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Sustainable Farming as Counterbalance: Revitalizing Pomponangi Farmer Group in Mining and Industrial Park-Dominated Regions

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ABSTRACT
This study aims to evaluate the effectiveness of the "*Harmoni Makarti*" Corporate Social Responsibility (CSR) program, initiated by Hengjaya Mine, in revitalizing the Pomponangi farmer group through the introduction of sustainable farming practices as a counterbalance to industrial dominance. The research employed a quasi-experimental Difference-in-Differences (DiD) approach to analyze changes in land use, crop diversification, production costs, and farmer income. Data were collected through surveys, soil quality measurements, field observations, and analysis of farmer group records. Statistical analysis, including paired t-tests, was used to measure the program's impact. The intervention yielded significant positive outcomes. The program successfully secured farmland tenure, slowing conversion rates. It reduced average production costs by 21% (Rp 195 per kg) through the adoption of organic fertilizers and pesticides. Crop diversification increased from 4 to 10 types, leading to a 164% surge in average annual farmer income (from Rp 23.55 million to Rp 62.25 million). Furthermore, the establishment of market linkages with a local enterprise (*BUMDES*) generated an additional Rp 30.35 million in weekly revenue. The program also achieved a high Community Satisfaction Index score of 85.31. The "*Harmoni Makarti*" program demonstrates that well-designed CSR initiatives can effectively empower local farmer groups, promote sustainable agriculture, and enhance economic resilience in regions dominated by extractive industries. The findings suggest that such a model of corporate-community partnership is replicable and offers a viable strategy for achieving balanced regional development.

Keywords: Sustainable farming, CSR intervention, agricultural resilience

INTRODUCTION

Makarti Jaya Village in Morowali is rapidly transforming due to expanding mining operations and industrial parks focused on nickel extraction. This growth is changing land use patterns, converting productive farmland into housing and commercial spaces to accommodate a growing population (Lambin & Meyfroidt, 2011). As a result, agricultural land is shrinking, and traditional farming is becoming less viable, particularly among younger generations drawn to industrial jobs. This shift has led to labor shortages and diminished agricultural knowledge, exacerbated by environmental degradation from excessive chemical use and industrial encroachment, resulting in declining soil health and crop productivity (Guo, et al., 2010; Scientific Reports, 2025).

The remaining farmlands are often underutilized or repurposed for rental housing, reflecting a devaluation of agriculture (Hall, Hirsch, & Li, 2011). If this trend continues, Makarti Jaya may lose its agricultural base, threatening local food security and environmental sustainability (Cahyono, Permana, & Aryadi, 2025; Taylor & Francis, 2024). To mitigate these impacts, sustainable practices must be implemented to restore productivity and ecological integrity (SUSTINERE, 2022. Therefore, it is critical that remaining farming areas are preserved and managed through sustainable practices that restore productivity and ecological integrity. Rehabilitation of degraded soils—through organic matter restoration, reduced agrochemical inputs, and agroforestry techniques—can enhance resilience and productivity (Lo et al., 2024; Pretty, Williams, & Toulmin, 2011).

The core issue is the progressive loss of agricultural land and the socio-economic marginalization of local farmers. Remaining farmlands are often underutilized or repurposed for rental housing, reflecting a broader devaluation of agriculture (Hall, Hirsch, & Li, 2011). Farmers face limited numbers, income disparities, land shortages, and unfair market competition. Without intervention, Makarti Jaya risks losing its agricultural base entirely, threatening local food security and environmental sustainability (Cahyono, Permana, & Aryadi, 2025). The urgency of this situation lies in the accelerating rate of land conversion and the erosion of local farming livelihoods. Immediate action is required to preserve remaining farmland, rehabilitate degraded soils, and empower farmers through sustainable practices to ensure food security and ecological balance in the face of relentless industrial expansion.

A significant gap exists in the literature regarding the tangible impacts of CSR-driven sustainable farming programs in counterbalancing the effects of mining and industrial parks. There is a lack of empirical evidence on how such initiatives can specifically revitalize farmer groups, secure land tenure, reduce production costs through organic practices, and create viable market linkages in these high-pressure contexts. This research offers a novel, empirical case study examining the direct impacts of a targeted CSR program—Hengjaya Mine's *Harmoni Makarti* initiative—on the Pomponangi farmer group. It employs a quasi-experimental Difference-in-Differences (DiD) approach to quantitatively measure changes in land use, crop diversification, production costs, and farmer income. The study provides a unique model of institutional collaboration between a mining company, local government, and a farmer group to create a sustainable agricultural counterbalance to industrial dominance.

