Effects of Farm Income Diversification and Labor Out-Migration on Rice Household Productivity in Indonesia

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ABSTRACT

This study analyzed the impact of income diversification on agricultural output in Indonesia. We specifically focused on the effects of the cultivation of multiple crops, household heads' employment in non-agricultural sectors, and regional differences in paddy rice productivity per area. We assessed cross-sectional data from the 2013 Census of Agriculture in Indonesia. Indonesian farmers actively channeled wage income into spending on agricultural inputs to improve yields. However, agricultural production continued to depend on human labor, and labor force loss due to wage labor employment was observed. In terms of magnitude, the effect of productivity gains due to labor force loss was larger and was not compensated for by the impact of wage income. Also, while the Indonesian government has been focusing on policies for subsidizing fertilizer use, the data show that less than 30 percent of households receive government subsidies for seeds, fertilizers, and machinery. These utilization rates should be improved.

Keywords: Indonesia, income diversification, paddy yield, agricultural productivity
JEL codes: Q01, Q12, O13

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INTRODUCTION

Indonesia has experienced remarkable economic growth and is now classified as a newly industrialized country. Although agriculture remains a significant sector in the Indonesian economy, its contribution to gross domestic product is on the decline, mainly supported by small-scale farmers.

In Indonesia, demand is rising for high value-added foods, such as vegetables, milk, and livestock (Khoiriyah et al. 2020). This trend reflects a broader pattern: as economies grow, they tend to rely less on staple foods. However, Indonesia's food consumption patterns more closely resemble those of low-income countries than those of middle-income ones, and the nation has one of the highest per capita rice consumption rates globally, second only to India (Sleet 2020). Per capita domestic rice production peaked at 256 kg per person in 1992 and has declined. In 2009, rice yields exceeded 5,000 kg/ha but have shown slow improvement thereafter (Figure 1). This production vulnerability underscores Indonesia's significant demand for rice. It has been reported that rice-centric policies have skewed production toward rice, diminishing overall agricultural diversity (Siregar and Suryadi 2006).

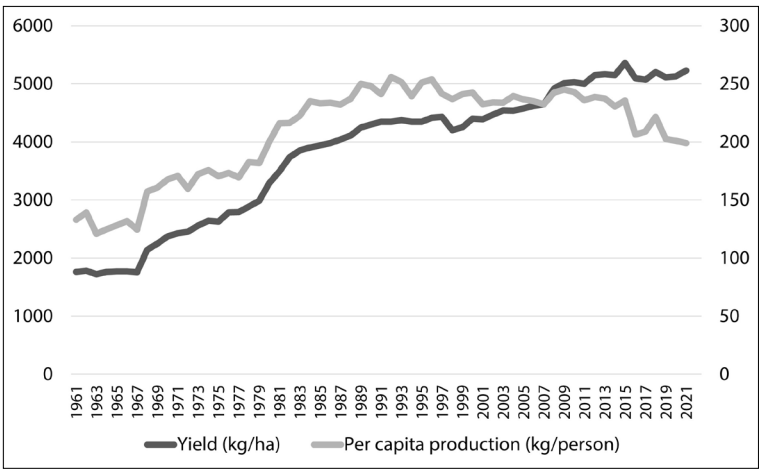
Given these conditions, Indonesia continues to demonstrate a high demand for staple foods, alongside an increasing demand for other crops. Conversely, the production base remains fragile, posing ongoing food security challenges for the country.

Indonesia teeters just on the brink of self-sufficiency in its staple food, rice. This advancement necessitates a shift toward more commercial farming practices among farm households. Commercialization leads farmers to limit crop variety and specialize, which in turn reduces diversity in crop production. Emerging trends indicate this shift. Mehraban and Ickowitz (2021) observed that with Indonesia's economic growth, consumption of meat and dairy products as protein sources has increased, while the intake of vegetables and fruits has declined. They described this as a negative trend in diet quality related to the increasing specialization in agriculture.

