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CHALLENGES OF LARGE-SCALE FARMING IN THE MERAUKE FOOD ESTATE: A COMPARISON WITH SMALL-SCALE FARMERS

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ABSTRACT

The Merauke Food Estate Programme invited large-scale agricultural companies to develop food crop farming in Eastern Indonesia, and XYZ Company (XYZ) is the only company involved in the programme. Unfortunately, the cultivated land area has slowly declined, low productivity, and the company is operating on a thin margin. This study sought to identify the cost structure of agricultural companies and small-scale farmers, analyze the rice farming of agricultural company and small-scale farmers and estimate the factors influencing the productivity of small-scale farmers. This research was conducted from May 2023 to March 2024. The methodologies employed were statistical descriptive analysis, financial analysis during the wet and dry seasons, and multiple linear regression. The company's input costs were higher due to the use of non-subsidised inputs than the small-scale farmer. The use of non-subsidised input for large companies was mandatory from the Indonesian government. The company earned profits of IDR 403,982 per hectare during the wet season and IDR 564,298 per hectare during the dry season. The small-scale farmers earned nine times more than the company. The influencing factors of productivity in small-scale farming were water irrigation, liquid and solid pesticides, labor, and the social factors were farmer experience and age. The food estate programme in Merauke was more suitable for small-scale farmers than large-scale companies. For increased productivity, small-scale farmers should be provided with adequate agricultural technologies, inputs, loans, and output insurance.

Key words: contractual farmer, cost structure, productivity, profitability, ridge regression

INTRODUCTION

Large-scale agricultural enterprises emerged in the 16th century, often linked to forced labor and slavery, and expanded rapidly post-colonialism to meet rising food demands. Max Weber (1950) identified a shift from traditional to rationalized, capitalist-driven farming, a transformation still debated today. Traditional agriculture prioritizes employment and livelihoods, whereas modern agriculture emphasizes efficiency, mechanization, and profit maximization (Zuo et al. 2015). Technological advancements, particularly in Asia and Africa, have reshaped farming, with mechanization reducing labor needs and cutting costs. In Africa, large-scale plantations support regional economies but often create economic and social enclaves, limiting integration with local communities (Hall et al. 2017). While such plantations in Ghana have facilitated capital accumulation and strengthened economic linkages, these have also reinforced rural elite structures and posed challenges to agrarian accessibility (Hall et al. 2017). In Indonesia, large-scale agriculture dates back to the colonial era when Dutch-owned plantations produced tea, sugarcane, rubber, and cloves before being nationalized. While these plantations focused on perennial crops requiring high capital investment, large-scale cultivation of annual food crops only emerged in the 1950s, with the Green Revolution, leading to rice self-sufficiency. Initially aimed at empowering local farmers rather than corporations, large-scale food crop agriculture under corporate management gained prominence only with the introduction of the food estate program.

The Indonesian government defines the food estate (FE) programme as a large-scale agricultural enterprise covering a minimum land area of 25 hectares that operates under the “agriculture-as-an-industrial-system” concept, involving scientific and technological support, capital investment, and modern organisation and management (Badan Litbang Pertanian 2011). This concept emerged in response to the global food crisis and addresses the government's responsibility to achieve the second Sustainable Development Goal (SDG), which aims to end hunger. The output of agricultural products must consistently rise to meet the growing global demand for food (Syaukat 2024). The government has limited financial capacity to support large-scale agricultural development, the involvement of private investors in these programs is essential. The FE is concentrated in areas outside Java, where land is extensively available.

The Indonesian government has implemented several FE programmes in various regions outside Java, including Kalimantan, Sumatra, and Papua since 1995. The food estate programme has been implemented in Merauke since 2006. This programme was designed to accommodate not only food crops but also palm oil commodities for renewable energy. However, food crops have struggled to attract investors due to their underdevelopment compared to the palm oil sector. The XYZ Company began investing in food crops with a concession area of 237,000 hectares, allocating 4,000 hectares for industrial forests and 1,000 hectares for food crop cultivation in 2015. The technology developed is an irrigation system utilizing biomass fuel, which is more energy- and cost-efficient. This irrigation system enables farmers to access water during the dry season, thereby increasing the cropping index to three plantings per year.

According to national rice productivity data, the average yield is 5.25 tonnes per hectare (Ihsan et al. 2020). In comparison, small-scale farmers in Merauke achieve a productivity level of 4.79 tonnes per hectare, while large-scale farming by XYZ Company yields only 1.75 tonnes per hectare (Table 1). These figures indicate that large-scale agriculture under corporate management performs significantly below both the national average and small-scale farming in Merauke. This presents a critical challenge, as the Food Estate Program relies on large-scale corporate agriculture to address food security concerns.

Table 1. Company vs small-scale farmer productivity from 2017 to 2023.