The primary objective of this research is to conduct a comprehensive analysis of the effectiveness of the *Harmoni Makarti* CSR program in revitalizing the Pomponangi farmer group through the implementation of sustainable agricultural practices. Specifically, this study aims to assess the program's tangible impacts on preserving farmland and securing land tenure, evaluating the reduction in production costs through the adoption of organic fertilizers and pesticides, measuring the resultant increase in crop diversification and farmer income, and analyzing the strengthening of market linkages and institutional capacity. The benefits of this research are multifold, offering practical, theoretical, and policy-oriented value. Practically, it provides a replicable model for other mining companies and communities facing similar industrial pressures, demonstrating a concrete pathway for CSR initiatives to foster genuine sustainable development. Theoretically, it contributes significant empirical evidence to the literature on sustainable agriculture and corporate social responsibility, particularly within the unique and challenging context of industry-dominated regions. For policymakers, the findings offer crucial insights into designing frameworks that encourage effective partnerships between industry and agriculture to ensure balanced and resilient regional development. Ultimately, the greatest benefit is directed toward the community, as this research underscores a viable strategy to enhance the economic resilience, food security, and long-term livelihood sustainability of farming communities amidst rapid industrial expansion.

METHOD

Study Area

Hengjaya Mine, a subsidiary of Nickel Industries Limited (NIC) based in Sydney, Australia, is located in Makarti Jaya village, Bahodopi district, Central Sulawesi, Indonesia. This operation encompasses Tangofa village and is near the IMIP industrial area. While some farmers in Makarti Jaya previously managed their farmland independently, Hengjaya Mine has partnered with the village government to form a farmer group of 15 members to enhance their capacity and organization. Through its CSR initiative, the *Harmoni Makarti* program, Hengjaya Mine aims to boost agricultural productivity by introducing sustainable farming practices, ultimately increasing farmers' capacity and incomes while minimizing environmental impact (Seckold, 2025).

Methods Design

This research employed the Difference-in-Differences (DiD) approach to evaluate changes in land-use patterns, crop diversification, farming costs, and farmers' income in the Pomponangi farmers group before and after program implementation. It also assessed the causal impact of organic farming on soil quality by comparing conventional and organic farmland. Additionally, quantitative analysis was used to measure the community satisfaction index from the *Harmoni Makarti* program.

Sample and Sample Size

This research focuses on the Pomponangi farmers group in Makarti Jaya village, which includes 15 registered farmers (9 male and 6 female) aged 26 to 51. Approximately 64% have completed elementary school, 21% have high school or vocational qualifications, 7% are middle school graduates, and the remainder hold bachelor's degrees. Soil samples were collected from three points in both organic and conventional farmland in the area.

Data Collection

Primary data collection for critical land distribution in Makarti Jaya village involved map digitization using aerial photos to identify and overlay critical land on Google Earth. Soil quality data were collected in November 2024 through *in situ* measurements at three organic and conventional farmland sampling points, using the Jinawi Basic handheld soil analyzer. The details of the sample, soil type, sampling point, and parameters measured are shown in Table 1 below.

Table 1. Soil quality data collection

Sample	Soil Type	Sampling point	Parameters measured	Equipment used
Semi-organic farmland (Demo land 1)	Peat	A1	Nitrogen (N), Phosphorus (P), Potassium (K), Temperature (T), Humidity (H)	Handheld soil analyzer Jinawi Basic
		A2	Nitrogen (N), Phosphorus (P), Potassium (K), Temperature (T), Humidity (H)	Handheld soil analyzer Jinawi Basic
		A3	Nitrogen (N), Phosphorus (P), Potassium (K), Temperature (T), Humidity (H)	Handheld soil analyzer Jinawi Basic
Chemical farmland	Clay loam	B1	Nitrogen (N), Phosphorus (P), Potassium (K), Temperature (T), Humidity (H)	Handheld soil analyzer Jinawi Basic
		B2	Nitrogen (N), Phosphorus (P), Potassium (K), Temperature (T), Humidity (H)	Handheld soil analyzer Jinawi Basic
		B3	Nitrogen (N), Phosphorus (P), Potassium (K), Temperature (T), Humidity (H)	Handheld soil analyzer Jinawi Basic

Primary data for this study were collected through questionnaires and field observations, involving interviews with 15 farmers. The aim was to assess the income impact of Hengjaya Mine's CSR program on farmer groups. All interviews were recorded while ensuring respondent confidentiality through numbered codes. Additionally, a community satisfaction index was measured via guided questionnaire interviews in January 2025, using a Likert scale with options ranging from "not satisfied" to "very satisfied," along with open-ended questions for further insights. Farming costs and market linkages were sourced from the Pomponangi farmer group's records and *BUMDES* Makarti Jaya village as secondary data.

