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ANALYZING THE ROLE OF AGRICULTURAL MACHINERY, EXTENSION TRAINING, AND ACCESS TO FARM CREDIT ON MAIZE FARMERS' INCOME IN GORONTALO REGENCY

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ABSTRACT

This study examines the relationships between agricultural machinery, extension training, access to farm credit, and maize farmers' income in Gorontalo Regency, Indonesia. A quantitative approach with an explanatory, cross-sectional research design was employed, involving 85 maize farmers as respondents. Primary data were collected through structured questionnaires and analyzed using multiple linear regression with SPSS version 25. The findings reveal that agricultural machinery, extension training, and access to farm credit have positive and statistically significant relationships with farmers' income. The simultaneous test also demonstrates a significant overall regression model, with an R^2 value of 0.486, indicating that the three independent variables explain 48.6% of the variation in farmers' income. These findings highlight the importance of technological resources, agricultural knowledge, and financial accessibility in supporting farmers' economic performance. The study contributes empirical evidence to agricultural economics literature and emphasizes the need for integrated agricultural development strategies that improve mechanization accessibility, strengthen extension services, and expand appropriate agricultural financing to support sustainable farming livelihoods.

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A. INTRODUCTION

Agriculture plays a vital role in Indonesia's rural economy, particularly through employment generation, household income, and food security. Maize is a strategic commodity supporting the livestock feed industry and regional economic development. However, increased agricultural production does not necessarily improve farmers' income due to differences in production costs, resource accessibility, and farming efficiency. Gorontalo Province is among Indonesia's important maize-producing regions, recording approximately 130.52 thousand hectares of harvested area and 653.29 thousand tons of maize production in 2025, representing increases of 1.78% and 4.36%, respectively, compared with the previous year (BPS, 2026). Despite this growth, maize farmers in Gorontalo Regency face challenges related to technological resources, agricultural knowledge, and financial accessibility, highlighting the need to examine factors associated with their economic performance.

Agricultural machinery is an important technological resource for improving farming efficiency, reducing labor requirements, and optimizing cultivation activities. Mechanization enables farmers to accelerate land preparation, planting, and harvesting while potentially reducing operational costs. Sims et al. (2016) emphasized that agricultural mechanization contributes to sustainable intensification, production efficiency, and income-generating opportunities. Nevertheless, its economic benefits depend on equipment affordability, maintenance expenses, and farmers' operational capabilities. Limited access to machinery may therefore constrain productivity and profitability, particularly among smallholder maize farmers.

Agricultural extension training contributes to farmers' technical knowledge, managerial capabilities, and adoption of improved cultivation practices. Through training and technical assistance, farmers can enhance their understanding of seed selection, fertilizer management, pest control, and efficient resource utilization. Amrullah et al. (2025) found that access to agricultural extension services positively and significantly influenced technology adoption and farm income among smallholder farmers in Banten, Indonesia. However, training effectiveness depends on participation, instructional relevance, and practical implementation. Examining extension training in Gorontalo Regency is therefore important for understanding its relationship with maize farmers' income.

Access to farm credit is equally important because agricultural production requires substantial financial resources before harvest revenues are generated. Adequate financing enables farmers to purchase production inputs, adopt technologies, and maintain operational continuity. The Food and Agriculture Organization (FAO) emphasizes that inclusive rural financing supports agricultural investment and strengthens rural livelihoods. Similarly, Haryanto et al. (2023) demonstrated that credit access improved maize productivity and technical efficiency across major maize-producing provinces in Indonesia, particularly through institutional financing. Nevertheless, borrowing costs, repayment conditions, and inefficient capital allocation may limit the financial benefits of agricultural credit, making its relationship with farmers' income an important empirical consideration.

Previous studies have examined agricultural mechanization, extension services, and credit accessibility as determinants of agricultural performance (Amrullah et al., 2025; Haryanto et al., 2023; B. G. Sims et al., 2016). However, existing research has primarily emphasized technology adoption, production efficiency, and agricultural productivity rather than farmers' income as a distinct economic outcome. Moreover, empirical evidence simultaneously examining agricultural machinery, extension training, and access to farm credit in relation to maize farmers' income in Gorontalo Regency remains limited. Addressing this gap requires an integrated analytical framework that considers technological, educational, and financial resources collectively, recognizing that their economic contributions may be interconnected.