In recent years, discussions on food security at the household level have focused more on the correlation between diet diversity and crop diversity. Small-scale farmers often rely on their homegrown crops for consumption. Consequently, many studies have developed an index on diet diversity as an indirect measure of a diet's nutritional quality and examined its association with farmers' crop diversity. The linkage between cultivating a variety of crops and maintaining a diverse diet—and the significance of local food production for self-sufficiency—cannot be overstated (Jones, Shrinivas, and Bezner-Kerr 2014; Jones 2016; Pellegrini and Tasciotti 2014; Rosenberg et al. 2018; Shively and Sununtnasuk 2015; Sibhatu, Krishna, and Qaim 2015; Sibhatu and Qaim 2018). These studies have revealed a relationship between the two variables, suggesting that increased crop diversity enhances diet diversity and contributes to household-level food security.

In Indonesia, certain rural areas still experience market failures, prompting studies on crop diversity (Pellegrini and Tasciotti 2014). For example, subsidized fertilizer is provided by the

Figure 1. Rice yield and per capita production in Indonesia



government, where the actual price of fertilizer is double the subsidized price. Farmers often lack access to subsidized fertilizers, which are in short supply in Indonesia. The government adopted a bureaucratic application system in which farmers apply for subsidized fertilizers through government-approved farmer groups. If the application process does not proceed as planned, farmers who do not belong to government-approved farmer groups are unable to receive subsidies. If subsidies are not provided, farmers are forced to choose between buying unsubsidized fertilizers at a higher price or using less fertilizer, reducing yield (Alta, Setiawan, and Fauzi 2021). However, increasing crop diversity often leads to labor dispersion and decreased productivity. Given Indonesia's desired goal of food self-sufficiency, promoting crop diversity in the traditional manner is impractical. Recent discussions on crop diversity have seldom addressed its relationship with agricultural productivity or assessed the extent of its impact. Thus, this study aimed to investigate this relationship.

Although Indonesia invests more in agricultural production support than any other middle-income country, its agricultural infrastructure is aging, and many farmers face challenges in purchasing inputs due to low farm incomes (Sleet 2020). Income diversification, involving the distribution of production assets among various on- and off-farm income-generating activities, has been proposed as a strategy to reduce household income variability and secure a minimum income level (Alderman and Paxon 1992; Abdulai and CroleRees 2001; Lanjouw and Lanjouw 2001; Joshi et al. 2004). Benefits of income diversification at the farm level include increased stability, improved farm income, and enhanced long-term farm income through investments in agricultural inputs.

From a food security standpoint, however, the labor force dedicated to family farming may decline, leading to fewer options for ensuring food availability. Income diversification presents farmers with the challenge of reduced labor input for their own production in the face of the potential benefit of increased off-farm wages. Our second research question thus explored how the reduction in labor and the potential wage gains from income diversification impact domestic agriculture.

Household decisions on income diversification and crop selection aim to maximize returns. In rural areas still affected by market failures, agricultural production and consumption decisions are intertwined and inseparable.

The urgency of producing rice as a staple food and ensuring nutrient-rich food supply remains a critical concern in Indonesia. For farmers, diversifying income sources may increase off-farm wages but also reduce their agricultural production—including for personal consumption—due to decreased family labor involvement. The effect of income diversification on agricultural productivity thus remains uncertain. By addressing these concerns, this paper offers policy recommendations for achieving food security in Indonesia, at the juncture of self-sufficient food production and commercial agricultural transformation.

