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Determinants of Farm Commercialization in Tidal Wetland Rice Farming

Dina Omayani Dewi^{1,2*}, Rita Nurmalina², Netti Tinaprilla², Saptana¹

¹ National Research and Innovation Agency, Jakarta 12970, Indonesia

² Department of Agribusiness, Faculty of Economics and Management, IPB University, Bogor 16680, Indonesia

ABSTRACT

Tidal lowlands are increasingly promoted for rice production in Indonesia in response to rising food demand and limited availability of suitable agricultural land. However, rice farming in these environments is characterized by unstable water regimes, high production risk, and weak market integration, which often limit farmers' transition from subsistence to commercial production despite increased use of modern inputs. This study examines the level and determinants of rice farming commercialization in the tidal lowlands of Sambas Regency, West Kalimantan, Indonesia, with explicit attention to agroecological risk. Primary data were collected through structured interviews with 143 rice farmers operating under different tidal overflow conditions. Commercialization is analyzed using multiple indicators capturing output sales, input market engagement, and cash income, and their determinants are examined using ordinary least squares (OLS) regression. The results indicate that rice farming in the study area is evolving toward semi-commercial systems, marked by strong integration into input markets but limited output commercialization and cash income. Tidal overflow conditions significantly shape commercialization outcomes, highlighting the role of agroecological risk in constraining surplus generation. Larger farm size, higher education levels, and the adoption of standard operating procedures (SOPs) are associated with stronger market participation, while higher household consumption needs and access to credit are negatively related to output sales and farm cash income, suggesting that credit is frequently used for consumption smoothing rather than productive in-

*CORRESPONDING AUTHOR:

Dina Omayani Dewi, National Research and Innovation Agency, Jakarta 12970, Indonesia; Department of Agribusiness, Faculty of Economics and Management, IPB University, Bogor 16680, Indonesia; Email: malyaputri@yahoo.com

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vestment. Overall, the findings reveal a segmented commercialization pathway in tidal rice systems and underscore the need for risk-reducing water management, improved farmer capacity, and better-targeted rural credit to support sustainable commercialization in tidal lowland agriculture.

Keywords: Tidal Wetlands; Rice Commercialization; Farm Product Sold Ratio; Input Market Integration; Semi-Commercial Farming; Credit Utilization; Land Management; Technology Adoption

1. Introduction

Tidal lowlands are increasingly recognized as strategic areas for expanding rice production, particularly in countries facing rising food demand and limited availability of suitable agricultural land. In Indonesia, these areas hold significant potential, yet rice farming in tidal environments remains challenging. Periodic tidal fluctuations, salinity, and nutrient variability create unstable production conditions and expose farmers to high levels of risk. These ecological constraints strongly influence farmers' decisions regarding input use, production intensity, and market participation^[1, 2].

At the same time, growing population pressure and food security concerns have renewed policy interest in improving productivity and commercialization in tidal lowlands. Commercialization, defined as the share of agricultural output sold relative to that consumed by the household, is shaped by a complex interaction of household characteristics, farm assets, technology adoption, and environmental conditions. Larger farm size and better access to physical assets generally increase farmers' ability to generate surplus for sale, while higher household consumption needs and risk aversion often reduce market participation^[3, 4].

Access to credit and financial services can support commercialization by enabling investment in productive inputs, but its impact depends largely on how credit is used. When loans are diverted toward household consumption rather than farming activities, their contribution to commercialization may be limited^[5, 6]. Similarly, poor market access and weak transportation infrastructure raise transaction costs and discourage farmers from selling larger volumes of output. In contrast, adaptive technologies, improved farm management practices, effective extension services, and supportive institutions can reduce production risks and strengthen farmers' en-

gagement with markets^[7, 8]. In tidal rice systems, however, high production uncertainty often leads farmers to prioritize household food security over market sales. Understanding how ecological risk, household behavior, and institutional conditions jointly shape commercialization decisions is therefore essential for designing effective policies in these marginal farming environments^[9, 10].

This study contributes to the commercialization literature by applying a multidimensional approach to commercialization analysis in a high-risk tidal wetland rice system. Unlike most previous studies that rely on a single output-based indicator and assume relatively stable agroecological conditions, this research examines commercialization through multiple dimensions—output sales, input market engagement, and cash income—within an environment characterized by persistent production risk. By doing so, the study highlights segmented commercialization pathways in which increased input and labor market participation do not necessarily translate into higher output commercialization. This approach provides new insights into how agroecological risk reshapes farmer behavior and challenges conventional assumptions about linear transitions from subsistence to commercial farming.

1.1. Research Gap

Despite a large body of literature on smallholder agricultural commercialization, empirical evidence from tidal lowland rice systems remains limited. Most studies focus on farming systems with relatively stable agroecological conditions, such as irrigated or upland areas, while the specific challenges of tidal environments are often overlooked. As a result, the role of hydrological instability and tidal overflow characteristics in shaping commercialization outcomes is not well understood.

