MIKAILALSYS
Journal of Multidisciplinary Sciences
e-ISSN : 2987-2286
p-ISSN : 2987-3924
Index: Harvard, Boston, Sydney, Copernicus, Sinta 4, Scilit, Semantic, Google, etc
https://doi.org/10.58578/mikailalsys.v4i3.11491

Extension Program Design for Utilizing Oil Palm Fronds to Produce Briquettes in Padang Bolak Julu District, North Padang Lawas Regency

Fachrurrozy Ahmad Ritonga, Firman Raydav Lamtorang Silalahi, Azis Herdiyanto Riyadi
Politeknik Pembangunan Pertanian Medan, Indonesia
rozyahmad135@gmail.com; firman.rlsilalahi@gmail.com

Article Info:

Submitted:	Revised:	Accepted:	Published:
Jun 12, 2026	Jul 10, 2026	Jul 22, 2026	Jul 27, 2026

Abstract

Oil palm plantations generate substantial quantities of underutilized frond waste, creating environmental concerns while limiting opportunities for value-added use. Converting oil palm fronds into briquettes offers a renewable energy solution that can simultaneously improve agricultural waste management and create additional economic opportunities for farmers. This study aims to develop an agricultural extension program, evaluate farmers' acceptance of its design, and assess its effects on farmers' knowledge, attitudes, and practical skills related to briquette production from oil palm fronds in Padang Bolak Julu District, North Padang Lawas Regency. Conducted from March to April 2026, the study employed an evaluative approach combining an assessment of the extension program design with an evaluation of its outcomes. Thirty farmers were selected through purposive sampling. Data were collected through observations, questionnaires, documentation, and pretest and posttest assessments and analyzed descriptively using percentage analysis and continuum-scale interpretation. The findings indicate that all extension components, including instructional materials, teaching methods, learning media, program intensity, location, scheduling, and implementation costs, were categorized as highly effective. Farmers' knowledge increased from 45.13% before the intervention to 84.87% afterward, while their attitudes toward the innovation were highly positive, with a score of 84.27%. Moreover, 76.67% of participants were classified as skilled in briquette production. The economic feasibility analysis produced a revenue–cost ratio of 1.72, indicating that briquette production is financially viable. The study concludes that a participatory and context-based extension program can effectively facilitate behavioral change and promote the conversion of oil palm fronds into value-added products. These findings provide practical implications for the development of locally responsive agricultural extension programs that support sustainable waste management, renewable energy production, and improved economic opportunities for farming communities.

Keywords: Agricultural Extension; Briquette Production; Oil Palm Fronds; Renewable Energy; Waste Valorization

INTRODUCTION

Sustainable economic development has become a central agenda for many countries in response to the increasing challenges of population growth, rising energy demand, and environmental degradation. Contemporary development paradigms no longer emphasize economic expansion alone but increasingly promote the efficient utilization of natural resources through value-added production and the implementation of circular economy principles. Within this framework, the agricultural sector plays a strategic role because it not only supplies primary commodities for food and industrial purposes but also generates substantial quantities of biomass that can be transformed into high-value products. The optimization of agricultural biomass utilization is therefore considered an essential strategy for improving the competitiveness of the agricultural sector while simultaneously supporting sustainable development goals (Tsiwiyati, 2024).

In Indonesia, this challenge has been addressed through the national downstreaming (*hilirisasi*) policy, which aims to increase the added value of domestic commodities. Downstreaming is understood not merely as the processing of raw materials into intermediate or finished products but also as a comprehensive economic development strategy designed to strengthen industrial competitiveness, expand employment opportunities, increase national income, and reduce dependence on raw commodity exports. Through this policy, Indonesia seeks to transform its economic structure from a commodity-exporting country into a producer of value-added products capable of generating broader economic benefits for society (Akhmadi, 2024).

The agricultural and plantation sectors provide significant opportunities for implementing downstream industrialization because Indonesia possesses abundant biological resources with considerable economic potential. Among these resources, oil palm has emerged as one of the country's most strategic plantation commodities. Besides serving as a major source of foreign exchange through the export of crude palm oil (CPO) and palm kernel oil (PKO), the oil palm industry supports the livelihoods of millions of people engaged in plantation activities and downstream industries. Consequently, oil palm has become one of the primary priorities in Indonesia's downstream development agenda (Abdul, 2023).

The continuous expansion of oil palm plantations has substantially increased national production capacity. However, higher production has also resulted in the accumulation of enormous quantities of agricultural residues generated during cultivation and processing activities. This situation presents a dual challenge. On one hand, unmanaged plantation residues may cause environmental pollution and ecological degradation. On the other hand, these residues represent valuable biomass resources that can be converted into economically beneficial products through appropriate downstream processing technologies. Therefore, plantation waste should no longer be viewed solely as an environmental burden but rather as a strategic resource capable of supporting sustainable economic growth (Hasibuan et al., 2023).

North Sumatra Province represents one of Indonesia's largest oil palm production centers, with plantation areas exceeding 1.3 million hectares in 2025. The extensive plantation area indicates an enormous availability of biomass resources that could support the development of various downstream products derived from oil palm residues. Besides producing crude palm oil, plantation activities generate considerable quantities of solid, liquid, and gaseous waste, all of which require appropriate management systems capable of balancing economic benefits with environmental sustainability.

Within North Sumatra, North Padang Lawas Regency has experienced substantial growth in oil palm cultivation and has become an important plantation-based economic region. The regency possesses tens of thousands of hectares of oil palm plantations distributed across several districts, including Padang Bolak Julu District. For local communities, oil palm cultivation serves as the primary source of household income and economic activity. Nevertheless, despite its considerable production capacity, the utilization of oil palm biomass remains largely limited to fresh fruit bunch production, while other plant components receive relatively little economic attention. This condition suggests that significant opportunities for increasing value-added production remain underutilized (Badan Pusat Statistik Kabupaten Padang Lawas Utara, 2025).