Year	Total area (Ha)	Company yield (kg/ha)	Small-scale farmer yield* (kg/ha)
2017	700.00	1,476.52	3,900.00
2018	400.37	1,609.83	5,280.00
2019	309.18	2,465.11	5,570.00
2020	526.78	2,676.52	5,590.00

Year	Total area (Ha)	Company yield (kg/ha)	Small-scale farmer yield* (kg/ha)
2021	330.19	1,735.33	5,670.00
2022	318.08	981.09	4,010.00
2023	222.69	1,303.00	N/A
Average	401.04	1,749.63	4,798.57

Source: XYZ Company's report (2024); * District Malind and Kurik in Figure (2018-2023)

There is a consistent decline in the cultivated land area managed by the company each planting year (Table 1). The productivity reached its lowest level in seven years due to a prolonged wet season, which led to severe flooding of rice fields, exacerbated by high pest infestations and plant diseases in 2022. Additionally, the number of agricultural staff has decreased steadily over the years. As a result, rice cultivation is no longer the company's core business. The company cultivated only six hectares of land for rice production, with all yields allocated to covering land rent payments to customary rights holders in 2024.

According to previous studies, the determinant factors that influences the productivity of rice are the availability of irrigation water, the quantity of seeds, fertilizers, and pesticides employed significantly affect the amount of rice produced. Additionally, labor and agricultural machines used for harvesting and drying are also important in rice production (Belenehu et al. 2021; Kumalasari 2018; Subagio et al. 2019; Tou 2017). Social factors influencing productivity are age, farming experience, and educational level (Tou 2017). In this study, the influence factor responsible for increasing the productivity of small-scale farmers was examined. These key factors would be adopted in large-scale farming systems.

The study sought to identify the cost structure of agricultural companies and small-scale farmers, analyze rice farming business in both agricultural companies and small-scale farms, and estimate the factors influencing the productivity of small-scale farmers. The findings from this analysis will provide recommendations for improving the development of rice cultivation in large-scale agricultural enterprises and identifying strategic advantages that the company can leverage to achieve long-term success within the Merauke Food Estate Program.

RESEARCH METHODOLOGY

Data types and sources. Data collection was conducted for ten months, from May 2023 to March 2024, during the wet and dry seasons, because productivity and cost structure differ between the two seasons. The research was conducted in the XYZ Company concession location in Kurik District, Merauke Regency. A group of small-scale farmers living in outside of company concession and Malind District, a neighboring district.

This research used primary data for quantitative analyses. Primary data were obtained from interviews with the following respondent: 1) XYZ Company representative and agricultural staff; 2) Representative of contract farmer as respondents was set at a minimum of 30% of the total contract farmers, with 17 farmers available and willing to be interviewed; and 3) The small-scale farmer representatives in Kurik and Malind Districts were selected using combination of probability and non probability sampling. The non-probability sampling used quota sampling based on the population in the targeted district. The population of farmer in Kurik District is 2419 families and Malind is 919 families. The quota determined 60 respondents in Kurik and 40 for Malind District, the total number of respondents is 100 families. The distribution of respondents in each village was determined using the proportional random sampling method. However, from 100 data only 78 farmers' data were deemed suitable for analysis due to missing data. The interviews were guided by a structured questionnaire. The data collected from the respondents included milled rice production, rice production, total input and input costs (fertilizers, pesticides, land rental, irrigation), and farmers' demographic data (age, education level, farming experience, and household size).

Data analysis. All the costs of farmer-*i*, namely the total input cost (TC_i) consist of total fixed cost (TFC_i) and total variable cost (TVC_i) of farmer-*i*. The total fixed cost (TFC) consists of land rent and the depreciation of agricultural machines, meanwhile, the variable cost (TVC) includes seeds, fertilizer, pesticides, labor, fuel, equipment rent, milling, and drying. The total cost of farmer-*i* was calculated as follows:

$$TC_i = TFC_i + TVC_i \tag{1}$$

After calculated the total cost of farmer-*i*, the revenue of farmer (TR_i) estimated followed by formula (2). Where P_i is the rice price for each respondent (Rp/kg), Q_i is the quantity of rice produced (kg).

$$TR_i = Q_i * P_i \tag{2}$$

The profitability was computed using the formula below, where π_i is the net profit of rice farmer per hectare and calculated as follows:

$$\pi_i = TR_i - TC_i \tag{3}$$

The feasibility of an agricultural business can also be seen from the RCR (total revenue and total cost ratio) and π/TC value as in the following formula (Kay et al. 2012):

$$RCR_i = \frac{R_i}{C_i} \tag{4}$$

$$\pi/C_i = \frac{\pi_i}{C_i} \tag{5}$$

Where π/TC is ratio profit and total cost. Productivity is derived from rice milled produce of farmer-*i* divided by the cultivated land. The formula for productivity is in the following formula:

$$\frac{Y}{L} = \frac{Y_i}{L_i} \tag{6}$$

Where Y/L is the productivity of the respondent (kg/ha), Y_i is the yield of milled rice per kilogram and L_i is cultivated area of farmer-*i* (ha).