In addition, existing studies commonly measure commercialization using a single indicator, usually the proportion of output sold, without capturing its multi-dimensional nature. This approach fails to explain situations where farmers intensify production through increased use of purchased inputs and labor but continue to sell only a small share of their output. Such a mismatch between input intensification and output commercialization is particularly relevant in high-risk tidal agroecosystems but has received little empirical attention.

Furthermore, while factors such as farm size, household consumption, credit access, technology adoption, and market access have been widely studied, their combined effects under different tidal overflow conditions have rarely been examined. In particular, the role of credit use—whether for productive investment or household consumption—and the effectiveness of adaptive technologies and institutional support in promoting commercialization in tidal rice farming remain insufficiently explored.

This study addresses these gaps by applying a multi-dimensional commercialization framework and explicitly integrating agroecological, household, market, and institutional factors in a high-risk tidal lowland context.

1.2. Research Objectives

Based on the identified gaps, this study aims to:

1. To examine the level of commercialization by considering a range of interrelated factors, including tidal land ecological conditions, household characteristics, access to assets and markets, and institutional support.
2. To identify the key drivers of commercialization and to develop policy recommendations tailored to local conditions.
3. To find out the strategies that increase the share of production marketed in tidal areas.

1.3. Theoretical Framework

This study is grounded in established theories of smallholder behavior and agricultural commercializa-

tion, while extending these frameworks to account for the distinctive and high-risk conditions of tidal wetland rice systems. Conventional analyses of commercialization are primarily informed by agricultural household models^[11], transaction cost economics, and market participation and commercialization pathway theory^[12, 13]. Together, these perspectives generally predict that improved access to land, inputs, credit, technology, and markets enables farmers to generate surplus production and increase output sales. Implicit in these models, however, is the assumption of relatively stable production environments, where risks are manageable and returns to market participation are sufficiently predictable.

Tidal wetland agriculture departs fundamentally from these assumptions. Rice farming in tidal environments is characterized by frequent flooding, unstable water regimes, soil acidity, and substantial yield variability, all of which introduce high and often covariate production risks. From the perspective of risk and uncertainty theory^[14], farmers operating under such conditions behave rationally by prioritizing food security and income smoothing over profit maximization. In this context, production decisions are closely linked to household consumption needs, consistent with the predictions of agricultural household models under imperfect markets. As a result, even when farmers adopt modern inputs or improved practices, often as a means of reducing production risk rather than expanding output, they may deliberately limit market sales to safeguard household food consumption.

Transaction cost economics provides further insight into why output commercialization remains limited despite increased engagement with input markets. In tidal wetland systems, variability in output quantity and quality increases marketing risk and raises implicit transaction costs associated with selling rice. Poor infrastructure, reliance on intermediary traders, weak contract enforcement, and informal credit arrangements further discourage farmers from committing a larger share of production to the market. These conditions reinforce conservative marketing behavior and are consistent with theories of imperfect markets and credit fungibility, where access to finance does not necessarily trans-

late into productive investment or higher commercialization outcomes.

The study also draws on commercialization pathway theory, which conceptualizes commercialization as a gradual and non-linear process rather than a uniform transition from subsistence to market-oriented farming^[12, 13]. In high-risk agroecological settings such as tidal wetlands, commercialization may occur selectively across different dimensions. Farmers may become increasingly integrated into input and labor markets while remaining weakly connected to output markets. This perspective is particularly relevant for explaining the frequently observed mismatch between high purchased input cost ratios and relatively low levels of output sales and cash income in tidal rice systems.

Building on these theoretical foundations, the present study applies Wharton commercialization indices within a risk-sensitive analytical framework. Rather than treating these indices as purely descriptive measures, the study employs them to examine how agroecological risk, household consumption pressures, institutional constraints, and farm management practices jointly shape multiple dimensions of commercialization. In doing so, the analysis extends classical commercialization theory by demonstrating that, under conditions of structural production risk, increased intensification does not automatically lead to higher output commercialization.

The theoretical contribution of this study lies in showing that tidal wetland rice systems require a modified commercialization framework, one that explicitly integrates agroecological risk, household risk-management behavior, and imperfect markets to accurately explain commercialization outcomes in marginal farming environments. This integrated framework provides a stronger conceptual basis for interpreting the empirical results and for designing policies aimed at promoting sustainable and context-appropriate commercialization in tidal lowland agriculture.

2. Materials and Methods

This research was carried out between June and September 2025 in Sambas Regency, West Kalimantan,

Indonesia. The study focused on rice farmers cultivating tidal lands with different overflow typologies (A, B, C, and D). A cluster random sampling approach was used, resulting in a total of 143 farmer respondents. Data were collected through structured interviews using a questionnaire, complemented by direct field observations.