Data Analysis

Quantitative methods were used to verify the collected data. Community satisfaction was assessed through a guided questionnaire, with results presented in statistical diagrams and narrative descriptions. Land information was digitized into readable maps and tables. Soil quality data were summarized, and their implications for crop diversification, farming costs, and farmer incomes were analyzed through literature review. Data analysis employed DiD methods and paired t-tests to compare pre- and post-program data, estimating effects on crop diversification, costs, and income.

Limitations within the Study

This study focused solely on the Pomponangi farmer group, limiting its assessment to a single group without a control group for comparison. This approach affects the credibility, generalizability, and interpretability of the results, especially in a complex and dynamic environment. To address potential bias, the authors employed quasi-experimental techniques, comparing outcomes before and after the CSR program with secondary data from similar contexts. Future research should include a comparison group, such as a control group or baseline communities, to enhance the validity of conclusions.

RESULT AND DISCUSSION

Overview of Harmoni Makarti Program Impact

The Harmoni Makarti sustainable farming program resulted in significant improvements in land use, crop diversity, farming costs, and farmer incomes. Using a Difference-in-Differences (DiD) approach, the analysis shows that, post-program, there was a preservation of farmland, increased crop diversification, reduced farming costs, and significantly higher incomes for farmers, with many outcomes statistically significant. The summary of the Harmoni Makarti program implications is shown on Table 2.

Table 2. Summary of Harmoni Makarti Program effects on key outcomes (before and after program)

Outcome	Before Program	After Program	Estimated Effect	Significance
Land-Use Patterns (Farmland Area)	Around 49.22 ha farmland (Year 2020) (No dedicated protected land)	Around 27.0 ha farmland (Year 2025) including 4.95 ha demonstration & group land	Slowed land conversion: About 32% of farmland secured from land use conversion from estimated 45% loss trend in past 5 years	No formal test (contextual comparison)
Crop Diversification (Crop Varieties)	About 4 crop types cultivated (monoculture prevalent)	About 10 crop types cultivated (per farmer around 2 types)	About 6 new crop types: broader crop mix aligned with market demand	Yes (all farmers diversified, $p < 0.01$)
Farming Costs (Production Cost per kg)	Average Rp 931.75 per kg (using chemical inputs)	Average Rp 736.50 per kg(with organic practices)	About 21% cost reduction: savings of Rp 195 per kg on average	Yes (paired t-test, $p < 0.05$)
Farmer Income (Annual per farmer)	Rp 23.55 million per year or equivalent to Rp 1.96 million/month	Rp 62.25 million per year or equivalent to Rp 5.19 million/month)	About 164% income increase: Around Rp 38.7 million/year per farmer	Yes (paired t-test, $p < 0.001$)

Source: Hengjaya Mine internal documentation, 2025

Pomponangi Farmer Group Overview

Before the Pomponangi farmer group was formed, farmers in Makarti Jaya village managed their land independently, facing issues like unproductive land from excessive chemical use, reduced farming areas due to land-use changes, and limited market access. These challenges made it harder for farmers to generate income. A 2024 study noted a significant decline in the number of farmers in Morowali, dropping from 13.54% in 2015 to 8.83% in 2019 (Cahyono, Permana, & Aryadi, 2025).

The Pomponangi farmer group, formed on October 16, 2023, and established on March 26, 2024, in Makarti Jaya village, consists of 15 farmers managing 7 hectares of land. The group aims to collectively organize farming activities, including daily operations, supply of resources, allocation of agricultural commodities, and recording expenditures and harvests for sale.

Community Response and Farming Practices

The community satisfaction index (CSI) measures program relevance to community needs, benefits, and sustainability. The Harmoni Makarti program, implemented by Hengjaya Mine, is highly relevant to the needs of Makarti Jaya village, with 93% of respondents finding it relevant or very relevant. This program is based on social mapping conducted in collaboration with a third party, which has been crucial for effective development strategies for successful community economic growth, as demonstrated by a similar case in Limbangan Traditional Market (Putra & Rudito, 2015).

