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Circular Economy Innovation in Zero-Waste Corn Utilization to Enhance Creative Economy and Sustainable Food Security

Masyadi[1]*, Surianti[2], M Afdal Tahir[3]
[1]Management, Universitas Lamappapoleonro, Soppeng, Indonesia
[2]Management, Universitas Lamappapoleonro, Soppeng, Indonesia
[3]Information System, Universitas Lamappapoleonro, Soppeng, Indonesia
*masyadi@unipol.ac.id

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Abstract

This Community Partnership Program was conducted in collaboration with the Kabuttu Farmers Group in Gattareng Village, Soppeng Regency, on August 10, 2025, and involved 31 participants, including corn farmers and community members. The problem addressed was the low added value of corn products and the underutilization of agricultural waste. Corn was primarily sold as dried kernels at low prices, while waste such as husks, stalks, and cobs was often burned, leading to both income loss and environmental degradation. The program aimed to enhance food security and increase farmers' income through circular economy principles and a zero-waste approach. Using the Participatory Action Research (PAR) method, the intervention included participatory planning, hands-on training, mentoring, the application of appropriate technology, and structured evaluation. Key activities included product diversification (e.g., corn tempeh and corn oil), waste processing (into compost and briquettes), financial management training, and digital marketing through social media and e-commerce platforms. The outcomes demonstrated measurable improvements. Product diversification increased from three to five processed products, and two new waste-based products (compost and briquettes) were developed. Digital marketing adoption rose from zero to four platforms (Shopee, Tokopedia, Facebook, WhatsApp Business), expanding market reach beyond local boundaries. Financially, farmers' average monthly income increased from IDR 1.53 million to IDR 3.2 million. Management capacity also improved: 60% of participants adopted simple bookkeeping practices and began structured business planning. The program contributed to SDGs 2 (Zero Hunger), 12 (Responsible Consumption and Production), and 13 (Climate Action), demonstrating the effectiveness of integrated, participatory empowerment in transforming rural agriculture sustainably.

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INTRODUCTION

Food security and the improvement of community income are two essential aspects of sustainable development. South Sulawesi Province, widely recognized as the food barn of

Eastern Indonesia, contributes significantly to national agricultural production, particularly rice and corn (Yusriadi, 2025). Corn is not only a strategic food commodity but also an alternative staple to rice and an important raw material for the feed, processed food, and bioenergy industries (Kristiyani, 2021).

Gattareng Village in Soppeng Regency is one of the agricultural centers in South Sulawesi with substantial potential. According to the Central Bureau of Statistics, the village has 603.35 hectares of farmland, with 78.5% of its population (2.411 people) working as farmers. Approximately 42.3% or 255.2 hectares of this land are devoted to corn cultivation, producing an average of 995.3 tons annually (Jamaludin et al., 2025). Despite this significant production, farmers face challenges that hinder productivity and income growth.

The Kabuttu Farmers Group, established in 2009 with 25 members, actively cultivates corn on 35.6 hectares of land with an average productivity of 3.9 tons per hectare per year. Nevertheless, several problems persist. At the production level, farmers still rely on conventional practices with limited access to improved seeds, fertilizers, pesticides, and efficient machinery. Training and technical assistance to improve farming practices remain minimal, a situation consistent with broader findings that limited access to modern technology and weak extension services continue to constrain smallholder productivity in Indonesia (Agussabti et al., 2022).

At the post-harvest stage, most corn is sold as raw, dried kernels at low prices (IDR 3,000–3,500/kg), which limits farmers' income to approximately IDR 1.53 million per month. Additionally, approximately 30% of corn biomass, including stalks, husks, and cobs, is either wasted or openly burned, resulting in air pollution and resource loss. If left unaddressed, these conditions will perpetuate cycles of poverty, environmental degradation, and food system inefficiency (Rashed 2024). Farmers will remain trapped in low-income agricultural practices, vulnerable to market fluctuations, and unable to compete in modern value chains (Perdana et al., 2023). Without urgent intervention, this not only threatens the sustainability of local livelihoods but also undermines broader national goals for food security, climate resilience, and rural economic transformation.