This study is based on primary data collected from 143 rice farmers cultivating tidal lowland areas in Sambas Regency, West Kalimantan. The respondents were distributed across four tidal overflow typologies (A, B, C, and D), representing different levels of hydrological stability and production risk. The distribution of respondents across overflow types reflects the dominant land typologies in the study area, ensuring representation of varying agroecological conditions.

The study is based on cross-sectional data and incorporates both qualitative and quantitative information. Qualitative data capture descriptive aspects that cannot be expressed numerically, while quantitative data consist of measurable variables. Both primary and secondary data sources were used in the analysis.

2.1. Analysis Method of Commercialization Index

Commercialization is one aspect of assessing the level of farmer market participation, which is measured using a commercialization index. The determination of commercialization indicators for farming is measured using the criteria for measuring the level of commercialization according to Miriti and Lambarraa-Lehnhardt^[15], namely:

- **Farm Product Sold Ratio (FPSR)**

Measures the share of farm output that is marketed.

$$\text{FPSR} = \frac{\text{Value of Farm Products Sold}}{\text{Total Value of Farm Products Produced}} \times 100\%$$

- **Labor Cost Ratio (LCR)**

Measures the dependence on hired labor, indicating commercialization and market integration.

$$\text{LCR} = \frac{\text{Cost of Hired Labor}}{\text{Total Labor Cost (Family + Hired Labor)}} \times 100\%$$

- **Purchased Input Cost Ratio (PICR)**

Measures reliance on market-purchased inputs rather than traditional or family-supplied inputs.

$$\text{PICR} = \frac{\text{Cost of Purchased Inputs}}{\text{Total Input Cost}} \times 100\%$$

- **Farm Cash Income Ratio (FCIR)**

The Farm Cash Income Ratio (FCIR) measures the proportion of a farm household's total income that comes from cash earnings from farming.

$$\text{FCIR} = \frac{\text{Cash Income from Farming}}{\text{Total Household Income}} \times 100\%$$

The criteria for the level of farmer market participation from the commercialization index are divided into four categories^[15], where: if the ratio value is <25: subsistence farming; $25 \leq x < 50$: semi-subsistence farming; $50 \leq x < 75$: semi-commercial farming; and ≥ 75 : commercial farming

2.2. Analysis Method of Factors Determining Commercialization

This study was conducted using quantitative methods. Quantitative methods are data analysis methods using multiple linear regression analysis with the STATA program, namely by analyzing the extent of the influence of independent variables on dependent variables. To determine the factors that influence commercialization, linear regression with the OLS Regression Model (Linear Model) was used. The mathematical model is as follows:

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \dots + \beta_{10} X_{10} + \beta_{11} X_{11} + \epsilon_i$$

Where: Y_i = commercialization; β intercept; ϵ_i = error term; X_1 = Overflow type; X_2 = Farm size; X_3 = Off-farm; X_4 = Market distance; X_5 = Credit access; X_6 = Household consumption; X_7 = Education; X_8 = Experience; X_9 = SOP implementation; X_{10} = Extension Intensity; X_{11} = Risk preference.

Ordinary Least Squares (OLS) is used to identify relationships in the context of limited cross-sectional data.

3. Results

3.1. Characteristics of Survey Respondents

The analysis is based on primary survey data obtained from 143 rice farmers operating in tidal lowland areas of Sambas Regency, West Kalimantan, Indonesia. The sample encompasses farmers across four tidal overflow typologies (A, B, C, and D), reflecting differences in hydrological regimes, soil characteristics, and exposure to production risk. By covering all overflow categories, the study captures the ecological diversity inherent in tidal wetland rice farming systems.

The average age of respondents was approximately 17–72 years, indicating that rice farming in tidal environments is predominantly managed by economically active adults, with a significant presence of middle-aged and older farmers. The mean farming experience was 22 years, suggesting substantial accumulated knowledge in coping with fluctuating water regimes and soil constraints typical of tidal ecosystems. In contrast, the average level of formal education was 8 years of schooling, reflecting a moderate human capital endowment. Educational attainment is particularly relevant in this context, as it may influence farmers' capacity to adopt improved technologies, implement recommended management practices, and respond to market signals.

Regarding farm structure, the average cultivated rice area was 0.5 ha, confirming the predominance of smallholder production systems. Landholding size varied across overflow typologies, with relatively larger farms more frequently observed in areas characterized by more stable hydrological conditions, while smaller plots were common in higher risk zones. Such differences in land endowment are likely to affect production capacity, risk absorption, and surplus generation.