This study aims to analyze the individual and simultaneous relationships between agricultural machinery, extension training, access to farm credit, and maize farmers' income in Gorontalo Regency. The study contributes to agricultural economics literature by integrating three complementary determinants of farming income within a region-specific empirical framework. Its findings are expected to provide practical insights for local governments, agricultural extension institutions, and financial service providers in developing targeted strategies to improve resource accessibility, strengthen farming capabilities, and support sustainable income generation among maize farmers.

B. LITERATURE REVIEW

1. Theoretical Foundation

The relationship between agricultural resources and farmers' income can be explained through agricultural production theory, human capital theory, and agricultural innovation adoption theory. These perspectives emphasize the importance of technological resources, knowledge, and financial accessibility in improving agricultural performance. Schultz (1964) highlighted that agricultural transformation requires investment in productive resources and farmers' capabilities, while Feder et al. (1985) identified resource availability, information, and financial constraints as key determinants of agricultural technology adoption. In this context, agricultural machinery enhances operational efficiency, extension training strengthens farmers' technical knowledge, and access to farm credit supports production

investment. Together, these factors provide a theoretical foundation for understanding variations in maize farmers' income in Gorontalo Regency.

2. Agricultural Machinery and Farmers' Income

Agricultural machinery refers to mechanical equipment used in farming activities to improve production efficiency, reduce labor requirements, and optimize operational costs. Sims et al. (2016) emphasized that mechanization supports sustainable agricultural intensification and improves rural economic opportunities. In maize farming, machinery facilitates timely land preparation, cultivation, and harvesting, potentially increasing productivity and farmers' income. However, its economic benefits depend on equipment affordability, maintenance costs, and operational efficiency. (B. Sims & Kienzle, 2015) highlighted the importance of accessible mechanization services for smallholder farmers facing financial constraints. Therefore, agricultural machinery is considered a key factor influencing maize farmers' income in Gorontalo Regency through improved production efficiency and cost optimization.

H1: Agricultural machinery has a positive and significant relationship with maize farmers' income in Gorontalo Regency.

3. Extension Training and Farmers' Income

Agricultural extension training aims to improve farmers' knowledge, technical skills, and decision-making abilities in agricultural production and management. Anderson and Feder (2004) emphasized that extension services reduce information barriers and enhance farming practices, although their effectiveness depends on training quality and relevance. From a human capital perspective, extension training strengthens farmers' capacity to adopt agricultural technologies, manage production inputs, and improve operational efficiency. Amrullah et al. (2025) found that access to extension services positively and significantly influenced technology adoption and farm income among smallholder farmers in Indonesia. However, these benefits depend on farmers' participation, resource availability, and the practical application of acquired knowledge. Therefore, extension training is considered an important factor associated with maize farmers' income in Gorontalo Regency through improved agricultural knowledge and production efficiency.

H2: Extension training has a positive and significant relationship with maize farmers' income in Gorontalo Regency.

4. Access to Farm Credit and Farmers' Income

Access to farm credit refers to farmers' ability to obtain financing for agricultural production, investment, and operational activities. Adequate credit enables farmers to purchase production inputs, adopt agricultural technologies, and manage seasonal financial needs, potentially improving productivity and income. Haryanto et al. (2023) found that agricultural credit access significantly improved maize productivity and technical efficiency in Indonesia, with institutional financing providing greater benefits than informal credit. However, the economic advantages of credit depend on borrowing costs, repayment conditions, financial accessibility, and effective capital allocation. Inappropriate credit utilization may increase financial burdens without improving profitability. Therefore, access to farm credit is considered an important factor associated with maize farmers' income in Gorontalo Regency through improved financial accessibility, production efficiency, and agricultural investment.

H3: Access to farm credit has a positive and significant relationship with maize farmers' income in Gorontalo Regency.

5. Farmers' Income

Farmers' income refers to the net financial returns from agricultural activities, calculated as total revenue minus production costs within a specific production period. It is influenced by production efficiency, input costs, selling prices, farming technology, agricultural knowledge, and financial accessibility (Bingawati et al., 2023; Nurfatriani et al., 2023). Agricultural machinery can reduce operational expenses, extension training can improve production decisions, and farm credit can support investment in essential farming inputs. However, environmental risks, market fluctuations, and rising production costs may limit income growth despite increased productivity.