One of the major challenges associated with oil palm cultivation is the management of plantation residues generated during pruning and harvesting activities. These residues include empty fruit bunches, shells, fibers, trunks, fronds, liquid waste, and gaseous emissions. Improper management of these materials may contribute to soil degradation, water pollution, air contamination, and biodiversity loss. Furthermore, accumulated plantation residues may create favorable conditions for pests and plant diseases, thereby reducing plantation productivity over time (Hasibuan et al., 2023).

Among these residues, oil palm fronds constitute one of the most abundant forms of solid biomass because they are continuously produced through routine pruning operations. Each oil palm tree generates approximately twenty-two fronds annually, resulting in a substantial accumulation of biomass across plantation landscapes. Due to their rigid physical structure, oil palm fronds decompose relatively slowly under natural conditions. Consequently, many farmers simply pile the fronds between planting rows or burn them openly to facilitate plantation maintenance and field sanitation (Susanti & Wijaya, 2019).

Such management practices indicate that oil palm fronds are still widely perceived as agricultural waste with little or no economic value. In reality, numerous studies have demonstrated that oil palm fronds contain substantial biomass suitable for conversion into renewable energy and various value-added products. Treating these residues merely as waste not only creates environmental concerns but also represents a missed opportunity for improving farmers' income through resource diversification. Therefore, the principal challenge lies not in biomass availability but rather in the limited capacity to convert existing resources into economically valuable products (Paranita, 2020).

The urgency of biomass utilization has become increasingly important as Indonesia continues to rely heavily on fossil fuels to satisfy its growing energy demand. Household energy consumption remains dominated by petroleum products, coal, and liquefied petroleum gas, all of which are non-renewable energy resources with finite reserves. Moreover, extensive fossil fuel consumption contributes significantly to greenhouse gas emissions and global climate change. Consequently, developing renewable energy derived from agricultural biomass has become one of the strategic alternatives for strengthening national energy security while simultaneously supporting environmental sustainability (Papilo, 2012).

Among the available biomass conversion technologies, charcoal briquettes produced from oil palm fronds represent one of the most feasible alternatives for rural communities. Briquettes are manufactured through the carbonization of biomass, followed by mixing with binding materials and compression into dense solid fuel. Compared with raw biomass, briquettes possess several advantages, including higher calorific value, lower smoke emissions, easier storage and transportation, and more efficient combustion characteristics. These advantages make biomass briquettes an attractive renewable energy source capable of substituting conventional firewood and charcoal while simultaneously increasing the economic value of oil palm plantation residues (Lestari et al., 2022).

Furthermore, transforming oil palm fronds into charcoal briquettes is consistent with the broader objectives of sustainable agriculture and circular economy practices. Rather than allowing biomass residues to accumulate or be openly burned, farmers may convert plantation waste into commercially valuable products that contribute to household income, environmental conservation, and renewable energy development. This integrated approach aligns economic, environmental, and social objectives, making biomass utilization an important component of sustainable oil palm plantation management.

Previous studies have consistently demonstrated that oil palm fronds possess considerable potential as a renewable biomass resource due to their abundant availability and favorable physicochemical properties. As a continuously generated plantation residue, oil palm fronds provide a sustainable raw material for producing biomass briquettes while supporting value-added utilization of agricultural waste (Saputra et al., 2021).

Research has further confirmed the technical feasibility of oil palm frond briquettes as an alternative solid fuel. Studies have reported satisfactory calorific values, low moisture content, stable combustion performance, and acceptable ash content, indicating that briquettes derived from oil palm fronds can substitute conventional firewood and charcoal while contributing to renewable energy development (Saputra et al., 2021).The production process including drying, carbonization, grinding, binder mixing, molding, and drying—also relies on relatively simple technologies that can be adopted by rural communities without requiring substantial investment (Lestari et al., 2022).

Beyond briquette production, numerous studies have highlighted that various oil palm residues can be converted into value-added products such as bioenergy, organic fertilizer, livestock feed, construction materials, and industrial raw materials. These findings demonstrate that downstream utilization of oil palm biomass supports both resource efficiency and circular economy principles while reducing environmental pollution caused by unmanaged plantation waste (Hasibuan et al., 2023).

The economic benefits of biomass utilization have also been widely recognized. Converting plantation residues into briquettes increases the commercial value of agricultural waste, creates opportunities for rural entrepreneurship, diversifies farmers' income, and contributes to sustainable rural development (Padapi, 2022). Community empowerment programs have similarly shown that training and technical assistance improve local capacity to produce biomass briquettes and encourage wider adoption of renewable energy technologies (Permana et al., 2025).

Despite these promising findings, previous studies have predominantly emphasized engineering aspects, including biomass characteristics, production techniques, and briquette quality. Comparatively little attention has been devoted to the social dimension of innovation adoption, particularly how farmers perceive, accept, and implement downstream biomass technologies within their farming systems. Consequently, the role of agricultural extension in facilitating the adoption of oil palm waste utilization remains insufficiently explored.

Agricultural extension plays a strategic role in promoting innovation adoption by improving farmers' knowledge, attitudes, and practical skills through participatory learning and continuous assistance. Effective extension programs should therefore be designed according to farmers' needs, local resources, and socioeconomic conditions to encourage sustainable behavioral change and technology adoption (Law of the Republic of Indonesia No. 16 of 2006). The effectiveness of such programs is commonly evaluated through improvements in farmers' knowledge, attitudes, and skills as key indicators of behavioral change (Latif et al., 2024).