Rice farming constituted the primary livelihood source for most respondents. Nevertheless, a proportion of households engaged in off-farm activities as a strategy to diversify income and mitigate production risk. Access to agricultural credit was reported by 50% of farmers. However, qualitative evidence indicates that credit was not exclusively allocated to productive farm investment but was also used for household consumption.

tion smoothing, particularly during periods of yield instability or crop loss. Agricultural extension services were available in the study area, although the frequency and intensity of extension contact varied considerably among respondents, potentially influencing technology adoption and farm performance.

Average annual household consumption expenditure was approximately 16,000,000 IDR, reflecting modest income levels and a strong orientation toward household food security. Risk preference assessments indicate that most farmers exhibit risk-averse behavior, which is consistent with the high level of production uncertainty inherent in tidal lowland agriculture.

Overall, the sample represents small to medium-scale rice producers operating under heterogeneous agroecological and institutional conditions. Variation in demographic characteristics, asset ownership, market access, and risk exposure provides an essential contextual foundation for interpreting the commercialization indices and regression results. These structural and socioeconomic attributes jointly shape farmers' mar-

ket participation decisions and commercialization pathways in tidal wetland rice systems.

3.2. Commercialization Indexes

The commercialization indexes of rice farming on tidal land in Sambas Regency indicate a transitional phase from subsistence to semi-commercial systems. The farm product sold ratio (FPSR) ranges from 11.78% to 48.23%, revealing that most farmers remain semi-subsistence, particularly those in type D overflow areas who largely consume their own output (**Figure 1**). Previous studies show that these farming systems are typically marked by low levels of product sales and limited cash income, as production is largely oriented toward meeting household needs rather than supplying the market^[16-18]. A labor cost ratio (LCR) of 25–33% indicates a moderate level of engagement with the labor market, which aligns with findings that semi-commercial farms depend mainly on family labor and employ hired workers only during peak farming periods^[19,20].

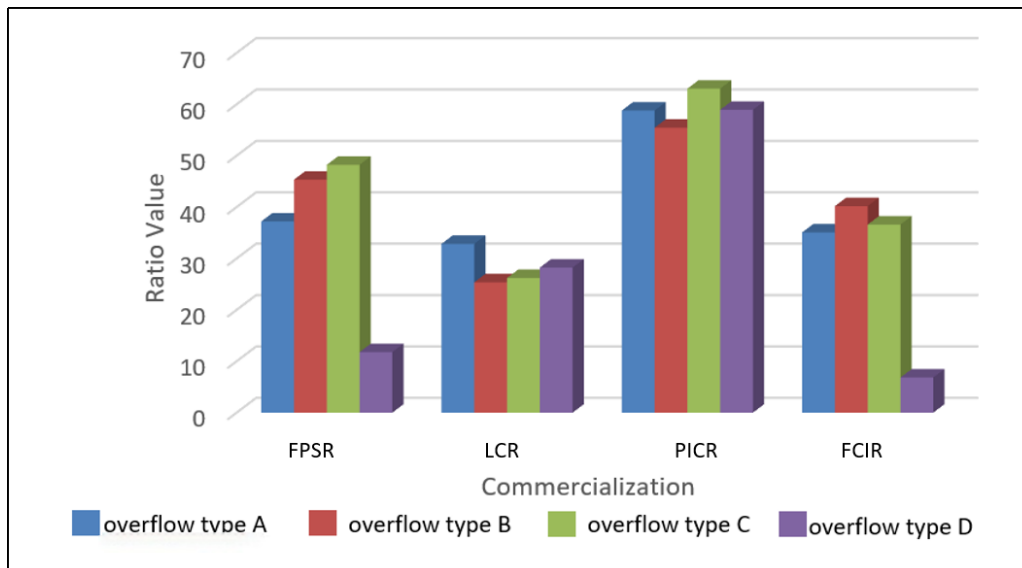


Figure 1. Distribution of Farm Commercialization Indicators across Tidal Overflow Types in West Kalimantan, Indonesia.

By contrast, the relatively high purchased input cost ratio (PICR) of 55–63% points to strong engagement with input markets, driven by the adoption of modern farming technologies—often well before full integration into output markets occurs^[21]. This mismatch between input use and output sales is common

in smallholder systems operating in high-risk environments, where market barriers, limited liquidity, and production uncertainty reduce farmers' willingness to sell produce despite using improved technologies^[22]. As a result, the low farm cash income ratio (FCIR), ranging from 6.84% to 40.19%, reflects constrained market

participation and a continued emphasis on household-oriented production. Overall, while rice farmers in the tidal areas of Sambas Regency are increasingly adopting commercial inputs, their production decisions remain largely focused on securing household food needs rather than maximizing marketable surplus.

