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TECHNICAL EFFICIENCY IN SMALL-SCALE 'BUNGULAN' BANANA PRODUCTION IN COTABATO, PHILIPPINES: A STOCHASTIC FRONTIER ANALYSIS

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Abstract

This study evaluates the technical efficiency of small-scale 'Bungulan' banana farming in Cotabato, Philippines, crucial for enhancing productivity. Given the Philippines' prominence as a banana exporter, it aims to identify factors impacting technical efficiency and address local challenges. Using stochastic frontier analysis, 182 members of the Organic Banana Producers Association (OBPA) were sampled through stratified techniques. These farmers, engaged in 'Bungulan' farming for over three years on land under 10 hectares, provided primary and secondary data. Results showed 43.96% of farms had efficiency levels below 0.50, and only 3.30% achieved near-optimal efficiency (>0.90). Key findings include the significant impact of quality planting materials on efficiency (coefficient: 3.76). Increased production correlates with higher efficiency, while family labor and training programs show mixed effects. Regular extension contacts and proximity to markets reduce inefficiency, emphasizing advisory services and market access. Recommendations include improving planting materials, optimizing labor, and enhancing training, extension services, and infrastructure.

Keywords: ‘Bungulan’ Banana, Technical Efficiency, Stochastic Frontier Production.

1.0 INTRODUCTION

1.1 Background

Banana production is vital for global agriculture, contributing significantly to food security and economic stability. The Philippines is a major exporter, ranking second globally as of 2022 (Philippine Banana Industry Roadmap, 2019-2022). The 'Bungulan' banana (*Musa paradisiaca suaveolens* Blanco), an organically grown variety, thrives in forested, hilly areas with minimal weeding. It is renowned for its high vitamin A content, sweetness, aroma, and excellent quality, primarily exported to Japan (Philippine Banana Industry Roadmap, 2021-2025; Faylon et al., 2004). Classified as a triploid acuminata clone (AAA), 'Bungulan' ranks fifth among Philippine banana cultivars due to its robust qualities (Eximasian International Trading Group, 2024; Hariyanto et al., 2021). Despite its prominence, the industry faces challenges such as pest infestations, high input costs, and fluctuating market prices (International Trade Center, 2021; FAO UN, 2020). The Philippines exports about 3.5 million tons annually, with production concentrated in Mindanao—particularly Davao, Northern Mindanao, and Soccskargen. The Cavendish variety leads at 53% of production, followed by Saba (28%), Lakatan (10%), and 'Bungulan' (9%) (Bananalink, 2024). Extreme weather and climate change exacerbate challenges like crop disruption, food and water shortages, flooding, and increased pest issues, making the Philippines one of the top five most affected countries as of 2017 (Bananalink, 2024; International Institute for Sustainable Development, 2023). Sustainability is crucial as pests, high input costs, poor infrastructure, and marketing difficulties affect production (International Trade Center, 2021; FAO UN, 2020). Rising input costs and climate issues further strain farmer incomes due to expensive inputs and resource management problems (PBIR, 2021-2025). In response, small-scale farmers are transitioning to 'Bungulan' with support from local governments, the Department of Agriculture, and the Don Busco Foundation. This shift has improved economic outcomes, aligning with Sustainable Development Goal No. 8 - Good Jobs and Economic Growth (Neuvo et al., 2018). Despite these efforts, factors influencing technical efficiency in small-scale 'Bungulan' production, particularly in Cotabato, remain underexplored (Madau et al., 2017). This study aims to analyze technical efficiency using stochastic frontier analysis, providing insights to enhance productivity and sustainability in the region's banana sector.

2.0 LITERATURE REVIEW

2.1 Banana Bungulan Variety

The 'Bungulan' banana is a notable Philippine variety known for its high Vitamin A content, sweetness, and aromatic, high-quality pulp, ideal for desserts like banana bread (EITG, 2024; PBIR, 2021-2025). Also known as "Pisang Masak Hijau" in Malaysia, it uniquely remains green when fully ripe (PBIR, 2021-2025). 'Bungulan' produces bunches with 6 to 12 hands, each containing 12 to 20 long, slightly curved, angular fingers (EITG, 2024). Economically significant, particularly in Japan's export market since 1989, 'Bungulan' supports smallholder farmers (Basan, 2021). Efforts to reduce postharvest losses and promote organic farming, supported by local governments and organizations like the Don Bosco Foundation, have bolstered its role in agriculture (Neuvo et al., 2018). Despite its benefits, 'Bungulan' is susceptible to nematodes and moderately resistant to the banana bunchy top virus (PBIR, 2021-2025). Mindanao is the primary producer, followed by Visayas and Luzon (PSA, 2020).

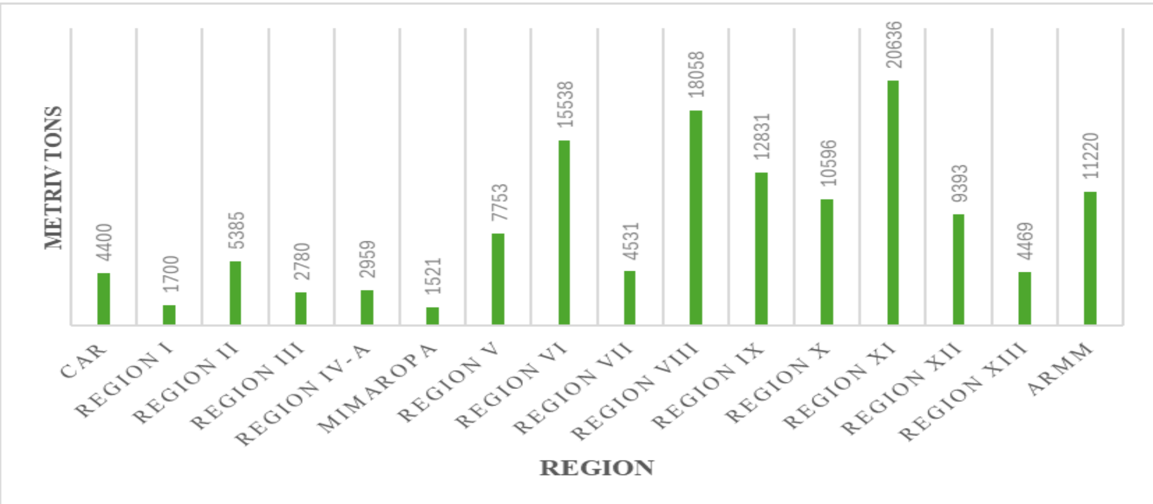

Figure 1: 'Bungulan' banana production in MT in the Philippines (PSA, 2020).