In this research, the factors that influenced the productivity of independent farmers were determined using multiple linear regression with standard equations like the following formula (Gujarati and Porter 2009):

$$Y_i = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + b_9X_9 + b_{10}X_{10} + b_{11}X_{11} + b_{12}X_{12} + U_i \tag{7}$$

where Y_i is productivity of respondent (kg per hectare), X_i denotes as farm input variables, X_1 = water irrigation (m^3), X_2 = seed (kg per hectare), X_3 = urea fertilizer (kg per hectare), X_4 = Phonska fertilizer (kg per hectare), and X_5 = liquid pesticide (ml per hectare), X_6 = solid pesticide (gr per ha), X_7 = treatment activity (man working days), X_8 = harvesting machines (hours), and X_9 = drying machines (hours), variables social-economic i.e $X_{10} =$ age (years), $X_{11} =$ education (years), X_{12} = farming experience (years). In addition, a represents a constant or intercept, $b_1 \dots b_{12}$ denotes the coefficients of the independent variables, and U_i is the error term.

The model is initially subjected to classical assumption tests to ensure that the parameter values are unbiased, linear, and has minimum variance among various potential estimators. This classical assumption tests encompass linearity, normality, heteroscedasticity, and multicollinearity. If there is multicollinearity, the model will employ ridge regression. Ridge regression effectively addresses the problem of multicollinearity (Hoerl 2020; Hoerl and Kennard 1970). Ridge regression modifies ordinary least squares (OLS) by introducing a regularization term as a penalty. This penalty was the sum of the squares of the model coefficients, as described in the following formula:

$$L2 = \|b\|^2 = b_1{}^2 + b_2{}^2 + b_3{}^2 + b_4{}^2 + b_5{}^2 + b_6{}^2 + b_7{}^2 + b_8{}^2 + b_9{}^2 + b_{10}{}^2 + b_{11}{}^2 + b_{12}{}^2 + U_i \quad (8)$$

Where $L2$ penalty is sum of the squares function, $b_1 \dots b_{12}$ denotes the estimator of the independent variables, which produces a new formula, the ridge regression estimator. Within it, the effect on the model is controlled by the hyperparameter lambda (ƛ):

$$RSS_{L2} = \sum_{i=1}^{n}(Y_i - \bar{Y})^2 + ƛ\sum_{j=1}^{n} b_j^2 \quad (9)$$

Where RSS_{L2} is new residual sum square with L2 penalty, Y_i is productivity farmer- i, and Ȳ is average of rice productivity, ƛ is hypermeter lambda as regulatization which implemented in the model and b_j is estimator for independent variable from 1 to j. In ridge regression, integrated hypermeter lambda to the RSS formula using L2 penalty term neutralizes excessively high coefficients by decreasing the values of all coefficient. In statistics, this phenomenon is known as coefficient shrinkage. Consequently, the ridge regression estimator computes new regression coefficients that lower the RSS of a given model. This process minimizes the influence of each predictor and alleviates the risk of overfitting or multicollinearity in the data. The model function was run using R studio.

RESULTS AND DISCUSSION

Identification of the cost structure of agricultural companies and small-scale farmers. XYZ Company commenced the cultivation of 1,000 hectares of land for paddy fields, employing a full workforce. The cost structure of rice farming was primarily comprised of production inputs such as seeds, fertilizers, pesticides, fuel, labor, land rent and output (Table 2). Despite employing the same cultivation techniques, small-scale farmers use fewer inputs than the company, except for fertilizers and fuel, which are subsidized by the government.

Table 2. Average of input, output and cost input of XYZ Company vs small-scale farmer, Wet season, 2024.

Input variable		Average Input-Output		Average cost (Rp/ha)	
		Small-scale	Company	Small-scale	Company
Seeds	kg/ha	67.47	75.00	8,091.00	15,000.00
Urea fertilizer	kg/ha	167.00	158.00	2,351.00	14,000.00
NPK fertilizer	kg/ha	155.00	134.00	2,295.00	14,000.00
Liquid pesticides	ml/ha	2,212.00	2,500.00	385.00	638.00
Granule pesticides	gram/ha	913.00	500.00	219.00	664.00
Fuel	liter/ha	56.00	25.00	13,797.00	20,000.00

Input variable		Average Input-Output		Average cost (Rp/ha)	
		Small-scale	Company	Small-scale	Company
Labor	Man days	27.36	53.67	150,000.00	160,000.00
Land rent	Rp/Ha	3.16	37.12	50,000.00	740,000.00
Yield (wet paddy)	kg/ha	3,917.86	3,193.00	11,000.00	11,000.00

Seed usage. The company uses a higher seed rate per hectare due to replanting to replace non-germinated seeds, whereas small-scale farmers rarely replant. Due to a lack of subsidised seeds, almost 80% of small-scale farmers used seeds from the previous harvest. Seeds derived from previous harvests tend to produce lower yields than green label seeds (F1/derivative 1). Farmers are strongly advised to use certified seeds to increase productivity. The company buys seeds from outside (Java Island), which is priced higher than from the local market. The company has standards for using superior and certified seeds so that purchases are made directly from seed suppliers in Java Island.