3.3. Factors Determining the Commercialization Index

3.3.1. Farm Product Sold Ratio (FPSR)

The regression results indicate that the model is statistically significant ($F(11,131) = 6.93$; $p < 0.001$),

suggesting that the explanatory variables, taken together, have a meaningful influence on the farm product sold ratio (FPSR). The model accounts for 36.77% of the variation in FPSR, while the remaining variation reflects factors not captured in the analysis (**Table 1**). The overflow type has a negative and statistically significant effect on FPSR ($\beta = -6.81$; $p = 0.013$), indicating that less favorable overflow conditions are associated with lower levels of commercialization. In contrast, farm size shows a positive and significant relationship with FPSR ($\beta = 27.96$; $p < 0.01$), implying that farmers with larger landholdings are linked to higher market participation.

Table 1. Determinants of the Farm Product Sold Ratio (FPSR) in Tidal Land Rice Farming in West Kalimantan, 2025.

Parameter	Coefficient	Standard Error	Z	$p > z $
FPSR				
Intercept	20.6224	14.8873	1.39	0.168
Overflow Type	-6.8062***	2.6914	-2.53	0.013
Farm size	27.9634***	7.3489	3.81	0.000
Off farm	-2.5954	6.0578	-0.43	0.669
Market distance	-5.1588	3.4350	-1.50	0.136
Access to credit	-17.5690***	4.6425	-3.78	0.000
Household Consumption	-1.45×10^{-6} ***	5.95×10^{-7}	-2.44	0.016
Education	2.9578***	0.892	3.31	0.001
Experience	-0.0978	0.1956	-0.50	0.618
Implementation of SOP	16.0465***	5.2631	3.05	0.003
Intensity of extension	1.4891	5.8915	0.25	0.801
Risk preference	-154.036	146.0469	-1.05	0.294
R-squared	0.3677			
Adj R-squared	0.3146			

Note: Primary data source processed; *** significantly different at level = 5%.

Access to credit shows a negative and statistically significant relationship with FPSR ($\beta = -17.57$; $p < 0.01$), suggesting that credit is often not used to expand market-oriented production. Household consumption expenditure also has a negative effect on FPSR ($\beta = -1.45 \times 10^{-6}$; $p < 0.01$), indicating that higher consumption needs reduce the share of output available for sale. In contrast, education has a positive and significant influence on FPSR ($\beta = 2.96$; $p < 0.01$), implying that better-educated farmers tend to be more market-oriented. The adoption of standard operating procedures (SOPs) further strengthens commercialization, as reflected by its positive and significant effect on FPSR ($\beta = 16.05$; $p < 0.01$). Other factors, such as off-farm employment, distance to markets, farming experience, extension inten-

sity, and risk preferences, do not show statistically significant effects on FPSR in this model.

The R-squared value of 0.3677 indicates that approximately 36.8% of the variation in commercialization is explained by the variables included in the model, while the remaining variation is influenced by factors not captured in the analysis. After adjusting for the number of explanatory variables, the Adjusted R-squared of 0.3146 shows that the model explains about 31.5% of the variation, which is reasonable for a socio-economic behavior study.

Multicollinearity was examined using the Variance Inflation Factor (VIF). The results show that all independent variables have VIF values below the commonly accepted threshold of 5, with values ranging from 1.07 to 1.71 and a

mean VIF of 1.21. The highest VIF values are observed for overflow type and risk preference; however, these values remain within acceptable limits and do not indicate serious multicollinearity. Overall, the results suggest that multicollinearity is not a concern, and all explanatory variables can be reliably included in the regression model.

3.3.2. Labor Cost Ratio (LCR)

The regression results show that only a few factors have a meaningful influence on the labor cost ratio (LCR) in tidal rice farming (**Table 2**). Farm size has a positive and statistically significant effect on LCR ($\beta = 12.29$; $p <$

0.01), indicating that farmers with larger landholdings tend to allocate a greater share of their production costs to labor. Access to credit, meanwhile, has a negative and weakly significant effect on LCR ($\beta = -4.09$; $p = 0.050$), suggesting that better access to financial resources is associated with a lower share of labor costs.

Other factors, including overflow type, off-farm employment, distance to markets, household consumption expenditure, education, farming experience, tidal land management practices, extension intensity, and risk preferences, do not show a statistically significant relationship with the labor cost ratio (LCR).

Table 2. Factors affecting the Labor Cost Ratio (LCR) on Tidal Land West Kalimantan, Indonesia in 2025.