Field observations in Padang Bolak Julu District indicate that oil palm fronds remain largely underutilized despite their abundant availability. Farmers continue to depend primarily on fresh fruit bunch production, while pruned fronds are left unused in plantations and downstream utilization has not yet been incorporated into local agricultural extension programs. As a result, farmers receive limited information regarding briquette production and its economic potential.

These conditions reveal a clear discrepancy between the availability of biomass resources and farmers' capacity to utilize them productively. Existing studies have mainly focused on the technical feasibility of biomass briquettes, whereas limited research has integrated oil palm downstream utilization with agricultural extension planning, farmer acceptance, and behavioral impact evaluation. Addressing this gap is essential because successful downstream development depends not only on technological feasibility but also on farmers' willingness and capacity to adopt innovation through effective extension programs.

This study is grounded in the theory of agricultural extension, which views extension as a non-formal educational process aimed at improving farmers' knowledge, attitudes, and skills to facilitate behavioral change and innovation adoption. From this perspective, the success of agricultural innovation depends not only on technological advancement but also on effective communication, learning, and continuous support provided to farming communities (Law of the Republic of Indonesia No. 16 of 2006).

The study also adopts the concept of farmer behavior, encompassing knowledge, attitudes, and skills as key indicators of extension effectiveness. Extension programs are considered successful when they not only enhance farmers' understanding of an innovation but also encourage positive attitudes and strengthen their capacity to implement it in farming practices (Latif et al., 2024).

In the context of oil palm downstream development, behavioral change is essential for transforming oil palm fronds from agricultural waste into value-added products. Farmers who recognize the economic potential of biomass residues and possess the necessary technical skills are more likely to adopt briquette production, thereby increasing household income while reducing environmental problems associated with plantation waste.

The novelty of this study lies in integrating four dimensions that are commonly examined separately in previous studies: oil palm frond downstream utilization, agricultural extension design, farmer acceptance of innovation, and the evaluation of behavioral changes following extension activities. While previous research has mainly focused on technical aspects such as biomass characteristics, production methods, and briquette quality, this study emphasizes the social and behavioral dimensions of innovation adoption through agricultural extension.

This research also introduces farmer acceptance as an essential component in designing extension recommendations. By examining farmers' perceptions, understanding, and willingness to adopt biomass innovations, the study provides a more comprehensive assessment of extension effectiveness and supports the development of extension strategies that are responsive to local conditions.

Theoretically, this study contributes to agricultural extension literature by linking plantation waste utilization with innovation adoption and sustainable agricultural development. Practically, it provides recommendations for extension officers and policymakers in designing extension programs that promote biomass utilization, increase farmers' income, reduce plantation waste, and support renewable energy development.

Accordingly, this study aims to develop an agricultural extension design for utilizing oil palm fronds as charcoal briquettes in Padang Bolak Julu District, evaluate farmers' acceptance of the proposed extension program, and assess its impact on farmers' knowledge, attitudes, and skills. Ultimately, the study is expected to support sustainable oil palm downstream development through economic value creation, environmental sustainability, and community empowerment.

METHODS

This study employed a quantitative approach using a descriptive-evaluative research design to develop an agricultural extension program, assess farmers' acceptance of the proposed extension design, and evaluate the impact of extension activities on changes in farmers' behavior regarding the utilization of oil palm fronds for biomass briquette production. A quantitative approach was selected because the study aimed to objectively measure the effectiveness of the extension design using measurable indicators and to evaluate changes in farmers' knowledge, attitudes, and practical skills following the implementation of the extension program. The development of the extension design was based on the principles of agricultural extension stipulated in Law of the Republic of Indonesia No. 16 of 2006 concerning the Agricultural, Fisheries, and Forestry Extension System, while the formulation of extension objectives adopted the SMART and ABCD approaches recommended in Regulation of the Minister of Agriculture of the Republic of Indonesia No. 03/Permentan/SM.200/1/2018, together with the behavioral change concept proposed by Mardikanto (2018).

The research was conducted from March to April 2026, in Parupuk Jae Village, Padang Bolak Julu District, North Padang Lawas Regency, North Sumatra Province, Indonesia. The study site was selected using purposive sampling because the area represents one of the major oil palm production centers with abundant oil palm frond residues but has never received a specific agricultural extension program concerning the utilization of oil palm fronds for biomass briquette production. Furthermore, most fronds are still left to decompose or accumulated within plantation fields, indicating substantial potential for conversion into renewable energy products while simultaneously increasing the economic value of plantation residues.

The research design consisted of three sequential stages: regional potential identification, extension program design, and extension evaluation. Regional potential identification was conducted using the Rapid Rural Appraisal (RRA) approach to obtain comprehensive information regarding local conditions, farmer characteristics, available resources, and existing agricultural problems. The RRA techniques included secondary data review, field observation, interviews with key informants, participatory mapping, simple case studies, trend analysis, brief questionnaire administration, and rapid field reporting (Mardiana et al., 2025). The information obtained from this stage served as the primary basis for developing an extension program that corresponded to the actual needs and conditions of the farming community.

