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The Relationship Between IPM-Based Good Agricultural Practices and Sustainable Cocoa Productivity in the Buffer Zone of Lore Lindu National Park

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Abstract

Purpose of Study: To describe the implementation of Good Agricultural Practices based on Integrated Pest Management (GAP-IPM) and examine its relationship with cocoa productivity among JB Cocoa-assisted farmers in five villages in the buffer zone of Lore Lindu National Park, Palolo Subdistrict, Sigi Regency.

Methodology: This descriptive quantitative study used an associative approach and involved 35 purposively selected farmers. Data were collected through observation, interviews, Likert-scale questionnaires, and documentation. We analyzed implementation and productivity categories using chi-square and Fisher's exact tests.

Main Findings: Of the eighteen farmers, 51.4 percent had low GAP-IPM implementation, and 48.6 percent had high implementation. Pearson's chi-square was 24.115 ($df = 1$; $p < 0.001$), indicating a significant association between GAP-IPM application and cocoa productivity. Mean productivity was 865.4 kg/ha in the high-implementation group and 468.7 kg/ha in the low group. Consistent cultural, mechanical, biological, and selective chemical practices were associated with better productivity.

Novelty/Originality of This Study: The study provides evidence on the relationship between GAP-IPM implementation and cocoa productivity among company-assisted farmers in a national park buffer zone, highlighting its relevance to sustainable intensification and potential indirect conservation benefits.

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INTRODUCTION

Background of the Study :

Native to South America, cocoa (Theobroma cacao L.) is a tropical plantation crop grown by smallholder farmers throughout the warm, humid tropics, including Indonesia. It can flower and set pods year-round, providing farmers with a regular stream of daily or weekly income (Safitri & Ibrahim, 2025). Native to South America, cocoa (*Theobroma cacao* L.) is a tropical plantation crop grown by smallholder farmers throughout the warm, humid tropics, including Indonesia. It can flower and set pods year-round, providing farmers with a regular stream of daily or weekly income. Sigi Regency is a major cocoa production center in Central Sulawesi. Palolo Subdistrict is its largest contributor, with a reported cocoa area of 11,639 ha, production of 8,874.42 tonnes, and productivity of 0.76 tonnes/ha (Badan Pusat Statistik, 2026). Suitable agroecological conditions give Palolo

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considerable production potential but also require careful crop management to sustain agricultural development.

Palolo Subdistrict is particularly relevant to this study because it borders Lore Lindu National Park (LLNP), an important conservation area described in the cited literature as a UNESCO biosphere reserve and tentative-list site (Darojah & Putri, 2025). Farming activities in this buffer zone affect LLNP conservation through land-use pressure and potential pollution. Sustainable cocoa cultivation is therefore important for improving productivity while maintaining the surrounding area's ecological balance.

Land-use pressure in the LLNP buffer zone is reflected in changes in agricultural land use among communities surrounding the conservation area. Rukmana et al. (2024) describe transitions involving food crops and cocoa as households seek to meet their livelihood needs under restricted access to forest resources. Continuing expansion and changes in cultivated land indicate that sustainable cocoa farming in the buffer zone must be considered alongside efforts to control pressure on LLNP forests.

Literature Review :

Cocoa production in this region faces pest problems, particularly the cocoa pod borer (*Conopomorpha cramerella*), which bores into pods and damages beans, and the cocoa mirid (*Helopeltis* sp.), which pierces pod tissues and causes lesions that can kill young pods (Bakar, 2019). Findings from several villages in Palolo Subdistrict also show that poorly maintained cocoa farms experienced the highest incidence of black pod disease caused by *Phytophthora palmivora*, with yield losses reaching 161.17 kg/ha, substantially exceeding losses on intensively managed farms (Rohmando & Hartini, 2024). These differences highlight the importance of farm maintenance in limiting cocoa pests and diseases in the LLNP buffer zone.