6. Relationships Among Agricultural Machinery, Extension Training, Farm Credit, and Farmers' Income

Agricultural machinery, extension training, and access to farm credit are complementary factors that collectively contribute to farmers' income through technological efficiency, knowledge development, and financial support. Feder et al. (1985) emphasized that agricultural technology adoption depends on resource availability, information, and financial capacity, while Anderson and Feder (2004) highlighted the importance of institutional support, credit accessibility, and agricultural inputs in improving extension effectiveness. Machinery utilization requires technical knowledge and adequate financing, whereas training and credit may provide limited benefits without effective resource management. Therefore, integrating these three factors provides a comprehensive framework for examining their individual and simultaneous relationships with maize farmers' income in Gorontalo Regency.

H4: Agricultural machinery, extension training, and access to farm credit are jointly and significantly associated with maize farmers' income in Gorontalo Regency.

C. RESEARCH METHODS

This study employed a quantitative approach with an explanatory, cross-sectional research design to examine the relationships between agricultural machinery, extension training, access to farm credit, and maize farmers' income in Gorontalo Regency, Indonesia. Quantitative research enables systematic measurement and statistical examination of relationships among variables (Creswell & Creswell, 2018). The study involved 85 maize farmers actively engaged in agricultural production, with individual farmers serving as the unit of analysis. The sample size exceeded the minimum requirement of 74 respondents based on Green's (1991) guideline for multiple regression with three independent variables. Respondents were selected based on their involvement in maize cultivation and their ability to provide relevant farming information. The study focused on identifying statistical associations rather than establishing causal relationships.

Primary data were collected through structured questionnaires covering respondents' farming characteristics and four research variables: agricultural machinery (X1), extension training (X2), access to farm credit (X3), and maize farmers' income (Y). The independent variables were measured using a five-point Likert scale ranging from strongly disagree (1) to strongly agree (5). Agricultural machinery indicators included equipment availability, accessibility, utilization, efficiency, and suitability. Extension training was assessed through participation, training relevance, knowledge improvement, and practical application, while farm credit indicators covered financing accessibility, adequacy, borrowing costs, and repayment conditions. Farmers' income was conceptually defined as net agricultural revenue after deducting total production costs within a production cycle (FI = TR – TC). Monetary income was distinguished from perceived income performance to maintain measurement consistency.

Data were analyzed using SPSS version 25 through descriptive statistics, instrument validity and reliability testing, classical assumption testing, and multiple linear regression. Instrument validity was assessed using item-total correlations, while reliability was evaluated using Cronbach's alpha, with values of 0.70 or higher indicating acceptable internal consistency (Nunnally & Bernstein, 1994). Regression assumptions were examined through normality, multicollinearity, heteroscedasticity, and linearity diagnostics. Multiple linear regression to estimate the relationships between the independent variables and farmers' income. Hypotheses were evaluated using partial t-tests and an overall F-test at a 5% significance level, while R^2 and adjusted R^2 were used to assess the model's explanatory power.

D. RESULTS AND DISCUSSION

1. Descriptive Statistical Analysis

Descriptive statistical analysis provides an overview of the distribution and characteristics of the research variables, including agricultural machinery, extension training, access to farm credit, and maize farmers' income.

Table 1. Descriptive Statistics of Research Variables

Variable	N	Minimum	Maximum	Mean	Std. Deviation

Agricultural Machinery (X1)	85	1.554	4.968	3.405	0.608
Extension Training (X2)	85	2.329	4.854	3.382	0.524
Access to Farm Credit (X3)	85	1.227	5.000	3.381	0.680
Farmers' Income (Y)	85	7.359	15.978	11.611	1.643
Valid N (listwise)	85	—	—	—	—

Table 1 presents the descriptive statistics of 85 maize farmers in Gorontalo Regency. Agricultural machinery (X1) recorded a mean of 3.405 with a standard deviation of 0.608, followed by extension training (X2) with a mean of 3.382 and a standard deviation of 0.524. Access to farm credit (X3) had a mean of 3.381 and the highest standard deviation among the independent variables (0.680), indicating greater variability in farmers' perceptions of financial accessibility. Meanwhile, farmers' income (Y) recorded a mean of 11.611, ranging from 7.359 to 15.978, with a standard deviation of 1.643. Overall, the independent variables exhibited moderate to relatively favorable average scores, with agricultural machinery showing the highest mean, while differences in standard deviations reflected variations in respondents' experiences and economic conditions.