The extension program was designed based on seven principal components, namely extension materials, extension methods, extension media, extension intensity (volume), extension location, implementation schedule, and extension costs. The indicators for extension materials covered technical, economic, and social aspects, including ease of implementation, economic benefits, compatibility with local conditions, level of risk, and social acceptability. The indicators for extension methods evaluated the effectiveness of lectures, method demonstrations, and farm visits in improving farmers' understanding, learning experiences, participation, and knowledge retention. Extension media were assessed through the use of brochures, instructional videos, and real objects, with indicators including media attractiveness, effectiveness of information delivery, stimulation of farmers' interest, and enhancement of practical competencies. In addition, the study evaluated the appropriateness of extension frequency, accessibility of the extension venue, suitability of implementation time, and efficiency of extension costs. The evaluation of extension outcomes was based on the behavioral change framework proposed by Mardikanto (2018), encompassing three behavioral dimensions: knowledge (cognitive), attitude (affective), and skills (psychomotor).

The participants consisted of 30 oil palm farmers who were members of the Tani Suka Maju group in Parupuk Jae Village. Respondents were selected using a purposive sampling technique, resulting in a total sample of 30 farmers. Respondents were selected based on five inclusion criteria: (1) owning productive oil palm plantations, (2) managing a minimum plantation area of one hectare, (3) not previously utilizing oil palm fronds as value-added products, (4) being active members of the Tani Suka Maju Group, and (5) demonstrating openness toward agricultural innovation. These criteria ensured that participants represented the intended beneficiaries of the extension program and possessed the potential to adopt the proposed biomass utilization technology.

The study utilized both primary and secondary data. Primary data were collected through field observations, structured interviews, questionnaire administration, and documentation throughout the extension activities. Field observations were conducted to identify local environmental conditions, the availability of oil palm frond residues, farming practices, and supporting facilities for biomass utilization. Structured interviews were used to obtain information regarding farmers' characteristics, prior knowledge, and challenges associated with plantation waste utilization. Secondary data were collected through reviews of scientific literature, district agricultural extension program documents, institutional reports, and other references related to the utilization of oil palm fronds for biomass briquette production.

The research instrument consisted of a structured questionnaire developed according to an instrument matrix derived from the indicators of each extension program component. Prior to the main survey, the questionnaire was evaluated through a pilot survey involving approximately 10% of the planned sample, following the recommendation of (Connelly, 2008). Instrument validity was examined using the Pearson Product Moment Correlation method, while reliability was assessed using Cronbach's Alpha (Ghozali, 2021). The validity assessment indicated that 51 questionnaire items met the validity requirements, whereas nine items failed to satisfy the validity criteria and were therefore excluded from subsequent analyses. Furthermore, all research variables demonstrated Cronbach's Alpha coefficients exceeding 0.600, ranging from 0.829 to 0.956, indicating satisfactory internal consistency and confirming that the research instrument was reliable for data collection.

Data were analyzed using descriptive quantitative analysis. Information obtained during the regional potential identification stage was analyzed to support the preparation of the agricultural extension design, while data collected from the extension evaluation were analyzed using descriptive statistics, including frequency distributions, percentages, and score interpretations, to describe farmers' acceptance of the proposed extension program and the behavioral changes observed after its implementation. The impact of the extension activities was evaluated by comparing farmers' conditions before and after the extension program across the three behavioral dimensions, namely knowledge, attitudes, and practical skills. The findings were subsequently interpreted to determine the effectiveness of the extension design in improving farmers' capacity to convert oil palm fronds into biomass briquettes as an alternative renewable energy source. This analytical approach enabled the formulation of extension recommendations that are responsive to local farmer characteristics and regional conditions, thereby supporting the sustainable downstream development of oil palm biomass utilization.

RESULTS

This study evaluated the effectiveness of an agricultural extension program designed to promote the utilization of oil palm fronds as biomass briquettes and assessed its impact on farmers' knowledge, attitudes, and practical skills. The evaluation covered seven extension components, namely extension materials, methods, media, volume, location, timing, and implementation costs, followed by an assessment of behavioral changes among participants after the extension activities.

Overall, all extension components achieved the highly effective category, with effectiveness scores exceeding 84%, indicating that the extension program was well designed and appropriately aligned with farmers' learning needs and field conditions.

Table 1. Summary of Extension Program Effectiveness

Extension Component	Percentage (%)	Category
Materials	84.81	Highly Effective
Methods	86.07	Highly Effective
Media	84.10	Highly Effective
Volume	86.00	Highly Effective
Location	84.40	Highly Effective
Timing	87.11	Highly Effective
Cost	86.40	Highly Effective

Source: Compiled by the researcher (2026)

Table 1. Summary of Extension Program Effectiveness shows that all components of the agricultural extension program were classified as highly effective, with effectiveness scores ranging from 84.10% to 87.11%. Among the evaluated components, timing achieved the highest effectiveness score (87.11%), followed by cost (86.40%), methods (86.07%), volume (86.00%), materials (84.81%), location (84.40%), and media (84.10%). These findings indicate that the extension program was well designed and successfully implemented across all evaluated aspects.

Extension materials obtained an effectiveness score of 84.81%, with the social dimension demonstrating the highest level of acceptance compared to the economic and technical dimensions, indicating that the learning materials were closely aligned with the socio-cultural characteristics of the target farmers. Regarding extension methods, the program achieved an effectiveness score of 86.07%, where demonstration-based learning received higher acceptance than conventional lectures, suggesting that practical learning approaches were more appropriate for adult learners.

Extension media achieved an effectiveness score of 84.10%, with real objects outperforming videos and printed folders. The extension volume, consisting of two learning sessions supported by two complementary teaching methods, reached an effectiveness level of 86.00%. Furthermore, the extension location achieved 84.40%, indicating that accessible and field-relevant learning environments supported effective knowledge transfer. The timing component received the highest score among all indicators (87.11%), while extension costs achieved 86.40%, reflecting the efficient use of locally available resources during implementation.

The study further assessed changes in farmers' behavior after participating in the extension program by measuring knowledge, attitudes, and practical skills.