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2.2 Technical efficiency and factors influencing efficiency

Technical efficiency (TE) in crop production is shaped by demographic, socio-economic, and institutional factors such as age, education, household size, farming experience, and distance to market. Institutional factors include credit access, training, extension services, and government subsidies (Bagamba et al., 2007). Research on farm size and TE shows mixed results: Masterson (2005) found higher efficiency in smaller farms, while Yusuf and Malomo (2007) reported higher efficiency in larger farms. Mohammed (2018) noted TE ranging from 20% to 87%, averaging 61%. This study uses Stochastic Frontier Analysis (SFA) to measure TE, identifying inefficiencies and informing productivity improvements (Aigner, Lovell, & Schmidt, 1977; Kumbhakar & Lovell, 2003).

Key factors affecting technical efficiency include:

1. **Production Factors**: Planting materials (Tukela & Rambabu, 2021; Vinayagamoorthi et al., 2019), fertilizers (Acharya et al., 2020; Van Hung et al., 2022), pest control measures (Acharya et al., 2020; Bravo-Ureta et al., 2007), and labor (Arigor et al., 2022; Tukela & Rambabu, 2021) positively influence efficiency. Farm size also affects efficiency, with larger farms generally showing higher productivity but smaller farms often demonstrating greater efficiency due to decreasing returns to scale (Van Hung et al., 2022; Debebe et al., 2015).
2. **Institutional Factors**: Access to credit, extension services, training, and government support are critical. Extension services (Eutycus, 2019; Yang et al., 2018) and training (Van Hung et al., 2022) improve efficiency by providing farmers with new technologies and best practices. Government support (Angcos, 2021) can enhance efficiency through resource provision and policy interventions.
3. **Demographic and Socio-Economic Factors**: Age, education, farming experience, household size, and distance to market impact efficiency. Older farmers often exhibit higher efficiency (Eutycus, 2019; Hossain & Majumber, 2018), while higher education levels generally improve efficiency (Van Hung et al., 2022). Household size can negatively affect efficiency (Arigor et al., 2022), and proximity to markets (Gautam et al., 2012) can offer efficiency advantages. Off-farm activities' impact on efficiency is mixed, with some studies suggesting positive effects due to additional income (Asfaw et al., 2019), while others indicate potential negative effects from reduced farm attention (Tukela & Rambabu, 2021).

2.3 Reviews on determinants of TE

Table 1 provides a comprehensive review and description per parameter used in the study on the various determinants of technical inefficiency in agricultural production, specifically focusing on the 'Bungulan' banana farming context. The table lists key variables, their corresponding parameters, and the direction of their impact (positive or negative) on technical inefficiency, as identified by different authors.

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Table 1: Reviews on determinants of technical inefficiency

Variables	Parameter	Sign	Authors	Variables Description
Hired labor	$B_1 \ln X_1$	-	Kalule (2013)	Total labor is aggregated as man-days per hectare for all farm operations, including hired and family labor, in 2023.
		+	Amaza et al. (2006)	
Family labor	$B_2 \ln X_2$	+	Arigor et al. (2022) Vinayagamoorthi et al. (2019) Baruwa and Oke (2012)	
		-	Seok et al. (2018)	
'Bungulan' banana planting materials	$B_2 \ln X_3$	+	Arti & Leua (2022), Tesema (2022) Yeasmin (2021), Vinayagamoorthi et al. (2019)	Planting materials are consolidated, with total usage converted to a per-hectare basis, regardless of planting density.
Organic Fertilizer (kg/ha)	$B_3 \ln X_4$	+	Van Hung et al. (2022) Vinayagamoorthi et al. (2019) Amaza et al. (2006)	Organic fertilizer use is assessed by estimating total kilograms applied and converting it to a per-hectare basis.
		-	Omondi et al. (2020)	
Age of household head in year	$\delta_1 Z_1$	+	Arti & Leua (2022), Hossain et al. (2015), Omondi et al. (2020), Eutycus (2019), Hossain and Majumber (2018), Amaza et al. (2006),	The age of the household head is determined by counting the number of years he has lived.
		-	Seok et al. (2018), Khai and Yabe (2011)	
Highest education attainment (Number)	$\delta_2 Z_2$	+	Arti & Leua (2022), Hossain et al. (2015), Van Hung et al. (2022), Kalule (2013), Omondi et al. (2020), Tesema (2022) Amaza et al. (2006)	Education is categorized as: 1 - Elementary level 2 - Elementary graduate 3 - High school level 4 - High school graduate 5 - College level 6 - College graduate
		-	Seok et al. (2018)	
'Bungulan' farming experience in year	$\delta_3 Z_3$	+	Arigor et al. (2022), Yeasmin (2021) Kalule (2013), Khai and Yabe (2011)	Farmer's experience is determined by the actual number of years he has been engaged in 'Bungulan' banana cultivation.
		-	Eutycus (2019), Hossain et al. (2015)	
Household size (Number)	$\delta_4 Z_4$	+	Arti & Leua (2022), Seok et al. (2018)	This is determined by the number of family members in the household
		-	Arigor et al. (2022), Eutycus (2019) Kalule (2013)	
Number of trainings attended per year	$\delta_5 Z_5$	+	Van Hung et al. (2022) Cañete and Temanel (2017)	This is assessed by counting the training sessions attended by each 'Bungulan' banana farmer in 2023.
Number of extension contacts per year	$\delta_6 Z_6$	+	Arti and Leua (2022), Tukela and Rambabu (2021), Omondi et al. (2020) Eutycus (2019), Amaza et al. (2006)	This parameter counts extension agent visits to 'Bungulan' banana farms for monitoring and services during 2023.
Distance of farm to market in meter	$\delta_7 Z_7$	-	Van Hung et al. (2022), Tesema (2022)	Distance from the farm to the market or packing house is measured in meters, indicating proximity for selling harvested products.
		+	Gautam et al (2012)	

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Farm size in hectare	δ_8 Z_8	+	Arti & Leua (2022), Van Hung et al. (2022), Tesema (2022), Yeasmin (2021), Hossain et al. (2015), Tukela and Rambabu (2021), Omondi et al. (2020), Kalule (2013), Bagamba (2007), Amaza et al. (2006)	This parameter is determined by asking individual farmers to estimate the area, in hectares, allocated for 'Bungulan' banana cultivation.
		-	Debebe et al. (2015)	
Sex in birth (dummy)	δ_9 Z_9	+	Omondi et al. (2020)	"Sex in birth" is recorded as 1 for male and 0 for female, categorizing individuals based on their sex at birth.