One relevant response is to integrate Good Agricultural Practices (GAP) with Integrated Pest Management (IPM). GAP provides technical cultivation guidance intended to ensure food safety, protect the environment, and improve farmer welfare (Ollendorf et al., 2026). IPM is a systematic approach to keeping pest populations within economic thresholds. It combines four complementary methods: cultural, mechanical, biological, and chemical control, with synthetic chemical pesticides used only as a last resort (Octasari et al., 2019).

GAP-IPM implementation in the LLNP buffer zone is reflected in an empowerment program in Bakubakulu Village, Palolo Subdistrict, which encourages farmers to maintain cocoa farms sustainably while protecting the national park's functions (Hapid et al., 2018). This experience supports the view that improved cocoa productivity and buffer-zone conservation can advance together and provides a relevant foundation for continued farmer development programs involving corporate partners.

Gap Analysis :

Field-level GAP-IPM implementation may vary even among farmers who have received assistance. This study focuses on the relationship between these differences and cocoa productivity among JB Cocoa-assisted farmers in the five selected buffer-zone villages.

Rationale of the Study

Effective GAP-IPM implementation requires continued assistance. Cocoa productivity in Central Sulawesi remains constrained by pests and diseases, limited access to technology, aging trees, and limited partnerships (Parawansa, 2025). PT Jebe Trading Indonesia (JB Cocoa), a cocoa processing and trading company with longstanding farmer partnerships in Indonesia, provides GAP-IPM assistance in Palolo Subdistrict. Its farmer development program includes extension activities, technical cultivation assistance, GAP training, and sustainability initiatives intended to improve the quality and quantity of farm-level cocoa production. Bobo, Kapiroe, Sejahtera, Karunia, and Sintuwu are JB Cocoa-assisted villages in Palolo. They directly border LLNP and form part of its buffer zone.

Purpose and Hypothesis of the Study

This study analyzes the relationship between GAP-IPM implementation and cocoa productivity among sampled farmers in these five villages, assuming that differences in field-level IPM implementation are reflected in farmers' production outcomes. The findings are expected to inform

future cocoa farming development and support conservation of the Lore Lindu National Park buffer zone. The study hypothesized a significant association between the level of GAP-IPM implementation and cocoa productivity.

METHOD

Research Design :
This study employed a descriptive quantitative design with an associative approach. Descriptive statistics described the observed data without drawing general conclusions beyond the study context (Sofwatillah et al., 2024). The study measured GAP-IPM implementation using a Likert-scale questionnaire and categorized the resulting scores to describe implementation in the field. The study calculated cocoa productivity from farmers' actual production and land-area data and also categorized it. The associative component examined the relationship between these two variables using a chi-square test (Nugraha, 2024).

Participants and Sampling :
The study was conducted in Palolo Subdistrict, Sigi Regency, in July 2026. The location was selected purposively (Santosa & Metri, 2025), because Palolo is a principal cocoa production center in the regency. The study selected five villages in the LLNP buffer zone: Bobo, Kapiroe, Karunia, Sintuwu, and Sejahtera. Farmers in these villages had received GAP assistance and training through JB Cocoa's Sigi Cluster, making them relevant to the study objectives. The study used purposive sampling, selecting respondents based on criteria aligned with the research objectives (Himam et al., 2026), to recruit 35 JB Cocoa-assisted farmers: 10 each from Karunia and Sintuwu and five each from Bobo, Kapiroe, and Sejahtera. Eligibility criteria were ownership of cocoa farmland, cocoa trees aged approximately 5–20 years, and participation in JB Cocoa's farmer assistance program.