Parameter	Coefficient	Standard Error	Z	$p > z $
LCR				
Intercept	19.9656	6.6466	3.00	0.003
Overflow Type	-0.1682	1.2016	-0.14	0.889
Farm size	12.2866***	3.2810	3.74	0.000
Off farm	1.4055	2.7046	0.52	0.604
Market distance	2.1183	1.5336	1.38	0.170
Access to credit	-4.0930**	2.0727	-1.97	0.050
Household Consumption	-2.68×10^{-7}	2.65×10^{-7}	-1.01	0.314
Education	0.3822	0.3984	0.96	0.339
Experience	0.0213	0.0873	0.24	0.808
Implementation of SOP	-1.6254	2.3498	-0.69	0.490
Intensity of extension	-0.8037	2.6303	-0.31	0.760
Risk preference	-60.1140	65.2045	-0.92	0.358
R-squared	0.1575			
Adj R-squared	0.0868			

Note: Primary data source processed; *** significantly different at level = 5%; ** significantly different at level = 10%.

The R-squared value of 0.1575 indicates that about 15.8% of the variation in the dependent variable is explained by the variables included in the model. After adjusting for the number of explanatory variables, the Adjusted R-squared of 0.0868 shows that the model explains approximately 8.7% of the variation, suggesting a relatively limited explanatory power. This indicates that while the included variables have some influence, a large share of the variation is driven by other factors not captured in the model. Such results are common in socio-economic and behavioral studies, where outcomes are influenced by complex and context-specific factors that

are difficult to fully measure.

3.3.3. Purchase Input Cost Ratio (PICR)

The regression results suggest that several factors play an important role in shaping the purchased input cost ratio (PICR) in tidal rice farming, which reflects the extent of farmers' engagement with input markets (**Table 3**). Overflow type shows a positive and statistically significant effect on PICR ($\beta = 2.74$; $p = 0.020$), indicating that farmers operating under more stable and manageable overflow conditions (Types C and D) tend to devote a larger share of their production costs to purchased inputs.

Table 3. Determinants of the Purchased Input Cost Ratio (PICR) in tidal land Rice Farming, West Kalimantan, Indonesia in 2025.

Parameter	Coefficient	Standard Error	Z	$p > z $
PICR				
Intercept	49.3085	6.4031	7.70	0.000

Table 3. *Cont.*

Parameter	Coefficient	Standard Error	Z	$p > z $
Overflow Type	2.7356***	1.1576	2.36	0.021
Farm size	8.3472***	3.1608	2.64	0.009
Off farm	6.7235***	2.6055	2.58	0.011
Market distance	-1.9246	1.477	-1.30	0.195
Access to credit	-1.7393	1.9968	-0.87	0.385
Household Consumption	-1.48×10^{-7}	2.55×10^{-7}	-0.58	0.563
Education	0.0318	0.3838	0.08	0.934
Experience	0.0193	0.0841	0.23	0.819
Implementation of SOP	-1.7396	2.2636	-0.77	0.444
Intensity of extension	1.6320	2.5340	0.64	0.521
Risk preference	4.3653	62.8153	0.07	0.945
R-squared	0.1411			
Adj R-squared	0.0690			

Note: Primary data source processed; *** significantly different at level = 5%.

Farm size also has a positive and statistically significant relationship with PICR ($\beta = 8.35$; $p = 0.009$), indicating that farmers with larger landholdings tend to rely more heavily on purchased inputs. Non-agricultural income likewise shows a positive and significant effect on PICR ($\beta = 6.72$; $p = 0.011$), suggesting that additional income sources help ease financial constraints and support investment in market-based inputs. In contrast, other factors—including market distance, access to credit, household consumption expenditure, education, farming experience, tidal land management practices, extension intensity, and risk preferences—do not show statistically significant effects on PICR. An R-squared of 0.1411 means that the model explains around 14.1% of the variation in the outcome variable. When the number of explanatory variables is taken into account, the Adjusted R-squared drops to 0.0690, indicating that the explanatory power

of the model is fairly modest. This suggests that, although some of the included variables do contribute to explaining the outcome, most of the variation is influenced by other factors outside the model. Such a result is not unusual in studies of farmer behavior or market participation, where decisions are shaped by complex conditions, unobserved risks, and local circumstances that are difficult to quantify.

3.3.4. Farm Cash Income Ratio (FCIR)

The regression results show that several factors have a significant impact on the farm cash income ratio (FCIR), which reflects how engaged farmers are in output markets (Table 4). Overflow type has a negative and statistically significant effect on FCIR ($\beta = -5.36$; $p = 0.011$), suggesting that farmers working under less favorable overflow conditions earn lower cash income from rice sales.

Table 4. Factors affecting Farm Cash Income Ratio (FCIR) on Tidal Land West Kalimantan, Indonesia in 2025.