2.4 Conceptual framework of technical efficiency

Technical efficiency is vital for boosting agricultural productivity, measured by comparing actual output to the maximum achievable output with given inputs (Bicknell & Renwick, 2019; Debebe et al., 2015). Stochastic Frontier Analysis (SFA) helps estimate production technology and technical inefficiency (Asefa, 2011). For 'Bungulan' banana production in Cotabato, technical efficiency is affected by socio-economic conditions, farm characteristics, institutional support, and resource ownership (Nyagaka et al., 2010). Improving these factors is crucial for enhancing efficiency among small-scale farmers (Debebe et al., 2015). Figure 2, adapted from Tesema (2022), illustrates how these factors influence technical efficiency.

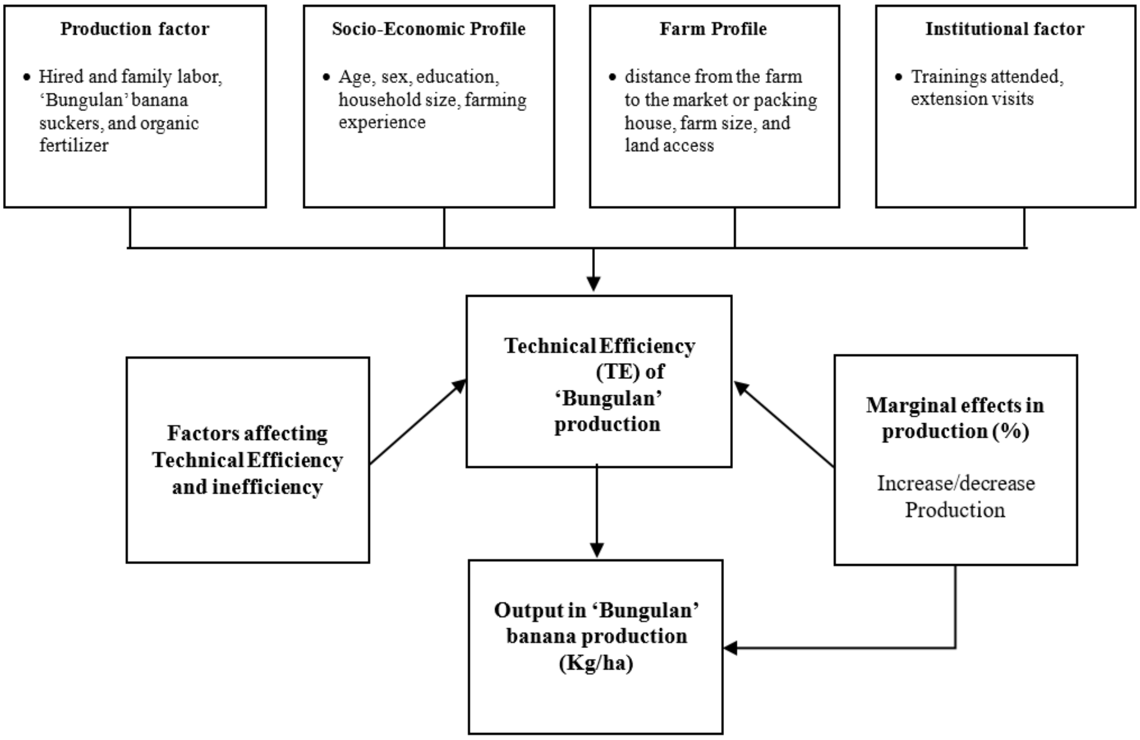

Figure 2: Conceptual framework of factors affecting technical efficiency.

(Source: Tesema, 2022)

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3.0 RESEARCH METHODOLOGY

3.1 Locale of the Study

As shown in Figure 3, this study was conducted in selected municipalities of Cotabato Province: Arakan, Banisilan, Kidapawan, Matalam, Makilala, Magpet, and President Roxas. Located in the SOCCSKSARGEN region of the Philippines, Cotabato covers 9,317.30 square kilometers with a population of 1,490,618, making up 30.41% of the region's population.

The province has a population density of about 160 people per square kilometer and features varied topography, from level to very steep terrain, supporting diverse agriculture (PhilAtlas, 2023; PSA, 2020). Cotabato, the largest province in Region XII, spans 656,590 hectares and includes 17 municipalities and one city, Kidapawan City.

The economy relies heavily on agriculture, with bananas being a major crop. The province cultivates bananas on approximately 14,787.7 hectares, with 'Bungulan' variety occupying 9% of this area. Recent production totaled about 9,393 metric tons from 473 hectares (Province of Cotabato, 2023; Basan, 2021; PSA, 2023, 2020).