Instruments and Data Collection :
The study used primary and secondary data. The researchers collected primary data through observation, interviews, questionnaires, and documentation, supplemented by information from the Village Facilitator (VF) of JB Cocoa's Sigi Cluster until the information was considered adequate. Direct observations focused on JB Cocoa-assisted farmers implementing GAP-IPM in Palolo. Interviews used a Likert-scale questionnaire to score GAP-IPM implementation, following a comparable approach to measuring cocoa cultivation practices (Hasibuan & Nasution, 2020). The questionnaire also recorded production and farm area for calculating cocoa productivity. Documentation consisted of photographs of research activities. Secondary data were obtained from Statistics Indonesia (BPS), relevant literature, and supporting official documents.
We processed all data using the Statistical Package for the Social Sciences (SPSS), version 27. We analyzed respondent characteristics descriptively using frequency distribution tables to describe the sampled farmers' general characteristics. We measured GAP-IPM implementation using 15 Likert-scale statements with five response options, as shown in Table 1.

Table 1. Likert Scale

Score	Response
1	Strongly disagree
2	Disagree
3	Neutral
4	Agree
5	Strongly agree

Source: Sugiono, (2023)

Scoring and Analysis Plan :
Scores for the 15 statements were summed to obtain each respondent's total GAP-IPM implementation score, ranging from 15 to 75. Scores were classified as low or high using the median as the cutoff. The median was selected because the data were ordinal and, unlike the mean, it is less sensitive to extreme values. Harahap et al. (2025) explain the usefulness of the median for ordinal data. The observed median score was 63; respondents scoring ≤63 were classified as low, whereas those scoring ≥64 were classified as high.
Cocoa productivity was calculated from the production and land-area data recorded in the questionnaire using the following formula (Saputro & Helbawanti, 2020):

$$Productivity\ (kg/ha) = \frac{Cocoa\ output\ (kg)}{Farm\ area\ (ha)}$$

We also classified productivity using a median cutoff. The sample median was 625 kg/ha. We categorized respondents with productivity ≤624 kg/ha as low and those with productivity ≥625 kg/ha as high. Median cutoffs were used for both variables to obtain relatively balanced category sizes. Harahap et al. (2025) recommend the median when a stable measure of central tendency is required. The resulting categories were analyzed using the chi-square test, which Herinanto et al. (2024) describe as a useful statistical tool for examining relationships between categorical variables. The association between GAP-IPM implementation and cocoa productivity was tested using the chi-square statistic, calculated as follows (Wibowo, 2017):

$$\chi^2 = \sum \frac{(f_o - f_e)^2}{f_e}$$

where χ^2 is the chi-square statistic, f_o is the observed frequency, and f_e is the expected frequency.
The analysis cross-tabulated GAP-IPM implementation categories (low/high) against cocoa productivity categories (low/high). The hypothesis was that GAP-IPM implementation was significantly associated with cocoa productivity, with statistical significance defined as an asymptotic significance value below 0.05. Given the relatively small sample, expected cell counts could potentially fall below five. Setiawan et al. (2025) recommend Fisher's exact test as an alternative to the chi-square test under such conditions to ensure valid inference.

Instrument Validity and Reliability :
We tested instrument validity using Pearson product-moment correlations based on responses from 35 cocoa farmers. At a 5% significance level (df = 33), the critical r-table value was 0.334. The results indicated that all indicators of IPM-Based Good Agricultural Practices had correlation coefficients ranging from 0.592 to 0.773, which exceeded the critical value. Therefore, all questionnaire items were considered valid.
Reliability was assessed using Cronbach's Alpha. The IPM-Based Good Agricultural Practices construct achieved a Cronbach's Alpha of 0.812, which is well above the recommended cut-off of 0.70. This indicates that the questionnaire reliably measures the extent to which cocoa farmers in the buffer zone implement IPM-based Good Agricultural Practices.

Scope and Limitations of the Methodology :
This study examined the association between GAP-IPM implementation and cocoa productivity among 35 purposively selected JB Cocoa-assisted farmers in five villages within the buffer zone of Lore Lindu National Park. The small, non-probability sample limits the generalizability of the findings, and the observational design and bivariate chi-square analysis do not establish causality or control for potential confounders such as tree age, planting material, and farm management conditions. Furthermore, median-based categorization reduces the detail available in the original implementation scores and productivity measurements.