The program's benefits include increased knowledge and improved skills among beneficiaries, particularly in sustainable farming practices. All respondents reported enhanced understanding, while 80% noted improved skills in organic farming, moving away from harmful chemical fertilizers. Community capacity, built through knowledge, skills, and collaboration, is essential for fostering healthier communities and leveraging community development (Sail & Abu-Samah, 2010). While, communities' capacity also important to address problem, seize opportunities, and strengthen existing and emerging institutions.

Continuity in the program is evident, with 100% of beneficiaries acknowledging its sustainability (60% good, 40% very good). This consistency aligns activities that support community capabilities and income, which is crucial for community satisfaction and broader societal benefits. The overall community satisfaction index for the Harmoni Makarti program is 3.41, equating to an 85.31 rating of "very satisfied."Harmoni Makarti" as follows:

Table 3. Overall CSI Harmoni Makarti program

Index Value	Converted CSI	Remarks
3,41	85,31	Very satisfied

Source: Harmoni Makarti survey result, 2025

The community satisfaction index for the overall program is 3.41, equating to 85.31 when converted, indicating high satisfaction levels. Community members, especially in Makarti Jaya, view the program's relevance, benefits, and sustainability positively. A similar study in Bukit Batu district, Riau, showed that the Volunteer Fire Brigade program resulted in a CSI above 90%, highlighting significant social, environmental, and economic improvements from the initiative (Priambada, Hidayat, & Purwanto, 2021). Increasing society's capacity to meet their needs will significantly enhance social, environmental, and economic impacts.

Institutional-based Land Tenure Intervention

The company has partnered with the Makarti Jaya village government to address rapid land-use changes from industrial expansion. They encourage the formation of a farmer group to support farmers in managing their operations. Established in October 2023, the group aims to secure about 3.77 ha of land for farming under the Pomponangi farmer group management. Prior to this, the village struggled to control the conversion of farmland into housing and kiosks.

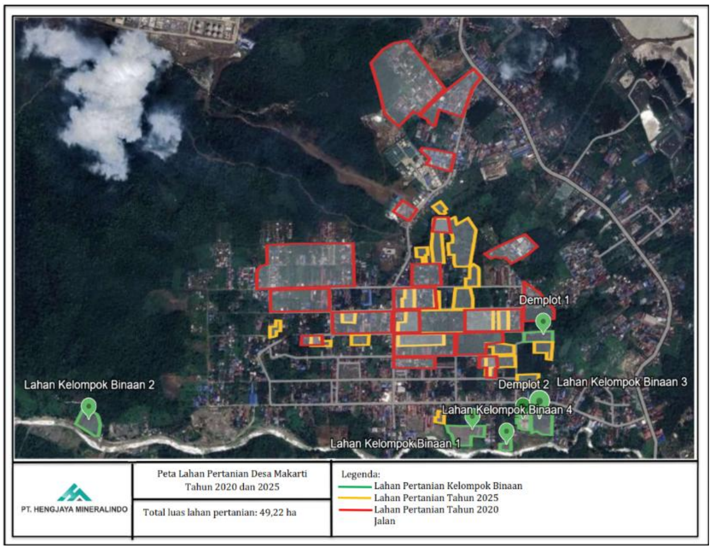

Figure 2. Farmland-use changes map of Makarti Jaya village
Source: Digitized map based on actual locations in Google Earth, 2025

Table 4. Total demonstrated farmland in Makarti Jaya village

Year	Total area (ha)
2023	1
2024	2
2025	7

Source: Measurement from digitized map based on actual locations in Google Earth, 2025

Before the Harmoni Makarti program, rapid industrial growth led to a significant loss of agricultural land in Makarti Jaya village, with farmland shrinking from 49.22 hectares in 2020 to about 27 hectares by 2025. The program was crucial in securing land tenure, with approximately 4.95 hectares (18% of the village's farmland) designated as demonstration farmland for the Pomponangi farmer group. This area increased from 1 hectare in 2023 to 7 hectares in 2025, helping to protect about 32% of the village's farmland from conversion to housing and kiosks during 2023-2025, compared to 45% lost in the previous five years.

Table 5. Allocated farmland of Makarti Jaya village in 2020 and 2025

Year	General Farmland (ha)	Demonstration Farmland (ha)	Group-Managed Farmland (ha)	Total Farmland (ha)
2020 (pre-program)	49,22 ha (all farmland)	–	–	49,22
2025 (post-program)	22,04 ha (traditional use)	1,18 ha	3,77 ha	27,00

Source: Measurement from digitized map based on actual locations in Google Earth, 2025

General-use farmland dropped to 22.04 ha by 2025 due to land-use pressures, but the Harmoni Makarti initiative successfully preserved 5 ha for agriculture, mitigating land loss. This program's impact is evidenced by the retention of approximately 32% of land that might have been converted, in contrast to a historical trend of nearly 50% loss over 5 years. While formal statistical testing isn't feasible for a single village, the slower decline in farmland and dedicated protected land suggest a positive effect from the program.