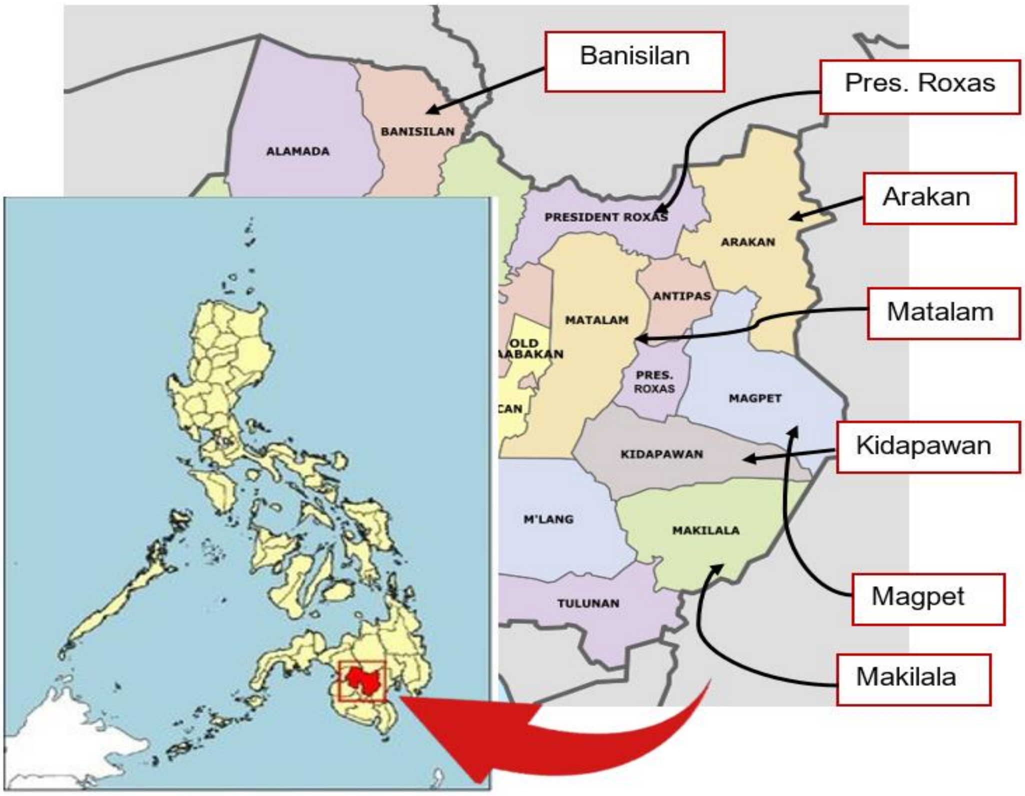

Figure 3: Map of North Cotabato (Source: NAMRIA Topographical Map/ Bureau of Soils and Water Management. https://www.geoportal.gov.ph/)

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The climate in Cotabato is characterized by hot and oppressive conditions, with temperatures ranging from 74°F to 94°F, and significant rainfall throughout the year. The month of June recorded the most rain, with an average of 7.0 inches, while March had the least, with 2.3 inches (Weatherspark, 2023).

Cotabato's diverse soils include undifferentiated mountain soils and clay loam in the plains, ideal for intensive crops. Fertile silt from the Cotabato Basin enriches agricultural lands. A shift to a market-oriented approach boosted banana cultivation, attracting major investors like DOLE-Stanfilco and Lapanday Global Fruits, enhancing the local economy and infrastructure (Province of Cotabato, 2023).

3.2 Participants and sampling design of the Study

The study focused on active members of the Organic Banana Producers Association (OBPA) who have cultivated ‘Bungulan’ bananas for at least three years on land not exceeding 10 hectares. Participants were household heads aged 18 and older, with decision-making authority over their farm and household resources, aligning with Debebe et al. (2015) and Bagamba (2007).

Using G*Power 3.1.9.7 (Faul et al., 2007), a stratified random sampling method selected 182 participants (shown in Figure 4) from 369 valid respondents, initially from 389. As gleaned in Table 2, Arakan had the highest engagement, representing 46.70% of the sample, while Matalam and Magpet had lower rates. In Mindanao, Cavendish plantations dominate banana production, but small-scale farmers focus on various banana varieties, including ‘Bungulan’.

These farmers typically manage farms ranging from less than one to 10 hectares, with the average farm size in the Philippines being 1.29 hectares (PSA, 2020).

Table 2: Banana Bungulan Farmer-respondents of the study, 2024

Municipality	Total ‘Bungulan’ banana producers	Selected ‘Bungulan’ banana producers	Percentage (%) of selected ‘Bungulan’ farmers
1. Arakan	174	85	46.70
2. Banisilan	79	39	21.43
3. Kidapawan City	8	8	4.40
4. Matalam	2	2	1.10
5. Magpet	5	5	2.75
6. Makilala	118	40	21.98
7. President Roxas	3	3	1.65
	389	**182**	

Note: The total number of respondents excludes 20 pilot testing respondents, resulting in 369 total respondents. (**Source:** Researcher’s survey, 2024).

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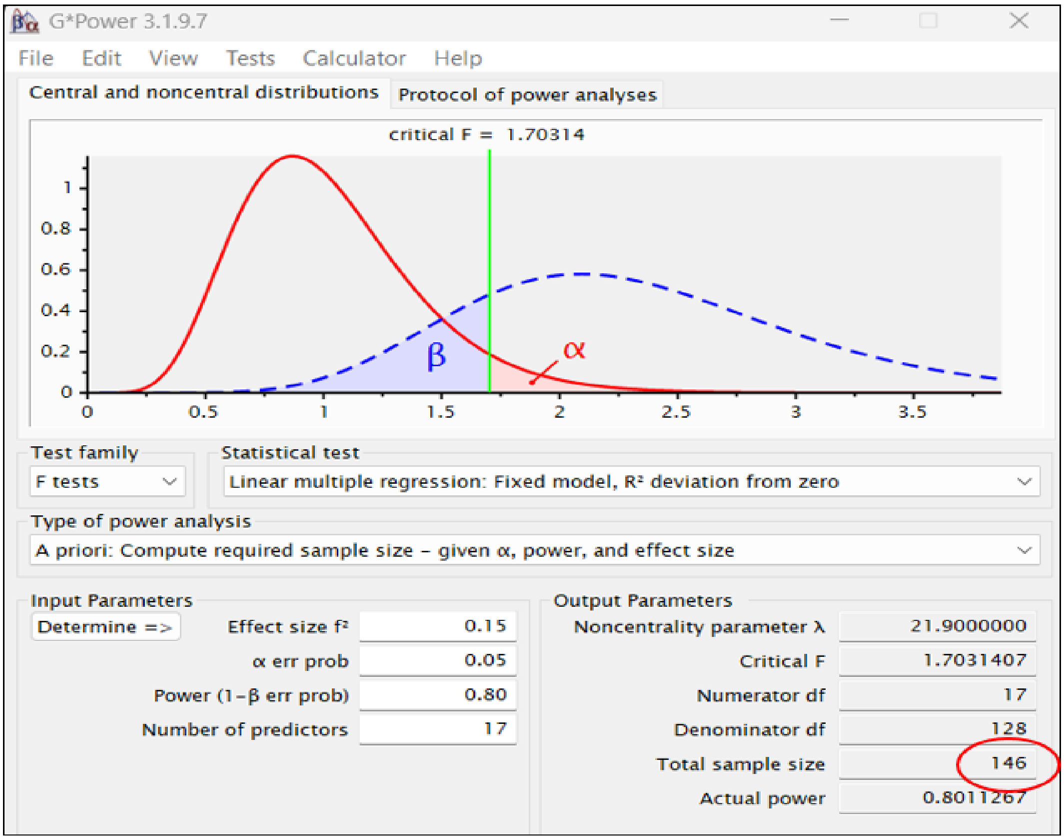

Figure 4: The study's minimum population size by G*Power software (Faul et al., 2007)

To stratify the sampling, Table 3 shows the population divided by farm size: Marginal (≤1.00 ha), Small (1.01 to 2.00 ha), Semi Medium (2.01 to 4.00 ha), and Medium (4.01 to 10.00 ha). Table 3 details landholding sizes based on the Horticultural Statistics at a Glance (2015) as cited by Vinayagamoorthi et al. (2019). The data indicates that 87.91% of 'Bungulan' banana farmers in Cotabato have landholdings of 1 hectare or less, with an average size of 0.26 hectares, underscoring the limited land resources available to most farmers.