Institutionally, the Kabuttu Farmers Group has yet to implement a structured management system. Poor organizational capacity, weak financial record-keeping, and a lack of managerial skills have hampered efforts to strengthen group-based agribusiness. In terms of marketing, the group is heavily dependent on middlemen, leading to income losses of up to 25% compared to direct local sales. Similar patterns have been observed in rural agricultural markets, where dependency on intermediaries reduces farmers' bargaining power and profitability (Oguoma et al., 2011). Digital platforms such as social media and e-commerce remain underutilized, limiting the expansion of market access, despite evidence that smart farming and digitalization can significantly enhance farmers' competitiveness and market integration (Agussabti et al., 2022).

Digital platforms such as social media and e-commerce remain underutilized, limiting market access expansion. However, evidence from community service projects shows that training in digital marketing significantly improves UMKM's ability to reach broader markets. For example Rosidi et al. (2023) found that after digital marketing training, 80-92% of coffee UMKM partners could publish their products through social media. Similarly, (Puspitasari., 2025) demonstrated that millennial farmers in Kota Batu reduced dependency on middlemen and expanded their market reach through digital communication technologies and intensive mentoring.

Given these challenges, interventions are urgently needed. This community service program is designed to (1) increase food security by diversifying corn-based products into tempeh and corn oil; (2) promote environmental sustainability by processing agricultural

waste into compost and briquettes in line with circular economy principles (Castrillón et al., 2021; Perdana et al., 2023); (3) strengthen institutional and managerial capacity through structured financial and organizational practices; and (4) expand market access by introducing digital marketing strategies (Masyadi & Mansur, 2021).

The program aligns with the Sustainable Development Goals (SDGs), particularly SDGs 2 (Zero Hunger), 12 (Responsible Consumption and Production), and 13 (Climate Action), as outlined by the United Nations (2015). In addition, the initiative supports the Higher Education Key Performance Indicators (*Indikator Kinerja Utama Perguruan Tinggi*/IKU) established by the Ministry of Education, Culture, Research, and Technology of Indonesia. Specifically, it contributes to IKU 2 (lecturers' activities outside the campus that involve the community or industry) and IKU 5 (lecturers' work being utilized by society), demonstrating the tangible impact of academic engagement. Moreover, the program aligns with the National Research Master Plan (*Rencana Induk Riset Nasional*/RIRN) in the area of agricultural waste management and with the Asta Cita national agenda, which emphasizes rural development, entrepreneurship, and the creative economy. Therefore, empowering the Kabuttu Farmers Group in Gattareng Village is both urgent and strategic for increasing agricultural productivity, improving farmers' livelihoods, and promoting sustainable rural transformation.

METHODS

This Community Partnership Program was implemented in Gattareng Village, Marioriwawo Subdistrict, Soppeng Regency, South Sulawesi Province. The village is recognized as one of the main corn-producing centers in the region, with 42.3% of its agricultural land, approximately 255.2 hectares, devoted to corn cultivation, yielding an annual production of 995.3 tons (Jamaludin et al. 2025). The primary partner in this program was the Kabuttu Farmers Group, comprising 20 farmers, most of whom are male, owning land between 0.5–1 hectare, with an average monthly income of less than IDR 2 million (Masyadi; Amrial; Andi 2024). The program was carried out over a six-month period, from April to September 2025.

Implementation of Activities

The program adopted a **Participatory Action Research (PAR)** approach, emphasizing the active involvement of farmer partners in every stage of implementation. This approach was selected to ensure that the intervention was not only relevant to farmers' needs but also capable of promoting empowerment and long-term sustainability.

1. **Preparation and Socialization**: The program began with meetings involving local government officials and the Kabuttu Farmers Group to identify core problems such as low-value-added corn products, unoptimized agricultural waste management, and limited market access. This participatory process ensured that the intervention design was tailored to real conditions in the field.
2. **Training and Capacity Building**: Structured training sessions were conducted, covering key topics such as corn product diversification (corn tempeh and corn oil), agricultural waste processing into compost and briquettes, and digital marketing strategies using e-commerce platforms and social media.
3. **Mentoring and Hands-on Practice**: Following the training, intensive mentoring was provided through hands-on product creation, basic financial recording, and digital promotion. This approach proved effective in significantly enhancing farmers' technical skills.