The assessment used a quasi-Difference-in-Differences approach by comparing changes in Makarti Jaya's farmland to regional trends, assuming that without the program, declines would follow prior rates. This interpretation relies on the assumption that external factors remained constant. The observed increase in demonstration farmland points to a strategic focus on enhancing agricultural practices and community-focused strategies, reflecting a commitment to sustainability and resilience despite the overall decrease in farmland allocation. Similarly, a case study of farmland use development at Zhejiang province, China has reported the proactive involvement of policymakers in the spatial land-use planning could balancing the impact between food security and ecological sustainability from agricultural transformation (Wang, et al., 2025).

Farmers' Capacity Building

To enhance agricultural productivity, private sector interventions are crucial in building farmers' capacity. In the Philippines, Philex Mining Company has successfully reduced local reliance on mining jobs by mentoring farmers and demonstrating additional income from village-based farming activities (Ambeguia, 2023). Similarly, Hengjaya Mine collaborated with local governments to create a farmer group, providing training on environmentally friendly practices, including organic fertilizers, irrigation techniques, and post-harvest processing.

Farmers also received training in administrative skills, such as developing organizational bylaws, and conducted market surveys to understand crop prices and demand. Aimed at increasing profitability, these initiatives included training on cultivating oyster mushrooms and creating processed products like vegetable chips and juices. This led to the formation of a female farmer group, Tadelufu, focusing on these new agricultural opportunities. A related study in Joga village, India, demonstrated improved income for a women's group through watershed-based activities, generating an additional Rs 22,000 annually from nursery initiatives (Petare, et al., 2018).

Figure 3. Vegetable-based processed product by Tadelufu female farmer groups
Source: Hengjaya Mine documentation, 2025

Reducing Reliance on Chemical Fertilizers and Pesticides

The company has implemented organic farming approaches to reduce reliance on chemical fertilizers and pesticides by teaching farmers to use livestock manure for compost and vegetable waste as plant-based pesticides. To enhance land productivity, farmers were trained to conduct soil tests and analyze key parameters like pH, nitrogen, phosphorus, potassium, electrical conductivity, temperature, and humidity. These tests, carried out on peatland and clay loam soils, aim to help farmers determine the right nutrients while maintaining soil quality. The chemical fertilizers used were NPK-type, while the organic fertilizers consisted of chicken manure, beef manure, and sawdust.

In May 2024, a soil test was conducted in Makarti Jaya to measure pH for cultivating mustard and grass water. The initial pH was 4.5, while the optimal range is 5.5-6.5 for grass water (Wang, et al., 2017) and 6.0-7.5 for mustard at a depth of 15-30 cm (Forjan, et al., 2018). Farmers were advised to use dolomite lime (Liu, et al., 2023) or compost (Citak & Sonmez, 2011) to significantly increase the soil pH.

Farmers were trained to create compost using chicken and beef manures combined with sawdust. Fresh chicken manure from the coop and beef manure from the cowshed in Makarti Jaya village were fermented for a few weeks before mixing. This process reduces harmful ammonium content and helps maintain soil pH without increasing the soil's electrical conductivity (Citak & Sonmez, 2011).

Farmers learned to create plant-based pesticides from papaya, soursop, tobacco, and betel leaves. The ethanolic extract from papaya leaves is a toxicant and repellent against German cockroaches (Blattella germanica) (Rahayu, Darmis, & Jannatan, 2020). Papaya leaves contain flavonoids, alkaloids, tannins, saponins, and terpenoids, contributing to their pesticidal properties (Purba & Muliarta, 2024). Soursop leaf extract shows significant insecticidal activity against fruit flies (Ekaningrum & Pujiati, 2023) and causes mortality in armyworms (Salessy, Awan, & Wael, 2022). Tobacco leaf extracts are effective against rice weevils (Kanmani, et al., 2021), while betel leaf extracts have demonstrated insecticidal activity against houseflies (Yushananta & Ahyanti, 2021).