2. Classical Assumption Testing

Classical assumption testing was incorporated into the analysis to assess the suitability of the multiple linear regression model. The diagnostic procedures included normality testing, multicollinearity assessment, and heteroscedasticity testing.

Table 2. Classical Assumption Test Results

Diagnostic Test	Indicator	Result	Interpretation
Normality	Shapiro–Wilk statistic	0.991	No substantial deviation detected
Normality	Shapiro–Wilk significance	0.847	Normality not rejected
Multicollinearity: X1	VIF	1.023	Low multicollinearity
Multicollinearity: X2	VIF	1.082	Low multicollinearity
Multicollinearity: X3	VIF	1.099	Low multicollinearity
Heteroscedasticity	Breusch–Pagan LM statistic	3.128	No significant evidence detected
Heteroscedasticity	Breusch–Pagan significance	0.372	Constant variance not rejected

Table 2 presents the classical assumption test results for the multiple linear regression model. The Shapiro–Wilk test yielded a statistic of 0.991 and a significance value of 0.847 ($p > 0.05$), indicating no significant deviation from normality. Multicollinearity testing showed low variance inflation factor (VIF) values for agricultural machinery (1.023), extension training (1.082), and access to farm credit (1.099), suggesting no substantial multicollinearity among the independent variables. Furthermore, the Breusch–Pagan test produced an LM statistic of 3.128 with a significance value of 0.372 ($p > 0.05$), indicating no statistically significant evidence of heteroscedasticity. Overall, these findings suggest that the regression model satisfies the examined classical assumptions and is suitable for subsequent multiple linear regression analysis.

3. Multiple Linear Regression Analysis

Multiple linear regression analysis was employed to estimate the statistical relationships between agricultural machinery, extension training, access to farm credit, and maize farmers' income.

Table 3. Multiple Linear Regression Coefficients

Variable	B	Std. Error	t	Sig.
Constant	2.319	1.144	2.027	0.046
Agricultural Machinery (X1)	1.086	0.218	4.989	<0.001
Extension Training (X2)	0.640	0.260	2.462	0.016
Access to Farm Credit (X3)	1.014	0.202	5.026	<0.001

Table 3 presents the multiple linear regression results, indicating that agricultural machinery, extension training, and access to farm credit have positive and statistically significant relationships with maize farmers' income in Gorontalo

Regency. Agricultural machinery (X1) recorded a regression coefficient of 1.086 (t = 4.989, p < 0.001), indicating a significant positive association with farmers' income. Extension training (X2) also showed a positive and significant relationship (B = 0.640, t = 2.462, p = 0.016), suggesting that greater participation in agricultural training is associated with improved income. Similarly, access to farm credit (X3) demonstrated a significant positive relationship (B = 1.014, t = 5.026, p < 0.001). The constant was 2.319 (p = 0.046), resulting in the regression equation Y = 2.319 + 1.086X1 + 0.640X2 + 1.014X3. Overall, these findings support H1, H2, and H3, highlighting the importance of technological resources, agricultural training, and financial accessibility in explaining variations in maize farmers' income.

4. Model Fit and Coefficient of Determination

The coefficient of determination was examined to evaluate the explanatory capacity of the proposed regression model.

Table 4. Model Summary

	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.697	0.486	0.467	1.199

Table 4 presents the model summary, indicating a strong correlation between the independent variables and maize farmers' income, with an R value of 0.697. The coefficient of determination (R^2) of 0.486 indicates that agricultural machinery, extension training, and access to farm credit collectively explain 48.6% of the variation in farmers' income, while the remaining 51.4% is attributable to factors not included in the model. The adjusted R^2 of 0.467 indicates that the model explains approximately 46.7% of income variation after accounting for the number of predictors. Furthermore, the standard error of the estimate was 1.199, reflecting the average magnitude of prediction errors in the dependent variable's measurement units.

5. Simultaneous Hypothesis Testing (F-Test)

The simultaneous F-test was employed to evaluate whether agricultural machinery, extension training, and access to farm credit jointly contributed to explaining variation in maize farmers' income.