4. **Evaluation and Reflection**: Regular monitoring was conducted to assess program achievements, identify field-level challenges, and make strategic adjustments as needed.

Method of Service and Materials Delivered

The methods employed in this program included **active participation, training, direct demonstration, and continuous mentoring**, which are proven to be effective for technology transfer and community empowerment (Yarlina & Hunda, 2021). The materials provided during the program consisted of:

1. Training modules on corn-based food product diversification,
2. Manuals on compost and briquette production,
3. Business and financial management tools,
4. Digital marketing guides utilizing smartphones and social media platforms.

Evaluation and Data Analysis

Program evaluation employed both quantitative and qualitative approaches. Knowledge improvement was measured using pre-test and post-test questionnaires that captured farmers' understanding of corn product diversification, agricultural waste processing (compost and briquettes), basic financial management, and digital marketing. Skill adoption was observed using training checklists that recorded participants' ability to follow each critical step of tempeh and corn oil production, operate the provided machinery, apply safety and hygiene procedures, and consistently process corn waste into compost and briquettes. In addition, simple quantitative indicators were collected, including the number of product types produced, the proportion of corn waste utilized, the number of farmers who applied bookkeeping, and the number of farmers who used digital platforms for marketing. Farmers' perceptions and experiences regarding the program's benefits, perceived constraints, changes in motivation, and institutional dynamics within the group were gathered through focus group discussions (FGDs) and in-depth interviews. Quantitative data were analyzed descriptively, while qualitative data were processed thematically to assess changes in behavior, capacity, and organizational practices (Puspitasari 2025).

The success indicators of the program included:

1. An increase in the variety and volume of corn-based processed products,
2. Utilization of corn waste into compost and briquettes,
3. Initial adoption of simple financial record-keeping practices, and
4. Early-stage use of digital platforms for product marketing (Masyadi et al., 2024).

RESULTS AND DISCUSSION

The implementation of the PKM program in Gattareng Village, Soppeng Regency, involved several stages: socialization, training, equipment handover, and mentoring. The results of these activities can be presented as follows:

Socialization and Partner Engagement

The program began with socialization activities attended by 25 members of the Kabuttu Farmers Group. Partners showed strong interest in product diversification, waste utilization, and digital marketing. This stage successfully clarified the program objectives and secured the farmer group's commitment.

Training Activities

Four training modules were delivered: (a) production of corn tempeh, (b) extraction of corn oil, (c) composting and briquette making from corn waste, and (d) financial management and digital marketing.

a) Pre-test and post-test evaluations indicated an increase in participants' knowledge, with an average improvement of 42% across modules.
b) Observation checklists showed that more than 80% of participants were able to follow and reproduce the steps for tempeh and corn oil production after the practical sessions.

These improvements are also reflected in Table 1, which compares conditions before and after the program.

Table 1 Comparison of pre-implementation and post-implementation conditions

No	Indicator	Pre-Implementation	Post-Implementation
1.	Production Aspect	Dried corn kernels, corn rice, boiled corn	Dried corn kernels, corn rice, boiled corn, corn tempeh, corn oil, compost, briquettes
2.	Management Aspect	No structured management	Effective management system, including planning, organizing, and financial recording
3.	Market Aspect	Marketing through collectors or limited local markets	Marketing via digital marketplace, social media, and direct sales

Technology Transfer and Equipment Handover

The program provided appropriate technology to support production and waste management: a corn grinder, oil press machine, waste chopper, and briquette machine (Figures 1). These tools were successfully demonstrated and adopted by the farmer group. Partners confirmed that these machines reduced processing time and increased efficiency.

(a) (b) (c)

Figure 1 (a) Electric oven dryer, 2025, (b) Cold oil press machine, 202, and (c) Briquette making machine

Product Diversification Outputs

1. Corn Tempeh: Farmers were able to produce corn tempeh with improved taste and texture, and samples were distributed within the local market.
2. Corn Oil: Small-scale extraction was successfully tested, producing oil suitable for household consumption.

3. Compost & Briquettes: Corn husks, stalks, and cobs were processed into organic compost and solid fuel briquettes. Around 30% of waste that was previously discarded was converted into usable products.