Figure 5. Compost making from sawdust, beef manure, and chicken manure
Source: Hengjaya Mine documentation, 2025

Table 6. Soil Test Result

Sample	Soil Type	Sampling point	Parameter						
			N (ppm)	P (ppm)	K (ppm)	pH	EC (ppm)	T (C)	H (%)
Organic farmland (Demo land 1)	Peat	A1	55,0	77,0	156,0	7,5	785,0	34,0	52,0
		A2	40,0	57,0	115,0	6,1	579,0	36,0	46,0
		A3	21,0	29,0	59,0	7,5	295,0	35,0	17,0
	Average		38,7	54,3	110,0	7,0	553,0	35,0	38,3
Chemical farmland	Clay loam	B1	63,0	89,0	178,0	7,9	894,0	37,0	24,0
		B2	83,0	117,0	235,0	7,7	1.179,0	34,0	26,0
		B3	93,0	131,0	263,0	7,9	1.305,0	36,0	41,0
	Average		79,7	112,3	225,3	7,8	1.126,0	35,7	30,3

Source: Internal soil quality measurement records, 2025

The soil analysis results on Table 6 show that the organic farmland has a lower EC, an indicator of soil salinity, compared to the chemical farmland. Higher EC values and nitrogen content in the chemical farmland indicate salt accumulation from excessive chemical fertilizer use, which can hinder crops' water and nutrient absorption. Research indicates that high soil salinity and nitrogen over-fertilization negatively affect cotton growth, delaying both vegetative growth and the initiation of the reproductive phase.

The EC values in soil correspond with pH levels. Chemical farmland has an average pH of about 7.8, making it more alkaline than organic farmland, which averages around 7.0. Research shows that organic fertilizers help retain water and reduce salinity in the 0-20 cm topsoil layer, improving root access to water. (Liu, et al., 2023). On the other hand (Alzamel, Taha, Bakr, & Loutfy, 2022), applying compost to sunflower crops can lower leaf pH and total nitrogen while increasing phosphorus and potassium content. This is due to microbial decomposition, which enhances soil nutrients. Soil pH is important for micronutrient availability, such as iron and zinc, essential for chlorophyll synthesis and photosynthesis, with optimal pH between 5.5 and 7.5. (Magomere, Msolla, & Tryphone, 2023).

The Pomponangi farmers group in Makarti Jaya village began using sustainable farming practices by collectively creating organic fertilizers and plant-based pesticides. This shift has reduced their reliance on chemical alternatives. The raw materials for compost, sourced locally from livestock waste, have also lowered production costs for fertilizers and pesticides.

Table 7. Production cost analysis before and after program intervention

Crops	Production cost (Rp/kg)		Variance (%)
	Before program (Rp/kg)	After program (Rp/kg)	
Green mustard	Rp 1.065,00	Rp 917,00	14%
Long beans	Rp 1.278,00	Rp 960,00	25%
Grass water	Rp 872,00	Rp 700,00	20%
Cucumber	Rp 512,00	Rp 369,00	28%
Average	Rp 931,75	Rp 736,50	21%

Source: Pomponangi farmer group internal records, 2025

As noted on Table 7, the average production cost of four cultivated crop types was Rp 931.75 per kg before program intervention. After adopting sustainable farming practices, including compost from livestock manure and plant-based pesticides, costs decreased by 21% to Rp 736.50 per kg. Long bean costs dropped 25% from Rp 1,278.00 to Rp 960.00, while cucumber costs fell 28% from Rp 512.00 to Rp 369.00 due to organic farming methods. This shift to organic practices has led to significant savings by eliminating costly chemical fertilizers and pesticides use (Priya & Sajwan, 2024).

Statistical analysis shows a significant cost decrease in crops: a paired t-test yields $p < 0.05$, affirming the mean cost drop. Despite a small sample size ($n=4$), all cases exhibited declining costs, suggesting a clear trend ($p \approx 0.06$ by sign test). From a Difference-in-Differences perspective, we note that without the program, input costs typically remain steady or rise due to inflation. The observed ~21% cost reduction post-adoption of organic inputs is attributed to the program, marking a statistically and practically significant impact on farmer earnings.

We assessed cost changes by comparing costs before and after for each crop type. Although the assumption of normal distribution is tentative due to the limited sample, all crops showed cost decreases, suggesting a likely negative mean change. External studies, including a 2015 analysis from Senegal, corroborate our findings of lower production costs with organic farming compared to conventional methods (Binta & Barbier, 2015). The consistent cost reductions across multiple crops and alignment with external literature support the conclusion that the program effectively lowered costs. While more data points would enhance the significance of our findings, the uniform direction of change and external evidence provide a strong basis to assert a significant cost-saving effect.