Table 3: Cultivated area for 'Bungulan' banana in Cotabato Region, 2024

Cultivated area in hectare	No. of Farms	Cumulative percent (%)	Total Area (Hectares)	Average size (hectares)
Marginal (≤ 1.00)	160	87.91	41.85	0.26
Small (1.01 to 2.00)	14	7.69	21.60	1.54
Semi Medium (2.01 to 4.00)	5	2.75	14.30	2.86
Medium (4.01 to 10.00)	3	1.65	21.00	7.00
Total	182	100	98.75	

Source: Author's calculations using IBM SPSS Statistics 25, 2024

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3.3 Research Instrumentation

The survey questionnaire used in this study was adapted from Angcos's (2021) research titled "Productivity and Technical Efficiency Analysis of Adlay (*Coix lacryma-jobi* L.) Farms in Bukidnon." It was modified to fit the data needed for assessing the technical efficiency of 'Bungulan' banana production, covering everything from cultivation to marketing practices, in line with the research objectives. The semi-structured questionnaire included various aspects such as socio-demographic information, land use, production details, and the challenges faced by 'Bungulan' banana farmers in the Cotabato Region for the year 2024.

3.4 Methods of data collection

From March to May 2024, data were collected from 182 ‘Bungulan’ banana farmers in the Cotabato Region using a pre-tested, semi-structured questionnaire. The study involved both primary data, obtained through farm visits and interviews, and secondary data from the OBPA’s production records for 2023.

Qualitative methods, including in-depth interviews with farmers and officials, were used to validate responses and understand the impact of farming techniques on efficiency. Direct observation and documentation of practices and conditions were also employed. Close-ended questionnaires were administered in the local language during structured interviews, with data collection covering a period of up to 12 months.

3.5 Methods of data analysis

The study's methodology follows the stochastic frontier production function, a method extensively used in agricultural efficiency research over the past two decades (Coelli, 1996, cited by Hossian et al., 2015). Coelli observed that 75% of studies on agricultural frontier models adopted this approach.

Stochastic frontier models incorporate a disturbance term that accounts for statistical noise, measurement error, and exogenous shocks beyond production units' control, thereby distinguishing these factors from technical inefficiency. This distinction reduces the risk of misattribution and provides a solid basis for statistical tests to evaluate production structure hypotheses and inefficiency levels, offering valuable insights into production performance.

3.6 Stochastic frontier model of technical efficiency and inefficiency

The study employs the Stochastic Frontier Analysis (SFA), a method based on the work of Aigner et al. (1977) and Meeusen et al. (1977). This model separates observed production outcomes into deterministic and stochastic components, allowing for the analysis of technical efficiency (TE) while accounting for statistical noise, measurement errors, and random shocks beyond the farmer's control.

The Cobb-Douglas production function was chosen for its simplicity (Coelli, 1995). While the Translog production function offers greater flexibility, it presents significant estimation challenges, particularly as the number of variable inputs increases, leading to a rise in the number of parameters to be estimated (España et al., 2024).

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The production function is specified as:

$$\ln(Y_i) = \beta_0 + \beta_1 \ln X_{1i} + \beta_2 \ln X_{2i} + \beta_3 \ln X_{3i} + \beta_4 \ln X_{4i} + e_i (V_1 - \mu_i) \quad \text{(Eq. 1)}$$

Where:

ln = denotes natural logarithm

Y_i = Output of banana Bungulan (kg/ha) of the i^{th} farm

X_1 = quantity of hired labor input in Man/Days per hectare of the i^{th} farm

X_2 = quantity of family labor input in Man/Days per hectare of the i^{th} farm

X_3 = quantity of suckers in pieces per hectare of the i^{th} farm

X_4 = quantity fertilizer input in kilograms per hectare of the i^{th} farm

X_5 = farm size (m^2) of the i^{th} farm

e_i = is composed of disturbance term made up of two elements (V_1- μ_i)

V_1 = random error (white noise), it accounts for the stochastic effects beyond the farmer's control such as (weather, pest, and diseases)

μ_i = non-negative random variable called inefficiency effects

Following Battese and Coelli (1988), the technical inefficiency model is specified as:

$$u_i = \delta_0 + \sum_{i=1}^{9} (\delta_i Z_i + V_i) \quad \text{(Eq. 2)}$$

u_i = is the technical inefficiency of the i^{th} 'Bungulan' banana farm and is assumed to be a function of farm-specific socio-economic and farm management practices.

δ_0 = is the intercept term of technical inefficiency model.

$\delta_{0,,,,}$ δ_9 = are the coefficient of parameter estimates of the technical inefficiency variables.

Z_i = stand for vectors of the farmer specific variables that affect the technical efficiency of the ith 'Bungulan' banana farmers such as age, highest educational attainment, household size, farmer's attended training, extension contacts, distance of farm to market or packing house, farm size, and sex in birth dummy (1-male, 0-otherwise).

The study employs a single-step estimation approach to simultaneously estimate the extent of technical inefficiency and identify the factors affecting it. This approach integrates both stochastic and inefficiency effects for a more comprehensive understanding of TE.

Technical Efficiency (TE) is calculated as the ratio between actual output (Y) and maximum potential output (Y*).

The formula used is: $TE = \frac{Y}{Y*}$ (Eq. 3)

Alternatively, Technical Inefficiency (TIE) is calculated as: $TE = 1 - TIE$ (Eq. 4)

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Based on past research, the final model is specified as, (Eq. 5):

$$\ln output\ of\ 'Bungulan' = \beta_0 + \beta_1 \ln hired\ labor + \beta_2 \ln family\ labor + \beta_3 \ln suckers + \beta_4 \ln organic\ fertilizer + vi + \delta_1\ age + \delta_2\ education + \delta_3\ farming\ experience + \delta_4\ HH\ size + \delta_5\ training + \delta_6\ extension\ contact + \delta_7\ distance + \delta_8\ farm\ size + \delta_9\ sex + u_i$$

3.7 Hypothesis of the study

Null Hypothesis (H_0): $H_0: \delta_1 = \delta_2 = \delta_3 = \ldots = \delta_9 = 0$ (Eq. 5)

Socio-economic and farm management variables do not significantly affect technical inefficiency (u_i), suggesting all farmers operate at full efficiency.