Table 2. Summary of Extension Outcomes

Indicator	Result
Knowledge (Pre-test)	45.13%
Knowledge (Post-test)	84.87%
Attitude	84.27%
Skilled Participants	76.67%

Source: Compiled by the researcher (2026)

Table 2. Summary of Extension Outcomes shows that the agricultural extension program produced positive changes in farmers' knowledge, attitudes, and practical skills regarding the utilization of oil palm fronds as briquettes. Knowledge scores increased substantially from 45.13% in the pre-test to 84.87% in the post-test, indicating a considerable improvement in participants' understanding after the extension activities. Farmers also demonstrated a highly positive attitude toward the promoted innovation, achieving an average score of 84.27%, which reflects their willingness to adopt briquette production as an alternative use of oil palm waste. Furthermore, 76.67% of the participants were classified as skilled in producing briquettes independently after completing the training, indicating that most participants successfully acquired the practical competencies introduced during the extension program.

In addition to evaluating behavioral changes, the study also assessed the economic feasibility of briquette production. The analysis showed that the production cost was IDR 8,698 per kilogram, while the selling price reached IDR 15,000 per kilogram, generating a profit of IDR 6,302 per kilogram with an R/C ratio of 1.72. These findings suggest that briquette production is economically feasible and has the potential to serve as an alternative income-generating activity for oil palm farmers. Overall, the findings indicate that the extension program not only enhanced farmers' knowledge, attitudes, and practical skills but also introduced an economically viable innovation with potential benefits for sustainable agricultural waste management and rural livelihoods.

DISCUSSION

The findings demonstrate that the agricultural extension program on utilizing oil palm fronds as briquettes was highly effective in improving farmers' acceptance of the innovation and promoting positive behavioral change. The consistently high effectiveness scores across all extension components, combined with substantial improvements in knowledge, attitudes, and practical skills, indicate that the extension program successfully fulfilled its educational and empowerment objectives. Rather than merely transferring information, the program facilitated a learning process that enabled farmers to understand, evaluate, and apply the proposed innovation within their farming context.

The high effectiveness of the extension materials suggests that the learning content was appropriately designed according to farmers' needs and local conditions. Among the three dimensions evaluated, the social aspect obtained the highest acceptance, indicating that the innovation was perceived as compatible with the farmers' daily activities, community values, and existing farming practices. This finding supports the argument that extension materials become more effective when they are contextualized within local socio-cultural conditions rather than being presented as generalized technological recommendations. This result is consistent with the findings of Irdiana et al. (2024), who reported that extension materials aligned with farmers' social conditions are more easily accepted. The high score for the economic dimension also indicates that farmers recognized the potential financial benefits of briquette production, supporting the findings of Khairunnisa & Djazuli (2024). Likewise, the strong technical acceptance confirms that practical and problem-oriented learning materials facilitate technology adoption, as emphasized by Salsabilla et al. (2023).

Extension methods also played a decisive role in determining program effectiveness. Demonstration-based learning achieved higher acceptance than lecture-based instruction, confirming that experiential learning remains the most appropriate approach for adult farmers. Demonstrations allowed participants to observe each production stage directly, ask questions during the process, and practice the technology immediately after receiving theoretical explanations. Such interactive learning strengthened both cognitive understanding and procedural knowledge. Meanwhile, lectures remained valuable for introducing fundamental concepts before practical activities were conducted. The complementary use of lectures and demonstrations therefore created an integrated learning environment in which conceptual understanding and practical competence reinforced one another. These findings are in agreement with Ridwansyah et al. (2025), who concluded that demonstration methods effectively improve farmers' knowledge and technical competence. The importance of direct practice is also supported by Mutia et al. (2022). Similar conclusions regarding the effectiveness of participatory extension methods were reported by Dewi et al.

(2024). Furthermore, emphasized that selecting appropriate extension methods is fundamental for successful technology transfer.

Media selection further contributed to the success of the extension activities. Real objects received the highest effectiveness score among all instructional media, exceeding videos and printed folders. This finding illustrates that tangible learning materials provide stronger experiential learning opportunities because farmers can directly observe, manipulate, and evaluate the innovation being introduced. Videos complemented the demonstrations by presenting production procedures systematically, whereas folders served as permanent learning references that participants could revisit after the extension sessions. Consequently, combining visual, printed, and hands-on media created a comprehensive learning environment that accommodated different learning preferences among farmers. This finding supports ,Rustandi & Warnaen (2019) who reported that real objects enhance farmers' comprehension by providing direct learning experiences. Similar results were reported by Yahya et al. (2021), who found that real instructional media significantly improve extension effectiveness.

The effectiveness of extension implementation was also influenced by organizational factors, including the number of meetings, learning location, implementation schedule, and operational costs. Although the program consisted of only two meetings, farmers perceived the learning intensity as sufficient because each session had a clear objective and complementary instructional strategy. This result indicates that extension quality is more important than extension frequency. Similar conclusions were reported by Febrian et al. (2025), who found that well-structured extension sessions are more influential than the number of meetings alone. Selecting accessible locations close to farmers' plantations also enhanced learning relevance because participants could directly relate the innovation to their farming environment. This observation is consistent with Fauziah et al. (2024). Flexible scheduling based on mutual agreement minimized conflicts with farming activities and contributed to high attendance, supporting the findings of Martina et al. (2024). Moreover, efficient utilization of locally available resources reduced operational costs without compromising program quality, which is consistent with Adlih et al. (2023).