Crop Diversification

One of the major problems of the low farmers' incomes is the limited crops commodities that farmers can supply locally (Marks, Sirithet, Rakyuttitham, Wulandari, & Chomchan, 2015). To initiate crop diversification, the farmer group classified their land to determine suitable crops before planting. This classification helps in developing a production plan and includes designing the layout for structures like warehouses and drainage channels. The integration of drainage and farmland as shown on Figure 6 aims to address irrigation needs while managing climate risks, such as floods from heavy rain or drought during dry seasons. A case study of Jawhar farmers in India highlights the effectiveness of this approach, where two check dams were built to manage water. The resulting silt helped retain moisture and nutrients, leading to a harvest of 513 kg of brinjal, 16.20 kg of chili, and 180 kg of pigeon pea (Petare, et al., 2018).

Figure 6. Makarti Jaya village farmland layout
Source: Pomponangi farmer group internal record. 2025

Before the intervention, farmers in the village primarily grew four types of crops, with many practicing monocropping, such as six out of eight farmers growing green mustard in

2023. This limited variety resulted in low incomes and market vulnerability. After the Harmoni Makarti program's training in production planning and agro-diversification, farmers began cultivating ten different crop commodities by 2024, with each farmer growing two or more types. This shift expanded their crop base from leafy vegetables and one legume to a diverse mix, including chillies, beans, eggplant, and cucumber, better aligned with market demand.

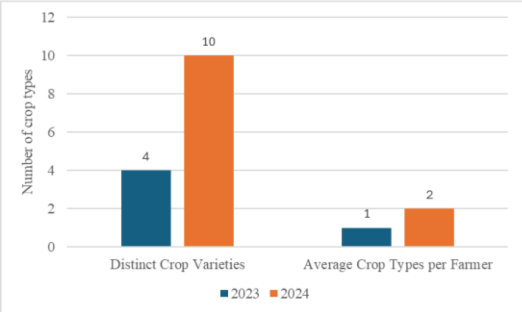

Figure 7. Crop diversification before and after program
Source: Pomponangi farmer group internal records, 2025

After the program, farmers expanded their crop diversity significantly, moving from an average of 4 to 10 types of crops, a 150% increase. This included high-value commodities like chili peppers and a variety of vegetables selected based on market surveys. Each farmer typically grew two different crops, effectively doubling their crop diversity. This change was statistically significant, with all 15 farmers diversifying and a clear median increase of one crop type.

Greater crop diversification led to higher resilience and income, enabling farmers to stagger harvests and access multiple markets. The program reported a 164% increase in average annual farm income due to the expanded crop portfolio. A 2023 study in Bangladesh highlighted that crop diversification enhances farmers' income and economic resilience, improving their ability to withstand shocks and contribute to food security amidst economic uncertainty (Islam, Jahan, Ema, & Ahmed, 2024).

The DiD analysis shows a significant increase in crop variety post-program, with no change before (static at 4 types). Without a control group, we assume that the program was solely responsible for this diversification, as such rapid changes are unusual without intervention. A statistical evaluation using a paired t-test confirms a significant increase in crop types per farmer ($p < 0.01$), with all farmers adopting at least one new crop, thus rejecting the null hypothesis. A similar analysis was conducted in a Bangladeshi integrated farming pilot to compare farmers' incomes before and after the intervention (Akter, et al., 2025). Likewise, an Indonesian swampland program (SERASI) analyzed pre- vs. during-program farm incomes using paired t-tests, confirming significant income increases under the program (Lestina, Mulyana, & Sari, 2022).

The DiD approach compares changes in crop variety in the intervention group to a comparable group without intervention. In the absence of a control community, we assume no change in variety, as regional farming practices were static. This is supported by the previously undiversified local farming status. Thus, the entire gain in crop diversity is attributed to the program, and the consistency of changes among farmers enhances its significance. We also ensured that new crop choices were based on market research rather than external market forces, reinforcing the causal interpretation (Europe Cap Network, 2018).

Farmer Income: Increase in Earnings

The comparison of crop revenues before and after the agricultural program shows a positive trend for most farmers, with revenue increases between 75% and 225% post-implementation ($p < 0.001$). In Indonesia, a "food diversification" initiative led to a 4.47% rise in farmers' income and a 4.7% decline in rural poverty, enhancing local food security. This highlights how diversifying crops can boost earnings and improve resilience against economic and climatic challenges (Rahmanto, Purnomo, & Kasiwi, 2021).