RESULTS AND DISCUSSION

Results and Discussion of GAP-IPM Implementation

GAP-IPM implementation among cocoa farmers in Palolo Subdistrict was identified from the total scores for the 15 Likert-scale statements. The scores of the 35 respondents were divided into two categories using the median cutoff of 63. Table 2 presents the distribution.

Table 2. Distribution of GAP-IPM Implementation Categories

Category	Number (n)	Percentage (%)
Low	18	51.4
High	17	48.6
Total	35	100.0

Source: Processed primary data.

Table 2 shows that 18 farmers (51.4%) had low GAP-IPM implementation and 17 (48.6%) had high implementation, so the distribution is fairly even. Despite receiving IPM support and training from JB Cocoa, field implementation varied widely. Some farmers consistently applied cultural practices (pruning, sanitation, selection of pest-resistant clones), mechanical methods (manual removal of pests, pod sleeving), biological control (using natural enemies), and selective pesticide use. Others had not applied all the components to the extent that they should have. Farmer-related constraints were primarily the farmer's age, the age of the trees (which made regular pruning and sanitation a very physical job), and lack of time due to off-farm activities. This aligns with Randa et al. (2026), who found that constraints to cocoa maintenance were related to farmer age and time availability rather than a lack of knowledge.

These results highlight the value of GAP-IPM for cocoa productivity. Farmers who consistently applied a combination of cultural, mechanical, biological, and chemical IPM practices effectively suppressed the major pests (cocoa pod borer and *Helopeltis* sp.). This aligns with Rachmani et al. (2025), who found that an integrated approach combining mechanical and biological methods with chemical control as a last resort (and only when absolutely necessary) can lead to a more effective pest management system.

Implementation also differed by cocoa type, namely local material and clonal cocoa. Rubiyo et al. (2020) identify selecting pest-resistant cocoa clones as an important measure to support productivity. Most respondents who still grew local cocoa had trees aged 20 years or older with very tall trunks. Pruning, pod sanitation, and manual pest removal were difficult without tools such as long poles. This is consistent with Airlangga et al. (2024), who identify aging trees as a major cause of low cocoa productivity and emphasize rejuvenation. Disease susceptibility and low productivity in local cocoa further compound these difficulties (Ariningsih et al., 2021). Tall, dense canopies restrict light penetration and maintain humid conditions. Overlapping branches also indicate infrequent pruning and limited IPM maintenance.

These conditions affect pest infestation, as damaged pods are often high in the canopy and therefore missed during farm inspections. Wahyuni and Reri (2022) also state that Helopeltis sp. is very sensitive to direct sunlight and prefers dense, humid farms. Leiwakabessy et al. (2020) also found moderate to severe black pod damage under dense shade and humid conditions, with many pods drying out or rotting before harvest. Such conditions will obviously extend the time pods take to develop in local cocoa and therefore reduce overall production. Local cocoa can still produce well as long as the trees remain productive and GAP is applied from the outset.

Respondents who adopted clonal planting material, including MCC 02, reported different conditions. Musa et al. (2022) report that the morphology of MCC 02 is less preferred by cocoa pod borer for oviposition, providing resistance and supporting production potential. Clonal trees also have shorter

trunks, making most canopy areas accessible and allowing more frequent and thorough pruning, sanitation, and pest monitoring. Wahyuni and Ndewes (2023) found that GAP incorporating superior clones increased flower numbers by up to 91.41% and pods per tree by up to 51.95%, highlighting clone selection as an important GAP component. Accessible canopies also make pod sleeving a practical mechanical IPM method. This practice was observed on one respondent's farm.