Beyond evaluating program implementation, the study demonstrated substantial behavioral changes among farmers. Knowledge increased markedly following the extension program, with post-test scores nearly doubling the initial pre-test results. This improvement indicates that combining lectures, demonstrations, discussions, and supporting media effectively facilitated knowledge acquisition. The increase in knowledge subsequently influenced farmers' attitudes, as reflected by the high willingness to adopt briquette production technology. Positive attitudes emerged because participants recognized that oil palm fronds, previously considered agricultural waste, could be converted into products with economic value while simultaneously contributing to environmental sustainability. Fadhilah et al. (2018) argued that improved knowledge serves as the foundation for developing positive attitudes toward technological innovation. Likewise, Rijal et al. (2024) emphasized that contextual extension methods increase farmers' motivation to adopt agricultural innovations.

The improvement in practical skills further confirms that the extension program succeeded not only in transferring knowledge but also in developing farmers' technical competence. More than three-quarters of participants were categorized as skilled in producing briquettes independently after participating in the demonstrations. Practical learning opportunities enabled farmers to master each production stage, including carbonization, grinding, adhesive mixing, molding, and drying. Nevertheless, several participants remained only moderately skilled or unskilled, indicating that mastering technical innovations requires repeated practice and continuous assistance. This finding supports Wangguway et al. (2023), who explained that farmers' practical skills develop progressively through continuous learning and repeated field practice.

An important contribution of this study lies in integrating extension effectiveness evaluation with an economic feasibility assessment of the promoted innovation. The calculated production cost, expected profit, and R/C ratio demonstrate that briquette production is financially viable. Consequently, farmers are encouraged not only to adopt environmentally sustainable practices but also to develop an alternative income-generating enterprise. This economic evidence strengthens the practicality of the innovation because adoption decisions among farmers are frequently influenced by expected financial returns in addition to technical feasibility.

From a theoretical perspective, this study contributes to agricultural extension literature by demonstrating that extension effectiveness should be viewed as a multidimensional construct involving instructional design, implementation quality, behavioral outcomes, and innovation feasibility. Previous studies generally evaluated these components separately, whereas this research integrates program effectiveness indicators with behavioral evaluation and economic analysis within a single assessment framework. This integrated approach provides a more comprehensive understanding of how extension activities facilitate technology adoption among farmers.

Practically, the findings provide valuable guidance for agricultural extension agencies and policymakers. Extension programs promoting agricultural waste utilization should prioritize contextual learning materials, participatory teaching methods, diverse instructional media, accessible learning environments, and economically feasible innovations. Such an integrated approach is likely to improve farmers' participation, strengthen technology adoption, and support sustainable agricultural development through value-added utilization of agricultural residues.

Despite these contributions, several limitations should be acknowledged. First, the study employed a one-group pretest-posttest design without a control group, limiting the ability to attribute behavioral changes exclusively to the extension intervention. Second, the study involved only 30 farmers from a single farmer group, reducing the generalizability of the findings to broader agricultural contexts. Third, behavioral evaluation focused primarily on immediate post-extension outcomes, without examining the long-term sustainability of innovation adoption. Future studies should therefore incorporate experimental or quasi-experimental designs, involve larger and more diverse farmer populations, and conduct longitudinal evaluations to assess whether knowledge, attitudes, skills, and briquette production practices are maintained over time.

CONCLUSION

This study aimed to design, evaluate, and assess the impact of an agricultural extension program promoting the utilization of oil palm fronds as briquettes to improve farmers' knowledge, attitudes, and practical skills in converting agricultural waste into value-added products. The findings demonstrate that the extension program was developed using valid and reliable research instruments and that all evaluated extension components including instructional materials, teaching methods, learning media, program intensity, location, scheduling, and implementation costs were categorized as highly effective. These results indicate that the extension program was appropriately designed according to farmers' learning needs, local conditions, and community characteristics, thereby creating an effective learning environment that facilitated knowledge transfer and technology adoption.

The study further revealed significant positive changes in farmers' behavior following participation in the extension program. Farmers' knowledge increased substantially after the intervention, accompanied by positive attitudes toward adopting briquette production technology and improved practical skills in independently producing briquettes from oil palm fronds. Furthermore, the economic feasibility analysis demonstrated that briquette production is financially viable, indicating that the promoted innovation not only contributes to environmentally sustainable agricultural waste management but also offers an alternative income-generating opportunity for farmers. These findings confirm that the study successfully achieved its objectives by demonstrating that a context-based extension program employing participatory teaching approaches, particularly demonstration methods supported by appropriate instructional media, can effectively enhance farmers' learning outcomes and encourage innovation adoption.

This research contributes to the development of agricultural extension science by highlighting that extension effectiveness should be understood as a multidimensional concept encompassing instructional design, implementation quality, behavioral change, and the economic feasibility of promoted innovations. Rather than evaluating these dimensions independently, this study integrates extension effectiveness, behavioral outcomes, and economic analysis into a comprehensive evaluation framework. From a practical perspective, the findings provide useful guidance for extension practitioners and policymakers in designing locally adapted extension programs that strengthen farmers' capacities while promoting sustainable utilization of agricultural residues and increasing rural economic opportunities.

Based on these findings, continuous extension support and technical assistance are recommended to strengthen farmers' competencies and ensure the long-term adoption of briquette production technology. Agricultural extension agencies and relevant institutions should provide advanced training, facilitate farmer group development, and support market access to enhance the sustainability and economic potential of briquette production. Future research is encouraged to involve larger and more diverse farmer populations, expand the geographical scope of investigation, and employ research designs capable of evaluating long-term behavioral change and technology adoption, thereby providing a more comprehensive understanding of the sustained impacts of agricultural extension programs.

REFERENCES

Abdul, A. (2023). *Hilirisasi Industri Kelapa Sawit di Indonesia*. PASPI.