Farmers have successfully transitioned to higher-value crops, such as red curly chili and cucumber, highlighting the importance of crop diversification. This shift enhances food security and increases income opportunities, addressing local supply challenges. As a result of the company's intervention, farmer incomes have risen by 164% from the 2023 baseline, going from approximately Rp 23,550,000 annually (around Rp 1.96 million monthly) to Rp 62,250,000 annually (about Rp 5.19 million monthly). A study in Jawhar, India (Petare, et al., 2018) found that promoting post-monsoon crop diversification improved grain yields and increased household income for farmers (Frontiers in Environmental Science, 2024).

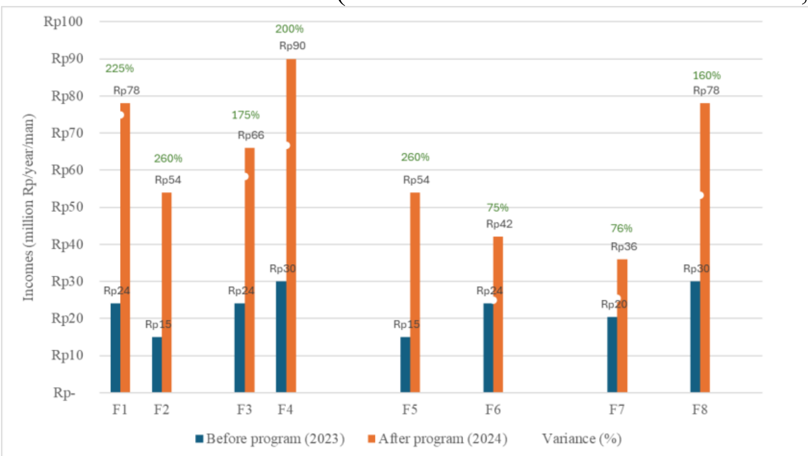

Figure 8. Farmers' income before and after program intervention
Source: Pomponangi farmer groups' internal records, 2025

We calculated the per-farmer income (revenue minus costs) for 8 farmers before and after an intervention, using survey data. A paired t-test showed a significant income increase (mean Rp 38.7 million, range Rp 15-54 million) with $p < 0.001$, supporting the assumption of normal distribution. A Wilcoxon signed-rank test also confirmed significance, as all farmers experienced higher income post-intervention. Similar studies, such as a rural Nepal agricultural extension on tomato production, successfully used paired t-tests to demonstrate significant gains. This highlights the effectiveness of paired t-tests in small-N farmer trials (Suvedi, Ghimire, & Kaplowitz, 2017).

Market Linkages and Revitalizing the Economic Activities in Makarti Jaya Village

Before the Pomponangi farmer group was established, farmers struggled to sell their crops due to limited market access, often relying on intermediaries who offered low prices (Climate Rights International, 2024). This scenario is common among smallholder farmers, as seen in Indonesia and the Philippines, where they have little control over market prices and return on their produce (Capacio, 2021). To address this, the Pomponangi farmer group partnered with BUMDES Sejahtera Bersama, revitalizing its business units to create a supply agreement that ensures regular sales to companies linked to larger supply chains like PT Tata Wisata. This collaboration exemplifies how BUMDES and cooperatives can effectively connect farmers to formal markets, enhancing their bargaining power and income (Asmeri et al., 2017).

Evidence shows that such partnerships significantly boost smallholders' earnings. For instance, BUMDES Sejahtera Bersama generated an average weekly income of Rp 30,350,000 through crop supply, indicating a positive impact on local business units. Similarly, corporate-backed programs, like Jollibee Foods' Farmer Entrepreneurship Program in the Philippines, demonstrated that farmers often earn 40-150% more when selling directly to companies compared to local markets (Capacio, 2021). Overall, strengthening local institutions can effectively bridge smallholders to larger market opportunities.

CONCLUSION

The efforts of Hengjaya Mine's *Harmoni Makarti* program in Makarti Jaya Village have effectively addressed the socio-economic challenges of local farmers affected by industrial expansion. By establishing the Pomponangi Farmer Group, the program improved community organization, secured agricultural land tenure, and enhanced farmers' skills in sustainable, organic practices. The initiative achieved a Community Satisfaction Index (CSI) of 85.31, indicating strong local approval. Key improvements included increased agricultural knowledge, better environmental practices, and a 21% reduction in production costs. Crop diversification expanded from 4 to 10 commodities, leading to a 164% increase in annual income, and stronger market linkages with *BUMDES Sejahtera Bersama* generated additional earnings of Rp 30,350,000 per week. Overall, the program has strengthened the agricultural resilience and economic sustainability of Makarti Jaya's farmers, illustrating how corporate interventions aligned with community needs can foster climate-resilient agriculture.

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