Pods sleeved in plastic early on were protected from direct contact with Helopeltis sp. and the cocoa pod borer, reducing the risk of infestation-related development failure. This agrees with Coma and Lakani (2021), whose study in Palolo found that sleeving reduced cocoa pod borer infestation and black pod disease compared with unsleeved pods. Combining sleeving with regular pruning also maintains an open canopy and improves light penetration. Open canopies reduce excessive humidity around pods and may consequently limit conditions favorable to Helopeltis sp. and black pod pathogens, particularly when supported by farm sanitation and regular pest monitoring. Rohmando and Hartini (2024) reported black pod incidence of only 4% and yield losses of 56.29 kg/ha on intensively maintained cocoa farms, compared with losses of up to 161.17 kg/ha on poorly maintained farms. Comprehensive IPM on clonal trees was associated with better productivity than management without a comparable approach.

Relationship Between GAP-IPM Implementation and Cocoa Productivity

We examined the relationship between GAP-IPM implementation and cocoa productivity using chi-square analysis. We first calculated productivity as production divided by farm area and categorized it using the median cutoff of 625 kg/ha. Table 3 presents the distribution.

Table 3. Distribution of Cocoa Productivity Categories

Category	Number (n)	Percentage (%)
Low	17	48.6
High	18	51.4
Total	35	100.0

Source: Processed primary data.

Table 3 shows that 18 farmers (51.4%) had high productivity and 17 (48.6%) had low productivity, using the median cutoff of 625 kg/ha. This relatively balanced distribution is similar to that of GAP-IPM implementation in Table 2 and provides a basis for examining the association between the variables. Wahyuni et al. (2019) likewise found that smallholder cocoa productivity under limited adoption of healthy cultivation technologies remained well below its potential, linking productivity gaps to the implementation of good cultivation practices.

Low productivity was also associated with local cocoa trees that were mostly old and had tall canopies, as discussed above. This highlights the importance of rejuvenation through gradual replacement with superior clonal planting material or side grafting, because trees beyond their productive age are unlikely to achieve optimal yields even under intensive maintenance. Hapsari et al. (2025) emphasize rejuvenation because cocoa has a productive lifespan of approximately 15–20 years and productivity declines after 20 years. Rejuvenation can also provide shorter, pest-resistant canopies that facilitate pruning, sanitation, and pod sleeving. Tree age and planting material may therefore also contribute to the observed productivity differences. Table 4 presents the cross-tabulation.

Table 4. Cross-Tabulation of GAP-IPM Implementation and Cocoa Productivity

GAP-IPM implementation	Low productivity	High productivity	Total
Low	16 (88.9%)	2 (11.1%)	18 (100%)
High	1 (5.9%)	16 (94.1%)	17 (100%)

GAP-IPM implementation	Low productivity	High productivity	Total
Total	17 (100%)	18 (100%)	35 (100%)

Source: Processed primary data.

Table 4 shows a consistent pattern between GAP-IPM implementation and cocoa productivity. Of the 18 farmers with low GAP-IPM implementation, 88.9% had low productivity. Conversely, 94.1% of the 17 farmers with high implementation had high productivity. Mean productivity was 468.7 kg/ha in the low-implementation group and 865.4 kg/ha in the high-implementation group, a nearly twofold difference. This pattern indicates a positive association between implementation and productivity, which was assessed statistically using the tests in Table 5.

Table 5. Chi-Square Test Results

Statistical test	Value	df	Asymp. Sig. (2-sided)
Pearson chi-square	24.115	1	<0.001
Continuity correction	20.907	1	<0.001
Likelihood ratio	28.327	1	<0.001
Fisher's exact test	–	–	<0.001
Linear-by-linear association	23.426	1	<0.001
N of valid cases	35		

No cells (0%) had an expected count below 5; the minimum expected count was 8.26.

Table 5 gives a Pearson chi-square of 24.115 (1 df), two-sided asymptotic significance $p < 0.001$. Fisher's exact test also gives $p < 0.001$. The linear-by-linear association statistic is 23.426 ($p < 0.001$), indicating a consistent association between the ordered categories. The results therefore support the hypothesis that GAP-IPM implementation is significantly associated with cocoa productivity among the farmers in the Palolo subdistrict.