Adlih, B., Mariyono, J., & Prayoga, K. (2023). *Faktor-Faktor yang Mempengaruhi Persepsi Petani terhadap Kinerja Penyuluh Pertanian di Kecamatan Taman Kabupaten Pemalang* [Undergraduate thesis, Universitas Diponegoro]. https://eprints2.undip.ac.id/id/eprint/13846/

Akhmadi, F. (2024). Analisis Dampak Hilirisasi terhadap Pertumbuhan Ekonomi di Indonesia. *Hatta: Jurnal Pendidikan Ekonomi dan Ilmu Ekonomi, 2*(1), 25–31. https://doi.org/10.62387/hatta.v2i1.18

Badan Pusat Statistik Kabupaten Padang Lawas Utara. (2025). *Kabupaten Padang Lawas Utara dalam Angka 2025*. https://palutakab.bps.go.id/id/publication/2025/02/28/8b08d955f61fafa46978a895/kabupaten-padang-lawas-utara-dalam-angka-2025.html

Connelly, L. M. (2008). Pilot studies. *Medsurg Nursing, 17*(6), 411–412. https://pubmed.ncbi.nlm.nih.gov/19248407/

Dewi, F. N. K., Oktaviani, D., Fadillah, W. N., Safitri, M. N., & Umiyana, A. A. (2024). Pengaruh Penyuluhan dengan Metode Demonstrasi terhadap Peningkatan Pengetahuan dan Minat Adopsi Teknologi Eco Enzyme. *Journal Science Innovation and Technology (SINTECH), 4*(2), 32–37. https://doi.org/10.47701/sintech.v4i2.3987

Fadhilah, M. L., Eddy, B. T., & Gayatri, S. (2018). Pengaruh Tingkat Pengetahuan, Sikap, dan Keterampilan Penerapan Sistem Agribisnis terhadap Produksi pada Petani Padi di Kecamatan Cimanggu Kabupaten Cilacap. *Agrisocionomics: Jurnal Sosial Ekonomi Pertanian, 2*(1), 39–49. https://doi.org/10.14710/agrisocionomics.v2i1.1327

Fauziah, L. A., Arvianti, E. Y., & Dyanasari, D. (2024). Analisis Perbedaan Sistem Penyuluhan Pertanian pada Masa Sebelum dan Selama Pandemi Covid-19 di Kabupaten Malang. *SEPA: Jurnal Sosial Ekonomi Pertanian dan Agribisnis, 21*(2), 273–288. https://doi.org/10.20961/sepa.v21i2.83882

Febrian, G., Dinarti, S. I., & Kurniawati, F. (2025). Analisis Faktor-Faktor yang Mempengaruhi Partisipasi Petani dalam Kegiatan Penyuluhan Pertanian Holtikultura di Desa Hargobinangun Kecamatan Pakem. *AGROFORETECH, 3*(3), 1766–1778. https://jurnal.instiperjogja.ac.id/index.php/JOM/article/view/2184

Ghozali, I. (2021). *Aplikasi Analisis Multivariate dengan Program IBM SPSS 26* (10th ed.). Badan Penerbit Universitas Diponegoro.

Hasibuan, A., Nasution, Q. F. N., Lubis, A. M. P., Harahap, A. A., & Nasution, S. P. (2023). Pemanfaatan Limbah Kelapa Sawit (Tandan Kosong Kelapa Sawit) sebagai Pupuk Organik yang Ramah Lingkungan di Kabupaten Labuhan Batu Utara. *Zahra: Journal of Health and Medical Research, 3*(1), 312–319. https://felifa.net/index.php/ZAHRA/article/view/453

Irdiana, E., Nurliza, N., & Kurniati, D. (2024). Optimalisasi Komunikasi Penyuluh Pertanian dalam Aktivitas Penyuluhan. *Jurnal Penyuluhan, 20*(1), 96–114. https://doi.org/10.25015/20202445928

Khairunnisa, E. A., & Djazuli, R. A. (2024). Analisis Efektivitas Program Penyuluhan Pertanian dalam Meningkatkan Produktivitas Kelompok Tani di Kecamatan Panceng, Kabupaten Gresik. *Jurnal Ekonomi Pertanian dan Agribisnis, 2*(1), 29–34. https://doi.org/10.62379/jepag.v2i1.1914

Latif, Y., Bempah, I., & Saleh, Y. (2023). Tingkat Pengetahuan, Sikap, dan Keterampilan Petani terhadap Usahatani Jagung di Kecamatan Tibawa Kabupaten Gorontalo. *AGRINESIA: Jurnal Ilmiah Agribisnis, 8*(1), 69–77. https://doi.org/10.37046/agr.v0i0.18386

Lestari, N. I., Anrabel, R., Kristanti, B. A., Qurniyati, Istianah, L., Nainggolan, D., Maulani, R., & Chandra, M. W. (2022). Pemanfaatan Pelepah Sawit Menjadi Briket sebagai Bahan Bakar Alternatif di Desa Rotan Mulya Sumatra Selatan. *BUGUH: Jurnal Pengabdian kepada Masyarakat, 2*(1). https://jurnalbuguh.unila.ac.id/index.php/buguh/en/article/view/699

Mardiana, T., Warsiki, A. Y. N., & Heriningsih, S. (2020). Menciptakan Peluang Usaha Ecoprint Berbasis Potensi Desa dengan Metode RRA dan PRA. *KoPeN: Konferensi Pendidikan Nasional, 2*(1). https://ejurnal.mercubuana-yogya.ac.id/index.php/Prosiding_KoPeN/article/view/1113

Mardikanto, T. (2018). *Sistem Penyuluhan Pertanian*. UNS Press.