Alternative Hypothesis (H_1): $H_1: \exists \delta_1 \neq 0$ (Eq. 6)

Technical inefficiencies (u_i) exist among farms, significantly influenced by age, education, experience, household size, training, extension services, farm size, market distance, and gender.

3.8 Statistical Validations and Robustness Checks

The study employed various tests to ensure unbiased estimates and assess sampling errors. The VIF test confirmed no multicollinearity issues, with values below 10 (detailed in Table 8). A heteroskedasticity test verified model robustness and outlier absence. The data was manually edited, coded, and analyzed using Microsoft Excel, Frontier 4.1c, IBM SPSS 25, and STATA 13.

3.9 Ethical Considerations

The researcher adhered to the Data Privacy Act (Republic Act No. 10173), obtaining all necessary permits and approvals. Informed consent was secured, with clear explanations of the study's purpose and voluntary nature. Confidentiality, anonymity, and cultural sensitivity were emphasized, ensuring ethical conduct and participant respect throughout the study.

4.0 RESULTS AND DISCUSSIONS

This chapter exhibits the socio-demographic and farm profile, technical efficiency levels, and factors affecting technical efficiency of 'Bungulan' banana farms in the Cotabato region. This section also presents the interpretation of the data and described logically through tables and figures.

4.1 Socio-demographic and farm profile of 'Bungulan' farmers

Knowing the backgrounds and farming conditions of banana Bungulan farmers is important for creating helpful farming policies and support. This section looks at the farmers' ages, education levels, farm sizes, and the resources they have access to. By examining these factors, we can learn more about the challenges and opportunities they face. This information will help in planning strategies to improve productivity, sustainability, and the overall economic health of farmers in the Cotabato region.

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4.2 Socio-demographic profile of 'Bungulan' farmers

The data from Table 4 presents a comprehensive overview of the socio-demographic characteristics of 'Bungulan' banana farmers in Cotabato for 2024. The average farmer is 46.75 years old, indicating a mature farming population that may be slower to adopt new techniques. Males dominate the farming community, with a sex ratio of 0.85. Educational attainment is relatively high, with most farmers having at least a high school education, potentially aiding better farm management. Household sizes average 3.99 members, impacting labor availability. Off-farm income varies widely, averaging 10,471.46 pesos, reflecting diverse economic conditions among the farmers. This significant variability indicates diverse economic conditions among the 'Bungulan' banana farmers in the area of study, which could affect their ability to invest in farm improvements.

Table 4: Descriptive statistics of Socio-demographic characteristics and farm profile of 'Bungulan' banana farmers in Cotabato, 2024

Variables	F (N=182)	Mean	Std. Deviation	Min.	Max.
Age		46.75	12.655	22	85
Sex in birth		0.85	0.3564	0	1
Male	150				
Female	32				
Highest Educational attainment		4.36	1.479	1	6
Elementary Level	6				
Elementary Graduate	20				
High School Level	22				
High School Graduate	48				
College Level	27				
College Graduate	59				
Elementary Level	6				
Household Size (No.)		3.99	2.042	1	14
Off-Farm income (Pesos)		10,471.46	10, 644.55	1, 000	90, 000

Source: Author's calculations using IBM SPSS Statistics 25, 2024

4.3 'Bungulan' banana farmers' farm profile

Table 5 outlines the profile of 'Bungulan' banana farmers, highlighting their relatively short experience in farming this variety, with an average of 4.69 years. The average distance from farms to packing houses is 26,718.06 meters, posing logistical challenges that may affect banana quality. Farmers attended an average of 3.91 training sessions, and technicians visited farms an average of 4.55 times, reflecting engagement in extension services crucial for improving practices. The average farm size for 'Bungulan' bananas is 0.5411 hectares, with most farmers operating small to medium-sized farms. Land access varies, with most farmers inheriting their land, which impacts farm stability and long-term planning.

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Table 5: Farm profile of 'Bungulan' banana farmers in Cotabato, 2024

Variables	F (N=182)	Mean	*SD*	Min.	Max.
Years in 'Bungulan' Farming (No.)		4.69	2.556	3	12
Distance of farm to packing house (Meters)		26718.06	36161.537	300	150000
Number of Trainings attended		3.9066	1.54386	2.00	8.00
Number of Visits by DA/Don Bosco Agents		4.5495	1.22374	0.00	11.00
Access to land		1.7692	0.97569	1.00	4.00
Inherited	105				
Bought	28				
Free Access	49				

Source: Author's calculations using IBM SPSS Statistics 25, 2024

4.4 Resource use per hectare of banana Bungulan farms

Table 6 provides an overview of resource use per hectare in 'Bungulan' banana production across Cotabato for 2024. The average yield is 7,558.59 kg/ha, with significant variability indicating differences in farm productivity, possibly due to varying management practices and input access. Hired labor averages 12.97 workers/ha, while family labor averages 41.97 workers/ha, highlighting the critical role of family involvement. Farmers plant an average of 797.50 suckers/ha, with diverse planting densities observed. Organic fertilizer use is inconsistent, averaging 223.46 kg/ha, pointing to a need for increased education on its benefits. The data suggests that enhancing labor efficiency, improving input use, and disseminating best practices could significantly boost productivity and sustainability in 'Bungulan' banana farming.

Table 6: Resource use per hectare in 'Bungulan' banana in selected municipalities of Cotabato, 2024

Variables	*Mean*	*SD*	*Min.*	*Max.*
'Bungulan' Production (Kg/ha)	7558.59	4725.93	297.00	28020.00
Number of Hired labor	12.97	16.50	0.00	69.00
Number of Family Labor	41.97	28.56	0.00	92.00
Number of Bungulan Suckers (pcs/ha.)	797.50	209.33	100.00	1300.00
Quantity of Organic Fertilizer (Kg/ha)	223.46	1550.09	0.00	20000.00

Source: Author's calculations using IBM SPSS Statistics 25, 2024

4.5 Technical Efficiency of 'Bungulan' banana Farms

Data from Table 7 on the technical efficiency (TE) of 'Bungulan' banana farms in Cotabato for 2024 show significant variation. Nearly 44% of farms have a TE below 0.50, with 22.53% falling below 0.30, indicating challenges such as limited resources and outdated techniques. In contrast, 33.52% of farms exhibit moderate efficiency (TE 0.81-0.90), but only 3.30% achieve near-optimal efficiency (>0.90), revealing substantial potential for improvement. The least efficient farms have an average TE of 0.0230, while the most efficient average 0.9588, highlighting notable productivity disparities. These findings suggest the need for targeted interventions, including training in modern farming techniques, better resource access, and infrastructure improvements. Policymakers and agricultural extension services should focus on

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advancing technology and management practices to boost overall efficiency and productivity.