Parameter	Coefficient	Standard Error	Z	$p > z $
FCIR				
Intercept	32.1065	11.5235	2.79	0.006
Overflow Type	-5.3594***	2.0833	-2.57	0.011
Farm size	11.2176**	5.6885	1.97	0.051
Off farm	6.4759	4.6891	1.38	0.170
Market distance	-2.2820	2.6589	-0.86	0.392
Access to credit	-13.3989***	3.5936	-3.73	0.000
Household Consumption	-7.53×10^{-7}	4.59×10^{-7}	-1.64	0.103
Education	1.6967***	0.6908	2.46	0.015
Experience	-0.1268	0.1514	-0.84	0.404
Implementation of SOP	14.5484***	4.0739	3.57	0.000
Intensity of extension	0.5563	4.5604	0.12	0.903

Table 4. *Cont.*

Parameter	Coefficient	Standard Error	Z	$p > z $
Risk preference	163.3525	113.0479	1.44	0.151
R-squared	0.3728			
Adj R-squared	0.3201			

Note: Primary data source processed; *** significantly different at level = 5%.

Farm size has a positive and marginally significant effect on FCIR ($\beta = 11.22$; $p = 0.051$), indicating that farmers with larger landholdings tend to achieve higher levels of commercialization. Access to credit, however, shows a negative and highly significant relationship with FCIR ($\beta = -13.40$; $p < 0.001$), suggesting that loans are often not directed toward market-oriented production. Education has a positive and significant effect on FCIR ($\beta = 1.70$; $p = 0.015$), implying that better-educated farmers are more capable of generating cash income from rice sales.

Furthermore, adopting tidal land management practices and standard operating procedures (SOPs) strongly enhances FCIR ($\beta = 14.55$; $p < 0.001$), highlighting the importance of effective management and modern practices in boosting market participation. Other factors—such as off-farm employment, market distance, household consumption, farming experience, extension intensity, and risk preferences—do not show significant effects on FCIR. An R-squared value of 0.3728 indicates that the model explains about 37.3% of the variation in the dependent variable, meaning that a substantial share of the observed differences can be linked to the factors included in the analysis. After adjusting for the number of explanatory variables, the Adjusted R-squared of 0.3201 shows that roughly 32.0% of the variation is still explained, suggesting that the model remains reasonably robust. In practical terms, this implies that the selected variables capture many of the key influences on the outcome, while the remaining variation reflects other unobserved factors and the inherent complexity of farmers' decisions.

4. Discussion

The results consistently demonstrate that agroecological conditions play a central role in shaping commercialization outcomes in tidal rice farming sys-

tems. The negative and significant effect of overflow type on output commercialization indicators indicates that less favorable hydro-geomorphological conditions characterized by frequent flooding, high soil acidity, and complex water management substantially constrain farmers' ability to generate marketable surplus. Under these conditions, production risk is high and yield stability is limited, encouraging farmers to prioritize household food security over market participation. This behavioral response is consistent with agricultural household theory and risk-based decision-making, which predict a stronger subsistence orientation when production uncertainty is elevated. Similar patterns have been documented in earlier studies showing that agroecological constraints reduce market participation, while more stable environments facilitate commercialization^[12, 13, 23]. These findings highlight the importance of investments in water control infrastructure, soil improvement, and adaptive technologies to reduce risk and support market-oriented production in tidal land systems^[24–26].

Farm size emerges as a consistently positive determinant of commercialization across multiple indicators, reinforcing the central role of landholding scale in surplus generation. Larger farms are better able to meet household consumption needs while still producing surplus for sale, resulting in higher farm production sales ratios (FPSR) and greater cash income from rice sales (FCIR). This finding aligns with both theoretical expectations and empirical evidence suggesting that larger land endowments enhance farmers' capacity to absorb production risk and engage with output markets^[12, 27]. In contrast, the negative association between household consumption expenditure and FPSR reflects the joint determination of production and consumption decisions under imperfect markets. Higher consumption needs reduce the share of output available for sale, particularly in risk-prone environments

where households place greater emphasis on food security^[28, 29]. Similarly, the negative effect of credit access on FPSR and FCIR suggests that rural credit in tidal areas is frequently used for consumption smoothing or debt repayment rather than for productive investment. This outcome underscores the fungibility of credit and highlights institutional weaknesses in monitoring and targeting agricultural loans^[30, 31].

Human capital and farm management practices play a critical role in mediating these structural constraints. The positive influence of education on both FPSR and FCIR indicates that better-educated farmers are more capable of managing production risk, adopting improved technologies, and accessing market information, which strengthens their engagement with output markets^[32]. Likewise, the significant role of standard operating procedure (SOP) adoption and tidal land management practices reflects the importance of effective water and soil management in stabilizing yields and improving productivity under challenging tidal conditions^[33]. These results suggest that commercialization in tidal systems depends not only on resource endowments but also on farmers' ability to apply context-specific knowledge and adaptive technologies.