Martina, T., Zuriani, Z., Riani, R., Zahara, H., & Barmawi, B. (2024). Identifikasi Model Penyuluhan Partisipatif pada Petani Padi di Kabupaten Aceh Utara. *Agrifo: Jurnal Agribisnis Universitas Malikussaleh, 9*(1). https://doi.org/10.29103/ag.v9i1.15983

Mutia, M., Munajat, M., & Fifian, P. S. (2022). *Efektivitas Penggunaan Metode dan Media pada Penyuluhan Pertanian di Kecamatan Lubuk Raja Kabupaten Ogan Komering Ulu* [Doctoral dissertation, Universitas Baturaja].

Padapi, A. (2022). Penyuluhan Optimalisasi Nilai Tambah Sekam Padi sebagai Briket Arang di Kabupaten Sidenreng Rappang, Sulawesi Selatan. *MALLOMO: Journal of Community Service, 3*(1), 1–6.

Papilo, P. (2012). Briket Pelepah Kelapa Sawit sebagai Sumber Energi Alternatif yang Bernilai Ekonomis dan Ramah Lingkungan. *SITEKIN: Jurnal Sains, Teknologi dan Industri, 9*(2), 67–78. https://doi.org/10.24014/sitekin.v9i2.593

Paranita, D. (2020). Kombinasi Campuran Pelepah Kelapa Sawit dan Kulit Kacang Tanah sebagai Bahan Baku Pembuatan Biobriket. *Al Ulum Seri Saintek, 8*(2), 45–53. https://doi.org/10.47662/alulum.v8i2.203

Permana, E., Manab, A., Wijaya, D. E., Gusti, D. R., Arsa, D., Hidayat, A. N., Shella, A. P., Prayogi, A. S., Situmerang, Y. D. W., Sihombing, F. S., & Ramadhan, F. (2025). Biobriket Pelepah Sawit di Desa Ibru sebagai Alternatif Energi Baru Terbarukan. *Berbakti: Jurnal Pengabdian kepada Masyarakat, 1*(4), 138–144. https://jurnal.mifandimandiri.com/index.php/berbakti/article/view/104

Ridwansyah, I., Sayekti, A. A. S., & Dinarti, S. I. (2025). Metode Penyuluhan Pertanian di Era 4.0 di Kecamatan Patuk Kabupaten Gunung Kidul Daerah Istimewa Yogyakarta. *AGROFORETECH, 3*(2), 1086–1091. https://jurnal.instiperjogja.ac.id/index.php/JOM/article/view/2068

Rijal, M., Euriga, E., & Nurlaela, S. (2024). Motivasi Petani dalam Pemanfaatan Lahan Pekarangan Kelompok Wanita Tani di Kalurahan Potorono Kapanewon Banguntapan Kabupaten Bantul. *Jurnal Ilmu-Ilmu Pertanian, 31*(1), 36–42. https://doi.org/10.55259/jiip.v31i1.37

Rustandi, Y., & Warnaen, A. (2019). *Buku Ajar Media Penyuluhan*. Pusat Pendidikan Pertanian, Badan Penyuluhan dan Pengembangan Sumber Daya Manusia Pertanian. https://repository.pertanian.go.id/handle/123456789/14272

Salsabilla, K. K., Suhirmanto, S., Rahmi, A., & Masri, M. (2023). Implementasi Kebijakan Penguatan Fungsi Penyuluhan Pertanian. *Jurnal Kebijakan Publik, 14*(4). https://doi.org/10.31258/jkp.v14i4.8355

Saputra, D., Siregar, A. L., & Rahardja, I. B. (2021). Karakteristik Briket Pelepah Kelapa Sawit Menggunakan Metode Pirolisis dengan Perekat Tepung Tapioka. *Jurnal ASIIMETRIK: Jurnal Ilmiah Rekayasa & Inovasi, 3*(2), 143–156. https://doi.org/10.35814/asiimetrik.v3i2.1973

Susanti, M., & Wijaya, E. (2019). Pemanfaatan Pelepah Kelapa Sawit sebagai Usaha Kreatif dalam Menunjang Perekonomian Masyarakat Desa Nakau Bengkulu Tengah. *Prosiding Seminar Nasional Teknologi Informasi Komputer dan Sains 2019*. https://jurnal.uimedan.ac.id/index.php/sintaks/article/download/877/704

Tsirwiyati, D. N. (2025). Transformasi Industri Kelapa Sawit: Hilirisasi Berkelanjutan Menghadapi Daya Saing Global dan Ekonomi Hijau. *Esensi Hukum, 6*(2), 27–45. https://doi.org/10.35586/esensihukum.v6i2.391

Wangguway, O., Purwanto, B., & Labatar, S. C. (2023). Efektivitas Peningkatan Pengetahuan Petani tehadap Pemanfaatan Limbah Sabut Kelapa sebagai Media Tanam Sawi Pakcoy (*Brassica rapa* L.) di Kampung Sauabas Distrik Manokwari Timur Kabupaten Manokwari. *Prosiding Seminar Nasional Pembangunan dan Pendidikan Vokasi Pertanian, 4*(1), 296–309. https://doi.org/10.47687/snppvp.v4i1.654

Yahya, M., Herawaty, Misiyem, & Lestari, E. W. (2021). Keefektifan Penggunaan Media Sesungguhnya dalam Penyuluhan Pengendalian Hama dan Penyakit pada Tanaman Jagung di Kabupaten Langkat Provinsi Sumatera Utara. *Agrica Ekstensia, 15*(2). https://ejournal.polbangtanmedan.ac.id/index.php/agrica/article/view/92