Previous research presents mixed views on efficiency. Masterson (2005) found smaller farms more efficient than larger ones, while Yusuf and Malomo (2007) saw high efficiency among large farms. Mohammed (2018) reported efficiency ranging from 20% to 87%, with an average of 61%. Other studies underscore the importance of input optimization and technical efficiency in enhancing small-scale banana farming.

Table 7: Overall technical efficiency level of 'Bungulan' banana farms in Cotabato, 2024

Range of technical efficiency distribution	Number of 'Bungulan' banana farmers	Percentage of 'Bungulan' banana farms
< 0.30	41	22.53
0.30-0.40	39	21.43
0.41-0.50	15	8.24
0.51-0.60	9	4.95
0.61-0.70	5	2.75
0.71-0.80	6	3.30
0.81-0.90	61	33.52
>0.90	6	3.30
Efficiency level of the least efficient farms	0.0230	
Efficiency level of the average efficient farms	0.5461	
Efficiency level of the most efficient farms	0.9588	

Source: Author's calculations using Frontier 4.1c (Coelli, 1996) and IBM SPSS Statistics 25, 2024

4.6 Determinants of technical efficiency

The technical efficiency of 'Bungulan' banana farmers in the Cotabato Region was analyzed using a Cobb-Douglas production function, with the estimation conducted through Maximum Likelihood Estimates (MLE) using Frontier 4.1 software. The study identified several key factors influencing technical efficiency and inefficiency among these farmers, providing insights that align with or challenge existing literature on agricultural productivity.

4.6.1 Key Findings on Production Factors

The study revealed in Table 8 that the production of 'Bungulan' bananas (measured in kg/ha) significantly impacts technical efficiency, with a coefficient of 3.7614644, highly significant at the 1% level. This finding suggests that increased banana production is strongly associated with enhanced technical efficiency, supporting previous studies by Coelli (1996) and Kumbhakar & Lovell (2003). Therefore, efforts to boost production levels are likely to improve efficiency.

Hired Labor ($\ln X_1$)*:* Hired labor per hectare showed no significant effect on technical efficiency, contrary to Amaza et al. (2006), who found a positive impact of hired labor on efficiency.

Family Labor ($\ln X_2$): Family labor significantly improves production efficiency at the 10% level, aligning with Bezu & Holden (2010) and Bravo-Ureta & Pinheiro (1997). Studies like Arigor et al. (2022) also highlight the effectiveness of household labor over hired labor,

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especially in remote areas like Cotabato.

Planting Materials (lnX_3): Quality planting materials per hectare significantly boost technical efficiency, as shown by the 1% significance level, consistent with findings from Arti and Leua (2022) and Robinson and Sauco (2010).

Organic Fertilizers (lnX_4): Organic fertilizers had no significant impact on technical efficiency currently, but studies by Hung et al. (2022) and Vinayagamoorthi et al. (2019) suggest that increased usage could enhance productivity, highlighting potential benefits from optimized application.

4.6.2 Perceptions from the Inefficiency Model

The inefficiency model explored various factors potentially contributing to inefficiency among 'Bungulan' banana farmers:

Age (Z_1): The farmer's age did not significantly impact inefficiency, differing from Arti and Leua (2022) and Mohammed (2018) who found younger farmers face resource constraints, while Seok et al. (2018) noted age-related efficiency decline.

Education (Z_2): Education level had no significant impact on inefficiency, unlike Arti and Leua (2022) who found educated farmers more efficient. This suggests education's impact on efficiency can vary by context.

Farming Experience (Z_3): The farming experience of 'Bungulan' banana growers was not a significant determinant of efficiency. This finding is supported by Kumbhakar et al. (2015), who argued that experience alone does not guarantee efficiency.

Household Size (Z_4): Household size did not significantly influence inefficiency, aligning with the findings of Arigor et al. (2022), who reported that larger households might reduce efficiency. However, some studies suggest that household size could increase efficiency if members are of working age and contribute to farm labor.

Trainings Attended (Z_5): Attending training programs showed a positive coefficient, suggesting increased inefficiency, possibly due to reduced farm operation time. However, Van Hung et al. (2022) highlight training's positive impact on efficiency through valuable skill and knowledge acquisition.

Extension Contacts (Z_6): Regular contact with extension agents significantly reduced inefficiency, highlighting the importance of advisory services in improving farm management and productivity. This finding is consistent with Arti and Leua (2022) and Amaza (2006), who emphasized the role of extension services in enhancing technical efficiency.

Proximity to Market (Z_7): Closer proximity to markets was associated with reduced inefficiency, suggesting that access to markets improves efficiency by providing better opportunities for resource access and information exchange. This aligns with the findings of Gautam et al. (2012), but Hung et al. (2022) cautioned that proximity alone might not guarantee efficiency if farmers reside far from their fields.

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Farm Size (Z_8): Larger farm sizes were associated with increased inefficiency, contradicting the findings of some studies, such as Arti and Leua (2022), which suggested that larger farms could be more efficient. The negative relationship observed in this study might reflect challenges associated with managing larger farms in the specific context of Cotabato.

Sex in birth (Z_9): The gender of farmers significantly influenced inefficiency, with male farmers being less inefficient than female farmers. This result is aligned with Omondi et al. (2020), who also found gender-related differences in inefficiency levels.

The significant σ^2 and γ values confirm inefficiency in the production process, validating the stochastic frontier model's fit. Targeted interventions—improving planting materials, optimizing family labor, enhancing training, and developing infrastructure—are recommended. These aligned with literature on human capital and market access, potentially boosting banana farmers' efficiency and productivity.