Fertilizer and pesticide use. Small-scale farmers use more fertilizers than the company. Fertilization is conducted twice over a single growing season: once when the rice reaches the age of 25–30 days and again at 45–50 days. Small-scale farmers use subsidised urea and NPK fertilizer that is 6 times cheaper than non-subsidized. When it comes to pest and disease management, there are significant differences in treatment depending on the type of pest or disease. The government does not subsidise for all type of pesticides. The company tends to spend more on these inputs than small-scale farmers, as it uses more varied products at specific dosages tailored to the type of pest. Small-scale farmers prefer to choose the granule pesticides because the price is cheaper than liquid pesticides. Sometimes small-scale farmers mix various types of pesticide brands to enhance its effectiveness, while companies prioritize the accuracy of dosages according to the specifications of the brands used.

Fuel. Farmers use fuel for mobilization of agricultural machinery. Smallholders use more fuel because hand tractors of the two-wheel type and small water pumps, 3-inch for irrigation, are used. The use of hand tractors for land cultivation consumes more fuel than 4-wheel tractors. In addition, the 3-inch water pump consumes more fuel and time than the 4/6 inches. Fuel is an agricultural input that receives subsidies from the government. The price of fuel for small-scale farmers has been added to the cost of oil for every liter of fuel used. The company uses less fuel because it uses a 4-wheel tractor and new technology water pumps for irrigation with biomass fuel, which is more cost-effective.

Labor allocation is higher in the company, as employees follow standard office hours, whereas small-scale farmers adjust their working hours based on field treatment needs. Labor wages in the company are higher due to the inclusion of income tax. Even though company labor expends more working hours at higher pay, some research in developing nations stated that family labor in small-scale farming is more productive than paid labor in agricultural companies. Smallholders often have greater yields than large-scale farming due to incentive compatibility (Akter et al. 2019; Chhom et al. 2023; Otsuka et al. 2016). Small scale-farms are generally more labor-intensive, whereas large farms tend to be more capital-intensive. In this context, a sense of belonging to the farmland is one of the key factors contributing to labor productivity in small-scale agriculture.

Land rental. The cultivated land area for small-scale farmers ranges from 0.375 to 10 hectares, with an average of 2 hectares per farmer. On average, small-scale farmers achieve higher rice yields than the company. Small-scale farmers are required to pay land rental fees to the government, known as *pajak lahan sawah* (land tax), though the amount is lower than that paid by the company. In contrast, the company must compensate landowners in addition to paying land rental fees. The company is obligated to provide 20 kg of rice and IDR500,000 rupiahs per harvested hectare as compensation. Both the company and small-scale farmers sell their rice to nearby rice mills, resulting in the same selling price of IDR11,000/kg at the time of the study.

Yield. Small-scale farmers produce higher yields compared to large-scale. These findings contribute to previous literature related to inverse relationship between farm size and productivity, particularly in developing countries (Verschelde et al. 2011; Munyanga and Jayne 2019; Sheng et al. 2019). This phenomenon is that smallholders tend to be more efficient in their use of labor. Economically, the principle of diminishing returns to inputs implies that smallholders typically intensify their input use on scarce land, whereas large-scale farms may experience declining marginal productivity if input use does not increase proportionally with land size. A study on the relationship between farm size and productivity in Burundi, found strong inverse relationship for farms between 0 and 3 hectares. For medium-sized farms (3–5 hectares), the relationship was relatively flat. However, for farms between 20 and 70 hectares, the relationship became strongly positive, indicating that larger farms were more productive. This relative productivity advantage of large-scale farms was largely attributed to differences in mechanization choices, which substantially reduced labor input per hectare (Munyanga and Jayne 2019).

Cost structures. The results of the input-output performance of small-scale rice farmers and companies were then processed to illustrate the cost structure of each stage of rice cultivation during the wet and dry seasons (Table 3).

Land preparation of small-scale farmers typically rent four-wheel tractor under a contract system for tilling and harrowing. On the contrary, the company uses its own four-wheeled tractors for tillage and only fuel and labor costs to cover. The company use non-subsidised industrial fuel, which is three times more expensive than the subsidised fuel. Labour costs are based on the regional minimum wage (UMR) standards, resulting in greater labour costs per workday. Overall, the technological and resource advantages give the company a greater efficiency in terms of cultivation per hectare.

The financing structures for irrigation during the dry season and the wet season differ greatly between the company and small-scale farmers. Small-scale farmers have to spend more on irrigation due to the higher fuel cost involved to channel water from the primary drainage. The company, on the other hand, uses biomass-fueled technology, which is 26 times cheaper than the irrigation system applied by small-scale farmers.