Labor and input commercialization display distinct but interconnected patterns. The positive relationship between farm size and the labor cost ratio reflects the labor-intensive nature of rice cultivation in tidal environments, where acidic soils, periodic flooding, and limited mechanization increase labor requirements even as farm size expands. This finding is consistent with previous studies documenting rising labor use and wage expenditures with scale in labor-intensive production systems^[34]. The weakly significant negative effect of credit access on labor costs suggests that financial access may allow partial substitution of manual labor with labor-saving inputs or services, such as herbicides or basic mechanization. However, the limited magnitude of this effect indicates that biophysical constraints continue to restrict labor substitution in tidal rice farming^[35]. The insignificance of education and extension services in explaining labor use further suggests that labor demand is largely driven by structural and environmental conditions rather than managerial

decisions alone^[36].

Input-market commercialization, measured by the purchased input cost ratio (PICR), is strongly influenced by agroecological stability, farm size, and household liquidity. More favorable overflow conditions reduce production risk and increase expected returns, encouraging farmers to invest in fertilizers, pesticides, improved seed varieties, and mechanization services. This pattern is consistent with evidence showing that reduced uncertainty promotes input intensification and technology adoption^[37, 38]. Larger farms benefit from economies of scale and rely more heavily on purchased inputs to enhance productivity and efficiency, particularly in environments where labor productivity is constrained^[39, 40]. The positive association between non-farm income and PICR highlights the role of household liquidity in enabling investment in modern inputs, especially in marginal agricultural systems^[41–43]. At the same time, the lack of significance of market distance and formal agricultural credit suggests that trader networks and local input suppliers help reduce spatial barriers, while formal credit remains weakly linked to productive input use^[35].

Taken together, the results reveal a segmented and non-linear pattern of commercialization in tidal rice farming systems, where integration into input and labor markets does not automatically translate into higher output sales or cash income. This finding challenges the conventional assumption in commercialization theory that intensification and market participation evolve simultaneously and along a linear pathway. By explicitly accounting for tidal overflow conditions and multiple dimensions of commercialization, this study demonstrates how persistent agroecological risk alters farmer incentives, reinforces subsistence-oriented behavior, and reshapes market engagement strategies. In doing so, the analysis extends existing commercialization frameworks by showing that commercialization outcomes in marginal and risk-prone environments cannot be fully explained without incorporating agroecological risk, household consumption pressures, and institutional constraints, thereby offering a more context-sensitive understanding of commercialization in tidal wetland agriculture.

5. Conclusions

1. The study demonstrates that agroecological conditions, particularly tidal overflow characteristics, play a decisive role in shaping commercialization outcomes in tidal wetland rice systems by increasing production risk and constraining surplus generation.
2. Farm size consistently enhances commercialization across output, input, and cash-income indicators, confirming its role in risk absorption and surplus production, while high household consumption needs reinforce subsistence-oriented behavior under imperfect markets.
3. Access to credit does not automatically promote commercialization; instead, credit is frequently used for consumption smoothing rather than productive investment, highlighting the importance of credit fungibility and institutional weaknesses in rural financial systems.
4. Human capital and effective farm management practices, including education and the adoption of standard operating procedures, help mitigate agroecological constraints by improving productivity, stabilizing yields, and strengthening farmers' engagement with output markets.
5. The analysis reveals a segmented commercialization pathway in which farmers are increasingly integrated into input and labor markets, while output commercialization and cash income remain constrained by agroecological risk, household food security considerations, and institutional limitations.
6. These findings challenge the conventional assumption that agricultural intensification and commercialization evolve simultaneously and instead support a multidimensional and non-linear view of commercialization in high-risk environments.
7. By explicitly incorporating agroecological risk and multiple commercialization indicators, the study extends existing commercialization frameworks and provides a more context-sensitive explanation of commercialization dynamics in tidal wetland rice farming systems.
8. From a policy perspective, the results underscore

the need for risk-reducing interventions—such as improved water management, adaptive technologies, and better-targeted credit—rather than strategies that focus solely on input intensification or market access.

Author Contributions

Conceptualization, D.O.D.; validation, R.N.; formal analysis, D.O.D. and R.N.; investigation, D.O.D., R.N. and N.T.; resources, D.O.D., R.N. and N.T.; data curation, D.O.D., R.N., N.T. and S.; writing—original draft preparation, D.O.D.; writing—review and editing, N.T.; visualization, D.O.D. and N.T.; supervision, N.T. and S.; project administration, D.O.D. and S.; funding acquisition, D.O.D. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

Ethical review and approval were waived for this study because it did not involve any experiments on humans or animals. Participation of respondents was voluntary, and informed consent was obtained prior to data collection. Respondents were assured of anonymity and confidentiality of their responses. The authors declared that no Institutional Review Board approval was required for this study.

Informed Consent Statement

Written informed consent was obtained from all participants prior to the study. Participation was voluntary, and all respondents were fully informed about the objectives and procedures of the research.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reason-

able request.

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Conflicts of Interest

The authors declare no conflict of interest.

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