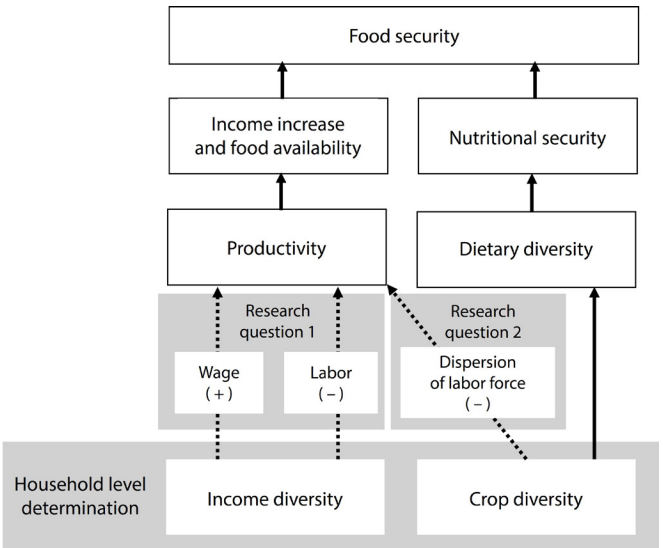
This study assessed the impacts of household off-farm income on rice production in Indonesia, especially focusing on the contributions of (a) economies of scope, that is, planting nonrice crops and raising poultry and livestock; (b) employment of household heads in non-agricultural (off-farm) jobs; and (c) regional/location effects.

We hypothesized that rice productivity is positively but not directly affected by factors (a) and (b), explained by nonrice employment and income alleviating the capital or liquidity constraints of rice farm households, consequently making it feasible to buy more productivity-enhancing inputs.

Analytical Approach

Figure 2 shows the framework of the study. It assumed that the employment of a family member for off-farm income has two simultaneous impacts on agriculture. Participation in wage labor can affect agricultural productivity through two pathways. First, wage labor employment reduces the amount of labor invested in home production, thereby reducing productivity. Second, higher

Figure 2. Linkage of income sources and crop diversification to food security



wages than those from family farming allow farmers to invest in agriculture, such as fertilizer and irrigation improvements, thereby increasing productivity. In other words, positive and negative effects simultaneously impact on home production. Rozelle, Taylor, and De Brauw's (1999) household model is an economic model that considers these simultaneities. This model is inspired by the "whole" household-farm model, which considers both the production and consumption aspects of the farm. Taylor (1987) included the impact of remittance inflows due to migration in the traditional household-farm model. Additionally, Rozelle, Taylor, and De Brauw (1999) expanded the analytical framework proposed by Taylor (1987) and developed it into a simultaneous agricultural household model. In this model, the household simultaneously determines the outflow of family labor, nonhomegrown income, and agricultural production.

Traditionally, analyses of the impact of nonfarm employment on agricultural production have employed the two-stage least squares (2-SLS) method based on the household model. This model assumes that the factors influencing agricultural production and nonfarm employment decisions are independent.

However, the recent diversification of agricultural crops shares a similar risk-hedging function through the diversification of income sources, which is comparable to the conventional effects of off-farm employment in farm households. In other words, crop diversification and off-farm employment compete, and the decision-making process involves complex labor allocation within the opaque structure of household finances. Additionally, the magnitude of off-farm wage income is influenced by the number of household members engaged in off-farm employment. Households with higher agricultural productivity tend to have fewer off-farm workers, which affects the overall size of off-farm wages. Furthermore, the presence of nonworking family members, such as children and older relatives, influences agricultural productivity and off-farm employment decisions.

To better account for this endogeneity, the model employs a three-stage least squares (3-SLS) method. This approach is used to estimate simultaneous equation models in which multiple equations interact with each other. When the error terms are correlated across equations, 3-SLS provides more efficient estimators than 2-SLS. The 3-SLS process consists of three steps. First, endogenous variables (in this case, wage income and the number of wage labor participants) are estimated using exogenous and instrumental variables. Second, the covariance matrix of the error terms is estimated, accounting for the correlations among the structural error terms across all the equations. Third, all the equations are estimated simultaneously, allowing for the joint assessment of various interrelated determinants. This method is well-suited to cases in which the error terms across equations are interrelated, enabling a comprehensive analysis of the factors affecting agricultural productivity, wage income, and labor participation.