There are no differences in the use of seeds and fertilizers during the dry season and the wet season between the company and small-scale farmers. However, the expenditures on pest and disease control differ between the two seasons. Due to fewer pest attacks, smaller quantities of pesticides are used during the dry season compared to the wet season, with small-scale farmers using slightly more presticides than the company. Despite less usage of pesticides, the company's overall cost is 22% higher than the cost borne by small-scale farmers.

For harvesting, company and small-scale farmers utilize combine harvesting machine. Due to the damage of harvesting machine of company at the time of data collection, the company rented these machines from local farmers. The rental cost, which includes both fuel and labor, ranges from 1,300,000 to 1,800,000.00 rupiah per hectare. Additionally, there are variations in the costs associated with transporting harvested grains from the fields to the drying location. Farmers who own tractors equipped with bedding for harvested grains, including both the company and small-scale farmers, can manage transportation independently. Conversely, those lacking such transportation must rely on external services, which charge between IDR8,000 and 10,000 per bag of paddy, resulting in significantly higher overall transportation costs.

Table 3. The cost structures of XYZ Company vs small-scale farmers during the dry and wet seasons in 2023.

Step	Unit	Wet season		Dry season	
		Company	**Small-scale**	**Company**	**Small-scale**
Land Preparation					
1. Land rent	Rp/ha	370,000	25,000	370,000	25,000
2. Irrigation cost	Rp/ha	10,220	827,820	30,660	1,034,775
3. Plowing/harrowing	Rp/ha	400,000	717,444	400,000	717,444
4. Labor	Rp/mandays	480,000	750,000	320,000	750,000
Seedling management					
1. Seed	Rp/ha	1,125,000	545,900	1,125,000	509,733
2. Labor, planting	Rp/mandays	160,000	150,000	160,000	150,000
3. Labor, replanting	Rp/mandays	160,000	150,000	160,000	150,000
Fertilizer application					
1. Urea	Rp/ha	2,223,480	720,063	2,100,000	392,617
2. NPK	Rp/ha	1,881,320	714,937	1,820,000	355,725
3. Labor	Rp/mandays	320,000	300,000	320,000	300,000
Treatment					
1. Liquid pesticides	Rp/ha	1,595,000	1,793,240	1,276,000	851,620
2. Granule pesticide	Rp/ha	332,000	339,894	232,400	199,947
3. Labor	Rp/mandays	1,280,000	1,200,000	960,000	900,000
Yield costs					
1. Harvester rent	Rp/ha	1,600,000	1,600,000	1,600,000	1,600,000
2. Transportation	Rp/ha	100,000	137,970	80,000	965,790
3. Dryer (electric)	Rp/ha	214,620	940,284	124,620	840,000
4. Rice mill (10:1)	Rp/ha	1,284,000	1,527,037	1,324,125	1,404,375
5. Depreciation cost	Rp/season	183,333	387,614	183,333	387,614
Total cost		**13,720,018**	**12,842,205**	**12,676,952**	**11,534,640**

Source: Research findings

Regardless of the weather, for the drying process, the company uses bed dryers, which enable a faster drying process and better-quality dried products compared to manual sun-drying. Currently, this technology is available at most rice mills, allowing its adoption by many small-scale farmers. The drying service is priced using a 15:1 paddy split system, starting from IDR12,000 per bag of grain, a rate the company could afford more cheaply than small-scale farmers. However, the company does not have a rice mill. Although it has intended to seek collaboration with rice mill operators, nothing has been realised as of now. Therefore, the company currently mills the harvest at the nearest private mill, which charges a 10:1 fee, or one sack of rice for every ten sacks produced.

However, with an average milled rice production lower than small-scale productivity, this company proved to be economically unfeasible. Furthermore, it faced the challenge of repeatedly processing and tilling the land to enhance soil nutrient content and reduce acidity, as newly cleared land requires substantial treatment. In order to sustain its operations amid these losses, the company established contractual agreements with neighboring farmers in 2017. Under this arrangement, contract farmers were allowed to cultivate land within the company's concession area through a rental system. Profit sharing was established at 14% for the company and 86% for the contract farmers.

During the wet season, the farming expenditure is 6% higher for the company than for small-scale farmers. If small-scale farmers use the same technology as the company, their costs could be reduced by 20%, saving IDR10,293,112.00. This would enable small-scale farmers to operate with less capital for every hectare and earn more profits. Therefore, farmers are encouraged to expand their cultivated land to capitalise on this potential. However, small-scale farmers have limited access to financial support, and some become trapped in debt to landlords with an unfair deal. According to research on small family farms in Indonesia, many small-scale farmers are constrained to prepare for self-investment and often sacrifice because of basic needs expenses like health or education (Purnawan et al. 2020). Integrated policies are needed to improve access to financial services such as mobile banking, savings incentives, low-cost credit, and insurance, which can help reduce financial risks and facilitate long-term investments.