These outputs demonstrate tangible progress in waste utilization and diversification, as illustrated in *Figure 5* showing partner challenges and opportunities.

5. Institutional and Financial Management

Members were able to begin documenting group income and expenses by implementing basic bookkeeping systems. Sixty percent of participants had implemented financial recording procedures in their operations after three months. With this development, informal organizational practices are giving way to more formal ones

6. Digital Marketing Adoption

Digital platforms such as WhatsApp Business and Facebook Marketplace were presented to partners. Ten farmers had created digital accounts and begun online product promotion by the program's conclusion. Social media was used to track early sales, but the volume was still small. Sales through the Shopee marketplace are shown in Figure 2.

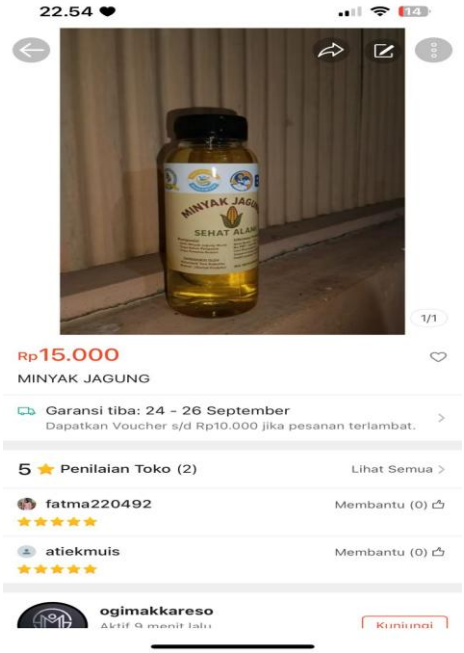

Figure 2 Sales through the shopee marketplace

Monitoring and Mentoring

To monitor implementation, monthly mentoring sessions were held. Farmers said they felt more confident about creating and selling a variety of corn products. But they also pointed out issues such as members' varying degrees of digital literacy and the seasonality of raw material availability. Table 2 lists additional program outputs and demonstrates how they relate to higher education performance indicators (IKU).

The PKM program successfully addressed the core problems faced by the Kabuttu Farmers Group, particularly the low value of products, poor waste management, and inadequate market access. Farmers received training and mentoring through the Participatory Action Research (PAR) approach, which enabled them to be directly involved in planning, practice, and evaluation at every stage of the program. This level of engagement not only allowed farmers to solve their problems through the program but

also ensured that the solutions provided were relevant to their urgent needs and sustainable for future use (Brown et al., 2022; Rohyani et al., 2021).

Program Outputs as Indicators of Success

The outcomes of the intervention were measurable and demonstrated significant improvement in partner capacities. A 42% increase in test scores and an 80% adoption rate in practical modules confirmed that structured training and mentoring enhanced both technical knowledge and practical skills (Enjolras et al., 2020). Product diversification into corn tempeh, corn oil, compost, and briquettes not only increased product value but also reduced environmental impact, in line with the principles of the circular economy (Castrillón et al., 2021)

Technology transfer through the provision of briquette machines, oil press machines, and grinders further strengthened these outputs. The introduction of small-scale mechanization reduced processing time, improved production efficiency, and built farmer confidence in handling new procedures, supporting earlier findings on the benefits of appropriate mechanization for smallholders (Sagwal et al., 2022).

Institutional strengthening was another notable output. About 60% of members adopted simple bookkeeping systems, reflecting progress toward transparent financial practices and better organizational governance. Such improvements are recognized as prerequisites for long-term resilience and access to external support (Listiana et al., 2021).

Digital Marketing And Market Expansion

The adoption of digital marketing platforms such as Facebook Marketplace and WhatsApp Business by ten farmers represented another milestone. While initial sales volumes remained modest, this initiative demonstrated the potential of digitalization to expand market access. Literature supports the notion that digital platforms, when combined with adequate mentoring, can enhance competitiveness and market integration (Manikandan et al., 2025). Nonetheless, digital literacy gaps among members remain a key barrier to wider adoption. Sales via Instagram are shown in Figure 3.