Recent research has extensively examined the effects of remittance receipts, a form of off-farm income, and labor outflows on agriculture,

resulting from labor migration (De Brauw 2010; Ghimire and Kapri 2020; Kapri and Ghimire 2020; Taylor and Adelman 2003; Tuladhar, Sapkota, and Adhikari 2014). These studies are also grounded in the household model because decisions regarding resource allocation for agricultural production, off-farm employment, and off-farm wage income are made simultaneously within the household. Using panel data from Vietnam and a 2-SLS model with instrumental variables, De Brauw (2010) assessed the impact of labor out-migration and remittances on agricultural production. The findings indicate that while migration does not affect agricultural productivity, it shifts cropping patterns from labor-intensive to land-intensive crops. Tuladhar, Sapkota, and Adhikari (2014) analyzed the impact of migration and remittances on agricultural productivity in Nepal using a 3-SLS approach. Their findings suggest that off-farm labor reduces agricultural output by creating labor shortages in the agriculture sector and that remittance-receiving households do not invest this income in productivity-enhancing agricultural capital goods and inputs. Using cross-sectional data from Nepal and a 3-SLS method, Ghimire and Kapri (2020) differentiated between earned remittances—income regularly generated from off-farm labor—and unearned remittances and analyzed the impact of each on agricultural productivity. Their findings indicate that unearned remittances may be allocated to increase agricultural productivity. Kapri and Ghimire (2020) employed cross-sectional data from Nepal and a 3-SLS approach to examine the effect of remittances on household-level agricultural productivity, measured as output per labor hour. Their overall findings revealed that households that received remittances were more productive. Furthermore, they found that households with lower productivity benefit more from remittances than those with higher productivity.

These studies utilize a 3-SLS approach because of several concerns related to endogeneity. First, household characteristics—both agricultural productivity and off-farm income—are influenced by factors, such as the number of dependents (e.g., children and older adults); the education level of the household head; and access to infrastructure such as markets. The second is the simultaneous determination of labor allocation between agricultural and non-agricultural sectors. Third, households with higher agricultural productivity tend to have fewer off-farm workers and, thus, lower off-farm wages, while a reverse relationship is also observed. Fourth, stochastic shocks such as accidents or social conditions can affect both agricultural production and off-farm labor. Fifth, unobserved variables may influence both agricultural productivity and off-farm income. Similar endogeneity concerns are likely relevant to the present analysis.

THE 2013 AGRICULTURAL CENSUS DATA

We assessed cross-sectional data from the 2013 Census of Agriculture in Indonesia. Using these data, we analyzed the relationship between productivity, the cultivation of multiple crops, and wage employment for households that produced paddy rice.

The Census of Agriculture is conducted every 10 years, with the 2013 Census of Agriculture (i.e., ST2013) being the sixth iteration. Agricultural activities covered in previous censuses include six subsectors: food crops, horticulture, plantations, livestock, fisheries, and forestry. The questionnaire also includes questions on family structure, income from non-agricultural activities, assets, socioeconomic status, and food security. The dataset encompasses all agricultural enterprises, including family-run farms and corporate businesses operating in Indonesia, and includes 415,874 households. For the purposes of this paper, the analysis focused on 109,106 households whose primary activity is agriculture, specifically rice production, and that do not contain outliers.