The challenges faced by XYZ Company highlight the difficulties of large-scale food crop farming in Indonesia, particularly in Merauke. Small-scale farmers have a deeper understanding of their land's conditions, cultivated through years of hands-on experience. For these farmers, agriculture is fundamentally intertwined with their way of life, and they are generally reluctant to change professions, regardless of the complex challenges they may face or the profitability of their farming practice. Small-scale agriculture in Merauke is quite dynamic and able to compete with large-scale companies. This is evident from the enthusiastic response of farmers to the offer to become a partner farmer of the company. Like small farming in Africa, these are excellent in productivity because of their size, and are very dynamic, so they do not need to be an obstacle to agricultural growth (Rada and Fuglie 2019).

In contrast, large-scale agricultural companies prioritize generating profits every season, which introduces a distinct set of challenges. However, these companies also play a positive role in fostering technological advancements and modernizing agricultural practices, thereby enhancing knowledge and techniques in seasonal crop farming. There is a highly insightful lesson learned from the Bonanza farms of the Northern Great Plains in the United States. These large-scale agricultural enterprises, which thrived in the 1800s, were ultimately dismantled and fragmented into smaller units through the land market. Large-scale farming enterprises are often considered a solution to the lack of infrastructure, technology, and financial access. However, only small newly established agricultural companies manage to survive beyond five years, even in well-established industries (Deininger and Byerlee 2012). The key challenges include unproven technology, weak institutional frameworks, high market barriers, and price risks, which frequently force companies to exit the agricultural sector or undergo restructuring (Deininger and Byerlee 2012). The XYZ company has managed to sustain itself due to several key factors. First, it maintains partnerships with farmers who continue cultivating crops on company-owned land. Second, the close relationship between the company's leadership and local government officials has enabled its operations to continue despite the absence of profits. Third, the company remains committed to conducting research through pilot cultivation of diverse plant varieties that can yield profits. Lastly, the company benefits from other profitable ventures, such as biomass power plants (PLTBM) and industrial forest plantations (HTI), which operate under the same corporate umbrella.

Agricultural development has primarily focused on scale enlargement, driven by central government policies and national food security agendas. Theoretically, increasing land area can enhance productivity and technical efficiency; however, large-scale farming is also vulnerable to market dependency and price volatility, particularly due to market deregulation and reduced input price support for producers. Crop diversification has been proposed as a solution to improve the sustainability of large-scale farming (Roest et al. 2018). By utilizing the same inputs, diversification can generate a variety of agricultural products, thereby increasing profitability. However, this approach requires new skills in cultivation, marketing, and the development of well-defined supply chains (Roest et al. 2018). This strategy has been implemented by XYZ company through seed cultivation and pilot projects citronella cultivation to meet market demands and explore sustainable and resilient models for large-scale agriculture.

Rice farming business of agricultural companies and small-scale farms. There is a difference in production yields and farming business between the company and small-scale farmers in both the dry and the wet season (Table 4). The company yielded 1.2 – 2.6 tonnes of milled rice per hectare over the research period, while independent farmers produced 1.4 – 3.5 tonnes.

Table 4. The production and profitability of company and small-scale farmers during the dry and wet seasons in 2023-2024.

Step	Unit	Rainy Season		Dry Season	
		Large-scale	Small-scale	Large-scale	Small-scale
Total Cost	Rp/ha	13,720,018.33	12,842,211.39	12,676,952.33	11,534,640.48
Production	kg	3,200.00	3,917.86	3,000.00	3,500.00
Losses harvested paddy*	kg	2,560.00	3,134.29	2,407.50	2,808.75
Losses milled dry paddy**	kg	1,280.00	1,567.14	1,203.75	1,404.38
Revenue***	Rp/ha	14,080,000.00	17,238,584.00	13,241,250.00	15,448,125.00
Profit	Rp/ha	359,981.67	4,396,372.61	564,297.67	3,913,484.52
R/C		1.03	1.34	1.04	1.34
π/C		0.03	0.34	0.04	0.34

Notes: *conversion rate of 80,025% based on BPS (2018); **conversion rate of 50% based on research findings (2023); ***rice price of Rp11,000/kg based on local market price in research period (2023)

Although the disparity in TC was not overly significant, based on the cost structure stated that the company accrued significantly lower profits than small-scale farmers. The R/C ratio values are above 1, which means business farming is economically feasible. For instance, small-scale farmers during the wet season achieved a revenue return of 1.34 times their costs. The results of this research are broadly consistent with previous farming studies conducted in the same region. In Semangga District, Merauke Regency, which reported an R/C ratio of 1.81 (Widyantari et al. 2022). When compared with rice farming businesses in production centers such as Cianjur and Karawang, West Java, the business feasibility in Merauke shows comparable results, with R/C ratios of 1.80 in Cianjur, 1.86 in Karawang, and 1.75 in Merauke (Agnesti et al. 2023; Kamil et al. 2023; Khairunisa et al. 2024).