Figure 6 Sales through the Instagram

Driving and Hindering Factors

Several factors facilitated the success of the PKM program: the strong organizational structure of the farmer group, the relatively close distance between the partner location and the implementing campus, and the consistent mentoring framework. Similar findings were reported by Yarlina and Hunda, who emphasized that institutional strength and localized collaboration enhance the effectiveness of rural economic empowerment initiatives (Yarlina & Hunda, 2021). Monthly meetings provided adaptive feedback loops, ensuring that issues such as uneven digital readiness and seasonal raw material availability were addressed promptly. These adaptive support systems are essential for sustaining program outcomes and fostering continuous innovation (Masyadi et al., 2024) Conversely, several challenges were identified, including limited initial knowledge of processing technologies, reliance on external facilitation during the early stages, and the need for continuous motivation to ensure long-term adoption. These barriers are consistent with the findings of Mohamad et al. (2023), who highlight that the sustainability of community programs depends heavily on continuous motivation, internal leadership, and knowledge transfer.

Contribution to Broader Development Goals

Beyond addressing local problems, the program contributed directly to global and national development agendas. The reduction in open burning practices supported SDG 13 (Climate Action); the adoption of waste-to-resource practices aligned with SDG 12 (Responsible Consumption and Production); and product diversification contributed to SDG 2 (Zero Hunger). These outcomes align with the recommendations of W Lang (Lang et al. 2024), who underscore the relevance of village-based interventions in achieving the Sustainable Development Goals, particularly within the agricultural sector. Additionally, the program strengthened the role of universities in society by contributing to Key Performance Indicators (IKU 2 and IKU 5), thereby demonstrating the critical role of higher education institutions in advancing sustainable rural development.

Synthesis

Overall, the PKM program illustrates that comprehensive interventions covering social, technical, institutional, and digital aspects are effective in transforming smallholder farming systems into more innovative, competitive, and sustainable enterprises. The combination of participatory approaches, measurable capacity improvements, technological innovation, and digital marketing integration underscores the program's contribution as both a problem-solving intervention and a strategic model for community empowerment.

CONCLUSION

Increased food security, improved farmer income, and the promotion of sustainable agricultural practices were the main goals of the Community Partnership Program (PKM), which was carried out in Gattareng Village in collaboration with the Kabuttu Farmers Group. With the help of the transfer of suitable technology that increased productivity and decreased waste, the program enhanced farmers' technical skills through product diversification (corn tempeh, corn oil, compost, and briquettes). The adoption of more structured group management and basic financial recording also demonstrated an increase in institutional capacity.

Even though different levels of digital literacy are still a problem, the advent of digital marketing platforms also increased initial market access and shown promise for wider

commercialization. Maintaining results, dealing with new issues, and encouraging members' adaptive learning all required ongoing mentoring. All things considered, the PKM program shows that integrated interventions—which include digitalization, financial management, technology transfer, socialization, and training are successful in converting smallholder farming systems into more sustainable and competitive businesses. In line with SDGs 2 (Zero Hunger), 12 (Responsible Consumption and Production), and 13 (Climate Action), this program highlights how higher education can strategically support national development goals and build community resilience.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTION STATEMENT

Conceptualization, M; methodology, M. and MAT; formal analysis, S; investigation, M and S; resources, MAT; data curation, M; writing original draft preparation, M; writing—review and editing, S and MAT; supervision, M. All authors have read and agreed to the published version of the manuscript.

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AUTHOR PROFILES

Masyadi,SE.,MM
masyadi@unipol.ac.id
Universitas Lamappapoleonro
https://scholar.google.com/citations?hl=id&user=5X_QSN0AAAAJr
https://sinta.kemdiktisaintek.go.id/authors/profile/6695077
https://orcid.org/0000-0001-8299-099X

Surianti,SE.,MM
surianti@unipol.ac.id
Universitas Lamappapoleonro
https://scholar.google.com/citations?hl=id&user=UF2mNcgAAAAJ
https://sinta.kemdiktisaintek.go.id/authors/profile/6695039

M. Afdal Tahir,S.Kom.,MMSI
afdal.tahir@unipol.ac.id
https://scholar.google.com/citations?hl=id&user=CC46-xQAAAAJ
https://sinta.kemdiktisaintek.go.id/authors/profile/6694398