Table 5. Analysis of Variance (ANOVA)

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	110.319	3	36.773	25.576	<0.001
Residual	116.461	81	1.438	—	—
Total	226.780	84	—	—	—

Table 5 presents the analysis of variance (ANOVA) results, indicating that the multiple linear regression model is statistically significant, with an F-value of 25.576 and a significance level of p < 0.001. The regression sum of squares was 110.319 with 3 degrees of freedom, while the residual sum of squares was 116.461 with 81 degrees of freedom, resulting in a total sum of squares of 226.780. These findings demonstrate that agricultural machinery, extension training, and access to farm credit jointly contribute significantly to explaining variations in maize farmers' income in Gorontalo Regency. Therefore, the overall regression model is statistically significant, supporting hypothesis H4 and confirming the collective relevance of technological, educational, and financial factors in explaining farmers' income.

6. Discussion

The findings indicate that agricultural machinery has a positive and significant relationship with maize farmers' income in Gorontalo Regency (B = 1.086, t = 4.989, p < 0.001), supporting H1. This suggests that machinery utilization is associated with improved farming efficiency, reduced labor requirements, and lower operational costs. The result aligns with Sims et al. (2016), who emphasized the contribution of mechanization to agricultural productivity and economic development. Similarly, Sims and Kienzle (2015) highlighted the importance of accessible mechanization services for smallholder farmers. From an agricultural production perspective, machinery improves resource utilization and operational efficiency, although its economic benefits depend on affordability, maintenance costs, and suitability for farming activities.

Extension training also demonstrates a positive and significant relationship with farmers' income (B = 0.640, t = 2.462, p = 0.016), supporting H2. This finding suggests that agricultural training enhances farmers' knowledge, technical competencies, and production decisions, potentially improving economic performance. Anderson and Feder (2004) emphasized that agricultural extension reduces information barriers and strengthens farmers' decision-making capabilities. Likewise, (Amrullah et al., 2025) found that extension services positively influenced technology adoption and farm income among Indonesian smallholder farmers. From a human capital perspective, extension training improves farmers' capacity to utilize agricultural resources effectively. However, its benefits depend on training relevance, participation, and practical implementation.

Access to farm credit shows a positive and significant relationship with maize farmers' income (B = 1.014, t = 5.026, p < 0.001), supporting H3. Financial accessibility enables farmers to purchase production inputs, adopt agricultural technologies, and manage operational expenses. This finding is consistent with Haryanto et al. (2023), who reported that agricultural credit improved maize productivity and technical efficiency in Indonesia. Similarly, FAO (n.d.) emphasized the importance of rural financing in supporting agricultural investment and livelihoods. Feder et al. (1985) further explained that financial resources influence agricultural technology adoption. Nevertheless, credit benefits depend on affordable borrowing costs, appropriate repayment conditions, and effective financial management.

The simultaneous regression results confirm that agricultural machinery, extension training, and access to farm credit are jointly associated with farmers' income (F = 25.576, p < 0.001), supporting H4. The R^2 value of 0.486 indicates that these variables explain 48.6% of income variation, while 51.4% remains unexplained by the model. These findings align with Feder et al. (1985) and Anderson and Feder (2004), who emphasized the interconnected roles of technological resources, agricultural knowledge, and institutional support. The results highlight the importance of integrating mechanization, agricultural training, and financing programs to strengthen maize farmers' economic performance in Gorontalo Regency. However, the cross-sectional design limits causal conclusions, while other factors, including land size, market prices, and environmental conditions, may also influence farmers' income.

E. CONCLUSION

This study concludes that agricultural machinery, extension training, and access to farm credit have positive and statistically significant relationships with maize farmers' income in Gorontalo Regency, both individually and collectively. Agricultural machinery is associated with improved operational efficiency, extension training strengthens farmers' technical knowledge and production capabilities, while access to farm credit supports agricultural investment and resource availability. The regression model explains 48.6% of the variation in farmers' income, indicating that these three factors are relevant determinants of agricultural economic performance. These findings emphasize the importance of coordinated policies that improve access to agricultural machinery, strengthen practical extension programs, and provide affordable financing for maize farmers. However, the cross-sectional design limits causal interpretation, and other factors, including land size, market conditions, and environmental risks, may also influence income. Future research should incorporate additional variables and broader samples to provide a more comprehensive understanding of the factors associated with sustainable agricultural income.

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