In the context of rice farming in Bangladesh for small-scale farms, the benefit-cost (B/C) ratio is 1.15 (Rahaman et al. 2022), while in Cambodia, the B/C ratio for medium-large scale (2-5 hectares) farms is 2.08 and for large-scale (above 5 hectares) farms is 1.74 (Chhom et al. 2023). This research found the R/C ratio for small-scale farmers to be larger than large-scale farms. Although the findings of this study indicate a greater income ratio in small-scale agriculture, there are instances, such as among small-scale farmers in Bangladesh, where the decline in profitability per hectare is more pronounced and these farmers are more vulnerable to rising input costs, including labor wages, fertilizers, and irrigation (Mottaleb and Mohanty 2015). A study conducted in Ebonyi State, Nigeria, reveals that while rice production is profitable, there is no significant difference in net income between small-scale and large-scale farmers. However, labor costs constitute a major component of total variable costs and are higher in large-scale farming. This study suggests that the equitable distribution of agricultural inputs could enhance output and income for farmers (Ohajianya and Onyenweaku 2003).

The cultivation area is not a crucial factor for achieving high profitability. Small-scale farmer has obstacles to maximizing the land area. According to field data from questionnaires, each farmer could only manage a maximum of around 5–10 hectares with the technology available. In addition, small-scale farmers also face limitations in capital and access to adequate and affordable agricultural inputs. Many small-scale farmers struggle to expand their farming cultivation due to the limited availability of subsidised fertilizers. Using non-subsidised fertilizers would consume a significant portion of their capital, which they often prioritise for pesticides and other inputs. On the contrary, the company has sufficient capital and technology to manage farming cultivation across a more extensive area and thus overcome these constraints.

The Indonesian regulatory framework stipulates that corporations engaged in agriculture must use non-subsidised input, resulting in higher input costs than small-scale farmers. This policy may discourage other companies involved in the farming business. The compensation and land rental fees that the company must pay to landowners become the total fixed cost for the company. Consequently, the company shifted its focus from food crop cultivation to other types of business.

Productivity in agriculture is significantly influenced by the nutrient content of the soil, which indicates land fertility. According to geomorphological research in Merauke, layers of pyrite and plinthite in certain areas are toxic and reduce soil fertility. To address this issue, it is essential to construct irrigation channels in a way that avoids disturbing the pyrite layer to prevent increased soil acidity. Fertilizer application should also avoid contacting the plinthite layer to ensure efficiency and prevent groundwater contamination (Sartohadi et al. 2015). Furthermore, a land suitability survey indicates that the agricultural land in Merauke falls into classes S2 and S3, suggesting it is moderately suitable for rice cultivation, with limiting factors such as nutrient availability, water supply, nutrient retention, and root media. Therefore, measures must be taken to enhance the land to a highly suitable class (S1) (FEB-Universitas Gajah Mada 2015).

Land productivity varies between different regions within a company's concession area. The company needs to conduct a comprehensive evaluation of the entire area to identify the most suitable locations for planting. Research and the implementation of appropriate cultivation techniques are crucial for ensuring high adaptability. Furthermore, the success of agricultural endeavors is influenced by factors such as farming experience and orientation. Establishing a strong connection between humans and nature is particularly challenging within the context of rice cultivation enterprises.

Determinants of rice productivity of small-scale farms. Factors that influence farming productivity are estimated based on several variables, including input usage and farmer skills. In this research, the determinant of the rice farming productivity model is estimated by testing 12 independent variables using multiple linear regression.

The calculated significance values and coefficients of determination can be seen in Table 5. The model explains 83,45% of the variability in the data, while the remaining 16,55% is attributable to other variables not included in the model. The model is valid with a 99% confidence interval, in accordance with the theory. The Variance Inflation Factor (VIF) variable was 3,17, which indicated no multicollinearity because the variable was under <5. The significant variables were age, farmer experience, water irrigation, liquid and solid pesticides, and labor.

The age variable has a negative coefficient, indicating that productivity increases with younger age farmers. The findings of this study contradict several studies that state older farmers possess more experience in managing their farming business, thereby enhancing rice production (Basriwijaya and Pratomo 2016; Salam et al. 2024; Siagian 2020). In fact, younger farmers, with their strong physical capabilities, cognitive skills, and willingness to take risks in farm management, are better positioned to adopt new technologies, enabling them to increase rice production.

Farmer experience is a significant social factor that enhances rice productivity in small-scale agriculture in Merauke. The theory of improving human resource quality and farmer experience highlights their importance in increasing productivity. The findings of this study align with research on the influence of capital, farming experience, and education on the increase in rice productivity in Gianyar, Bali (Wirayuda and Arka 2024). With extensive farming experience, farmers understand characteristics of paddy, soil types and their management, as well as weather patterns to predict pests, plant diseases, and the effects on plant growth.

