroforestry practices by 34% of respondents indicates that, with the right approach, farmers are willing and able to incorporate conservation practices into their farming systems without compromising productivity. These outcomes demonstrate that sustainable agriculture is not an idealistic concept but a practical goal achievable through participatory and hands-on education (Prasad et al., 2025). Going forward, this approach should be supported with local government incentives and policies that collectively encourage farmers to adopt long-term environmental stewardship.

One of the most critical findings from this study is that the success of technological adoption and environmental practices is heavily influenced by the strength of social capital within the community. 72% of farmers reported improved cooperation, and 89% actively participated in empowerment activities, indicating that program success is closely linked to grassroots social support. Digital cooperatives and farmer discussion forums have become crucial platforms for information exchange, trust-building, and collective action. From a development sociology perspective, this affirms that true empowerment occurs when communities develop a sense of ownership over the change process (Hirmer et al., 2022; Mozumdar et al., 2025). Therefore, the program's success lies in the quality of technology transferred and in the social mechanisms that facilitate mutual learning and community cohesion.

Strong quantitative data further substantiates the success of the model. The results of the paired *t*-test revealed a statistically significant difference between pre- and post-

intervention productivity levels ($p < 0.001$), confirming that the outcomes were a direct result of the program rather than incidental factors. Moreover, linear regression analysis identified three key success factors: access to digital technology ($\beta = 0.42$), strengthened social capital ($\beta = 0.36$), and sustainable farming training ($\beta = 0.30$). These findings indicate that multidimensional interventions combining technological, social, and educational components are more effective than single-focus approaches (Naga & Ebardo, 2025; Pang et al., 2024). Statistical evidence not only supports the empirical strength of the model but also provides a basis for replication and scaling in other regions.

Despite its success, the study acknowledges several challenges, including limited digital literacy among older farmers and inadequate internet infrastructure in remote and mountainous areas. These issues highlight the need for context-specific adaptation when implementing such models (Przybyłek et al., 2025). Field facilitators, technical advisors, and local policy support are critical in bridging these gaps (Hossain et al., 2025). In other words, the success in Enrekang cannot be attributed solely to the strength of the model but also to the synergy among local stakeholders. Therefore, future replication must emphasize adaptive, participatory, and sustainable approaches to ensure alignment with local community needs and capacities (Bano et al., 2025). These findings contribute significantly to developing responsive, community-based digital empowerment policies in agrarian regions of Indonesia undergoing digital and environmental transitions.

CONCLUSION

This study shows that the agrarian community empowerment model based on digital technology and environmental sustainability has a significant positive impact on Enrekang Regency, with an increase in shallot productivity from 9 to 12 tons/hectare and coffee from 1.2 to 1.5 tons/hectare, thanks to IoT-based weather and irrigation monitoring applications. Farmers' incomes increased by 50%, supported by a 20% reduction in production costs through organic fertilizers, water-saving irrigation, and broader market access through local e-commerce. In addition, environmental sustainability was strengthened by a decrease of chemical fertilizer use by 18% and irrigation water by 25%, with sustainable practices such as agroforestry and technology-based irrigation, which also strengthened social capital through modern farmer cooperatives with community participation reaching 89%. Although there are still obstacles in the form of limited internet infrastructure and low technological literacy, these challenges can be overcome through continuous education, support from local facilitators, and policies supporting digital transformation. Overall, this model is relevant to address local challenges in Enrekang Regency and can be replicated in other agrarian areas, offering a holistic approach that supports productivity, economic well-being, and environmental sustainability.

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