Table 8: Stochastic production frontier estimates for technical efficiency and inefficiency of 'Bungulan' banana farms in Cotabato, 2024

Variables and Parameters		Coefficient	Standard-error	t-ratio	VIF
Stochastic Frontier					
Bungulan production in kg/ha (ln$Y$)	β_0	3.7614644***	0.7309547	5.1459606	
Hired labor in MD/ha (lnX_1)	β_1	0.000358	0.0034078	0.1049196	2.09
Family labor in MD/ha (ln X_2)	β_2	0.012635*	0.0065791	1.9205321	3.20
Bungulan planting materials pcs/ha (ln X_3)	β_3	0.858832 ***	0.1132242	7.5852351	1.25
Organic fertilizers in kg/ha (ln X_4)	β_4	0.001324	0.0037403	0.3540520	4.65
Inefficiency Model					
Constant	δ_0	1.603334*	0.8566993	1.8715247	
Farmer's Age in years (lnZ_1)	δ_1	-0.009398	0.0094205	-0.997594	1.17
Education Level (ln Z_2)	δ_2	-0.028905	0.0809325	-0.357144	1.11
Bungulan Farming experience in years (ln Z_3)	δ_3	-0.023729	0.0469988	-0.504882	1.49
Household size (ln Z_4)	δ_4	0.046310	0.0562100	0.8238775	1.07
Trainings attended (ln Z_5)	δ_5	0.204077***	0.0761596	2.6795951	1.22
Extension contacts (ln Z_6)	δ_6	-0.262952 **	0.1076371	-2.442950	1.53
Proximity in meters from farm to packing house (ln Z_7)	δ_7	-0.000024 **	0.0000097	-2.491837	1.26
Farm size in hectare/s (ln Z_8)	δ_8	0.420738***	0.1161116	3.6235688	6.39
Sex in birth: 1- Male, 0-otherwise (ln Z_9)	δ_9	-0.588240 **	0.2664890	-2.207371	1.05
Sigma squared	σ^2	0.902268***	0.2576111	3.5024410	
Gamma	Γ	0.982632***	0.0098106	100.16036	
LR test of the one-sided error		69.1168			
log likelihood function		-132.2688			

Source: Author's calculations using Frontier 4.1c (Coelli, 1996) and Stata 13, 2024 for VIF

*** indicates significant at 1% (z value =/> 2.576), ** indicates significant at 5% (z value =1.960 <2.576),

* indicates significant at 10% (z value = 1.645 <1.960)

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4.8 Challenges in 'Bungulan' banana farming

The Table 9 in this study highlights the primary challenges faced by 'Bungulan' banana farmers, with adverse weather conditions being the most significant, affecting 79.25% of farmers. These climatic challenges, including droughts and landslides, demand robust support systems to mitigate their impact, echoing the findings of Lobell et al. (2008). The second major issue, reported by 69.81% of farmers, is pests and diseases, which lower crop yields and increase costs, aligning with Kumar and Omkar (2018). In contrast, the least reported challenges include the lack of government intervention (0.94%) and limited expansion area (2.83%). Addressing these issues through improved market access, pest management, and infrastructure investment is essential for boosting productivity and sustainability, as supported by Pingali (2007) and Sachs (2012). This multifaceted approach can enhance agricultural productivity, contributing to food security and economic stability (Hazell et al., 2010).

Table 9: Reasons that hindered 'Bungulan' banana farmers' goal to achieve optimum production in Cotabato, 2024

Statement	Frequency (F=106)	Cumulative percent (%)	Garette's Rank
Bad weather: Long dry spells and droughts, Strong winds during thunderstorms, and Landslides caused by too much precipitation in short periods.	84	79.25	1
Pests and diseases.	74	69.81	2
Distance to market.	49	46.23	3
Lack of resources to develop their farms (seedlings/ plantlets and organic inputs).	31	29.25	4
Threat of contamination from conventional farms using chemicals and pesticides.	30	28.30	5
Low soil fertility.	25	23.58	6
Absence of farm-to-market roads and shared service facility /vehicle/zipline for products.	24	22.64	7
Shortage of labor.	23	21.70	8
Low market price.	20	18.87	9
Lack of area for expansion.	3	2.83	10
Lack of government intervention.	1	0.94	11

*Multiple response**

Source: Author's calculations using IBM SPSS Statistics 25, 2024

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study on 'Bungulan' banana farmers in Cotabato highlights significant challenges affecting technical efficiency. Adverse weather impacts 79.25% of farmers, and pests and diseases affect 69.81%. Market access issues affect 46.23%, underscoring the need for better infrastructure. Key interventions include improving access to quality planting materials, optimizing family labor, and expanding training and extension services. Addressing these challenges could boost

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technical efficiency by up to 20%, enhancing productivity and sustainability. These findings are vital for stakeholders aiming to improve agricultural productivity and economic stability in Cotabato.

5.2 Recommendations

To address the issues, it is recommended to enhance training programs, improve infrastructure, and promote efficient use of fertilizers and labor-saving technologies. Support financial stability, secure land tenure, and invest in pest management and high-quality planting materials. Farmers should adopt best practices, while advocates promote Integrated Pest Management (IPM) and sustainable methods. Local governments should invest in infrastructure and support services, and policymakers should implement supportive policies to boost productivity and living standards.

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Biographical Sketch

The author is born on November 16, 1983, in President Roxas, Cotabato, she is the youngest child of Mr. Cresencio S. Lupas Sr. and Mrs. Petra P. Lupas. Starting her education early, she completed kindergarten and graduated from Antipas High School in March 2000.

She pursued Bachelor of Science in Agribusiness at Cotabato Foundation College of Science and Technology (CFCST) and graduated on March 31, 2005. Her professional career began in Davao City as a cashier and encoder at Park N' Shop - Supermarket, then promoted to purchasing assistant in four (4) months. She then worked as an administrative assistant at JDM 88 Agro-Ventures until December 2013.

Her job career in CFCST started in March 2015 as a job order clerk at graduate school office. While working, she earned a Master of Science in Agriculture and passed the Licensure Examination in Agriculture. She was then appointed as an Instructor I in Agribusiness Department in August 2017, and now pursuing Doctor of Philosophy in Agricultural Economics as a CHED-SIKAP grantee.

She is married to Romeo C. Pedroso Jr. and has three children: Bella Meroz (14), Bliss Marionette (11), and Romeo III (10).

Disclosure Statement

We, **MAYBELYN L. PEDROSO** and **LOWELLA R. ANGCOS**, hereby disclosed that we have no financial or personal conflicts of interest related to this research. We have no affiliations, financial interests, or personal relationships that could be perceived as influencing the outcome of this study. Our research and findings are conducted with impartiality and integrity, with the sole aim of contributing to the advancement of knowledge in the field. Any support or funding received for this study has been disclosed in the acknowledgements section of the research.

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