Table 5. Results of econometric analysis.

Explanatory variables	Coefficients	Significance
Intercept	-2,611.29***	0.002
Seed (kg/ha)	7.86684	0.174384
Irigation (m^3/ha)	0.50525***	2E-16
Urea fertilizer (kg/ha)	0.9846	0.439033
NPK fertilizer (kg/ha)	0,77665	0.259006
Granule pesticide (gr/ha)	0.25646***	0.000938
Liquid pesticide (ml/ha)	0.2241***	0.001391
Labor (Man working days)	69.7828***	2.51E-09
Harvesting (hours)	139.9075	0.073244
Drying (hours)	39.65099	0.211798
Age (years)	-4.3442***	0.00037
Education (years of schooling)	58.9026	0.85392
Farmer experience (years)	43.9515***	9.09E-12
F-value	374.5***	2.2E-16
Adjusted R-squared	0.8345	

Notes: ***significant at 99% confidence level

From the input, this research finds that irrigation, pesticides and labor significantly contribute to increasing productivity. The research aligns with the findings from several studies indicating that the factors significantly influencing rice productivity include urea and NPK fertilizers, pesticides, labor, and farmer age (Salam et al. 2024; Siagian 2020; Sonawane et al. 2016). Pesticides represent a crucial input for farmers, accounting for 33% of agricultural input costs within the cost structure. The estimated values for liquid and solid pesticides are 0.25 and 0.22, respectively. This indicates that to achieve a 1-unit increase in rice production, 0.25 and 0.22 units of pesticides are required. Although these coefficient values are relatively small, these variables significantly increase rice productivity.

Irrigation water is used as a variable because rice farming requires water, especially during its early growth stages. When the rice vegetative phase does not receive sufficient water, its growth will be hindered. An earlier study found that the amount of water applied significantly and meaningfully affects rice production in Pakistan (Shah et al. 2020).

The coefficient of labor is the highest among the significant independent variables, the most important variable for increasing rice productivity. The production of 1 kg of rice requires 69-man day hours (HOK), assuming other variables remain constant (ceteris paribus). The magnitude of the coefficient is positive, meaning that an increase in labor will enhance productivity. This aligns with the findings of previous studies (Belenehu et al. 2021; Neonbota and Kuneb 2016; Salam et al. 2024; Tou 2017) that demonstrate a positive and significant variable of labor. However, the sum of labor requires consideration, as excessive labor may increase production costs and reduce profits, recognizing that there is also a limit to labor's efficient capacity.

Social factors that statistically influence the increase in rice productivity in small-scale agriculture include age and farmer experience. These social factors are what large-scale need in rice cultivation to enhance their productivity. Companies must still learn to understand land conditions, interpret weather patterns, study the growth characteristics of rice, and consider other social factors to improve their productivity. This process requires a long-term commitment. Meanwhile, the company needs sufficient capital to manage fixed and total costs to continue paddy cultivation throughout the year planting. Although significant variable inputs such as irrigation water, pesticides, and labor can be managed by the company, factors such as work experience and the duration of farming cultivation are also essential for the company to enhance productivity.

The debate between small- and large-scale farming continues, but in the context of Indonesia as a developing country, small-scale farming for food crops has been proven to generate economic benefits, enhance farmers' well-being, support local communities, and contribute to regional development. Small-scale agriculture in Indonesia cannot be replaced by large agribusiness companies for food crop commodities. Indonesia's success during the Green Revolution demonstrated the sustainability of small-scale farming; however, improvements are still needed to mitigate the economic risks faced by small-scale farmers. The government should provide a specific program (policy) and facilitate the farmers to adopt technologies, especially in postharvest, to reduce paddy loss and increase productivity. These could include the use of a combined harvester, a flat bed drier for drying, and technology in rice milling (Falatehan et al. 2021). Studies on small family farms in Indonesia suggest three key strategies for enhancing farmer welfare. The first strategy involves ensuring access to financial services, market linkages, and public goods such as water management, technology, soil conservation, and social protection. Supporting small family farms through research and extension services to enhance resilience, provide appropriate technology, strengthen farmer organizations, and foster collaboration with national and international market actors comprises the second strategy. While investing beyond the farm by promoting rural non-farm economic activities and territorial development would be the third strategy (Purnawan et al. 2020).

CONCLUSION

Large-scale agricultural companies tend to spend more than independent farmers during both the wet and dry seasons. The differences in cost structures are attributed to variances in input costs and technology. On the other hand, independent farmers achieve greater income levels due to higher productivity. This productivity differential is likely due to land conditions, the differing ways in which farmers and the company manage the crops. The input variables that increase productivity significantly were pesticides, labor, and water irrigation. Independent farmers' productivity is influenced significantly by farmer age and experience. It is suggested that adequate technological support and secure availability of affordable inputs could help improve future food estate initiatives and ensure reliable downstream agricultural outputs.

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