The pattern in Table 4 underscores the importance of consistent IPM implementation for cocoa productivity. Farmers in the low GAP-IPM category rarely pruned or sanitized their farms, allowing dense, humid canopies favorable to Helopeltis sp. and cocoa pod borer. Sixteen of the 18 farmers in this category also had low productivity. In contrast, farmers in the high category regularly pruned, sanitized, sleeved pods, and used natural enemies, allowing earlier pest suppression and improved harvests. Planting material also affected ease of implementation: superior clones such as MCC 02, Sulawesi 01, and ICCRI 01 were easier to manage under GAP standards than local trees. Rafika (2022) similarly describes Sulawesi 01 and MCC 02 as superior clones with high and stable production, good adaptability, and improved cocoa quality.

The findings also suggest a beneficial role for JB Cocoa's GAP-IPM assistance among sampled farmers in the five study villages. Toknok et al. (2022) similarly found that continued assistance to cocoa farmer groups improved farmers' understanding and skills in good cultivation practices. Farmers who participated in assistance activities and implemented GAP-IPM more consistently were better able to suppress pests early and obtained higher yields than those with lower implementation. The differences in productivity categories and the significant association are consistent with the field-level benefits expected from such assistance.

Implications :
There's a very strong link between GAP-IPM and cocoa productivity, which is also relevant to LLNP conservation, as all five of the villages fall within the buffer zone. Where livelihoods depend so heavily on land, agricultural expansion into the forest is a real possibility. Rukmana et al. (2024) show that land-use dynamics around the LLNP are driven by changes in productivity and commodity prices. Enhanced cocoa productivity via GAP-IPM could enable land intensification (more output from the same area), reducing the need to expand into forest and the reliance on chemical pesticides. Hapid et al. (2018) also found that improved cocoa yields can increase farmers' awareness of the value of national park conservation. GAP-IPM could therefore improve farmer welfare while reducing pressure to encroach into the LLNP buffer zone.
Research Contribution :
The study documents the association between GAP-IPM implementation and cocoa productivity among JB Cocoa-assisted farmers in five villages in the LLNP buffer zone. It connects farmer-level cultivation practices with the broader discussion of sustainable cocoa intensification around a conservation area.

Limitations :
The research identified a simultaneous relationship involving all components of integrated pest management; however, it has yet to demonstrate the individual (partial) relationships of these four components with cocoa productivity.

Suggestions :
Based on these findings, cocoa farmers in Palolo Subdistrict, particularly those growing old local cocoa trees with tall canopies, are encouraged to gradually rejuvenate using superior clones such as MCC 02, S1, ICCRI 01, and other suitable clones. This would make GAP-IPM and other GAP practices easier to access and implement routinely, supporting improved cocoa productivity.

CONCLUSION

GAP-IPM implementation among JB Cocoa-assisted farmers in the LLNP buffer zone of Palolo Subdistrict was fairly evenly distributed, with 18 (51.4%) in the low implementation group and 17 (48.6%) in the high implementation group. The Pearson chi-square statistic was 24.115 ($p < 0.001$), indicating a significant association between GAP-IPM implementation and cocoa productivity. Mean productivity in the high-implementation group was 865.4 kg/ha, compared with 468.7 kg/ha in the low-implementation group (nearly double). Consistent application of cultural, mechanical, biological, and chemical IPM practices was associated with better suppression of both cocoa pod borer and Helopeltis sp. and higher productivity. JB Cocoa's assisted program supports the adoption of improved farm-level cultivation practices and may have some indirect conservation benefits for the LLNP buffer zone.

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AUTHOR CONTRIBUTION STATEMENT

Regarding the contributions of each author, SS contributed to data collection and analysis, as well as the comprehensive discussion. AL contributed to developing the research proposal and assisted the first author in evaluating the data analysis results and deepening the discussion. DH assisted the first author in refining the writing and checking the article for plagiarism.

AI DISCLOSURE STATEMENT

The author used the Grammarly application during the preparation of this work for proper and correct grammar usage.

CONFLICTS OF INTEREST

There is no conflict of interest with any other party in the writing of these research findings.

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