Table 1 presents basic statistical data for the two groups: households with only agricultural income (78,851 households) and households with both agricultural and non-agricultural incomes (19,974 households). Rice yields were slightly higher for households with non-agricultural income (4,110 kg/ha) than for those with agricultural income alone (3,923 kg/ha),

Table 1. Basic statistics

Variables	Income with only Agricultural Work (78,851 HH)	Income with Non-agricultural Job (19,974 HH)
Paddy yield (kg/ha)	3,923 (1,988)	4,110 (2,002)
Wage income (IDR 1,000/HH)[1]	2,100 (4,366)	7,408 (6,835)
Number of family members engaged in non-agriculture sector (people)*	0 (0)	1 (0.541)
Household size (people)*	4 (1.63)	4 (1.59)
Number of children (people)*	1 (0.945)	1 (0.923)
Number of elderly people (people)*	1 (0.483)	1 (0.476)
Ratio of households with working irrigation (%)	42.3 (0.491)	47.2 (0.495)
Ratio of households with livestock (%)	21.2 (0.409)	25.8 (0.438)
Ratio of households using fertilizer	96.4 (18.6)	97.3 (16.1)
Production diversity	2.0 (1.06)	2.18 (1.13)
Gender of household head (% of woman HH head)	11 (31.5)	5.8 (23.4)
Age of household head	50.9 (13.4)	48.7 (11.9)
Education level of household head (years)	5.30 (3.88)	6.09 (4.14)
Economic state (%)		
Significant decrease	1,138 (1.44)	247 (1.24)
Decrease	16,748 (21.2)	3,729 (18.7)
Same	43,53 (55.2)	10,458 (52.4)
Increase	16,051 (20.4)	5,161 (25.8)
High increase	1,375 (1.74)	379 (1.90)
Region (%)		
Sumatra	22,639 (28.7)	5,226 (26.2)
Java	32,689 (41.5)	8,842 (44.3)
Kepulauan Nusa Tenggara	5,973 (7.58)	1,648 (8.25)
Kalimantan	7,687 (9.75)	1,482 (7.42)
Sulawesi	9,451 (12.0)	2,682 (13.4)
Maluku and Papua	412 (0.520)	94 (0.47)

Notes: [1]USD 1 = IDR 10416.7 (2013); Since these are nominal values from the year of data collection, the exchange rate used is from 2013.

suggesting that households with non-agricultural income achieve higher yields. Wage income is significantly higher among households with non-agricultural income, likely reflecting the wage disparity between agricultural and non-farm employment. No significant differences were observed regarding family composition, percentage of households using irrigation, percentage owning livestock, or percentage applying fertilizers. With regard to livestock, the data primarily reflect the use of buffalo and beef cattle as draft animals for agricultural production. This indicates no notable difference in labor and capital related to agricultural productivity between the two household groups. There were also no significant differences in the age or educational level of the household heads across both groups, although household heads in the agriculture-only group were more likely to be female.

With respect to the current economic situation compared to one year ago, a slightly higher percentage of households with only agricultural income reported being "significantly worse off" or "worse off" (22.6%) compared to households with non-agricultural income (19.9%). Conversely, a higher percentage of households

with non-agricultural income reported that their economic conditions had "stayed the same" or "improved" (27.7%), compared to 22.1 percent for households with only agricultural income. These findings suggest that while agricultural production conditions did not differ significantly, households with non-agricultural income experienced greater improvements in their overall economic situation.

Regional distribution between the two groups had no significant differences, indicating that the data were drawn from similar geographical regions. Approximately 40 percent of all households in both groups were located in Java, which accounts for the largest number of households. Overall, households with non-agricultural income not only earned significantly higher wages, but also achieved higher rice yields per unit area and reported a greater improvement in their economic status.

As a supplement, 20 percent of all households had at least one wage earner. The nonfarm wage income per household is IDR 3.09 million per year, but this average also includes households with no wage income. The annual per capita wage for labor workers in the non-agricultural sector is approximately IDR 6.66 million.

Production diversity refers to the variety of crops and livestock types, including cereals, legumes, tubers, vegetables, fruits, meats, eggs, dairy products, spices, and fish. This classification is based on the work of Kennedy, Ballard, and Dop (2011). Mehraban and Ickowitz (2021) reported a positive relationship between production diversity and dietary diversity, using data from Indonesia. This finding supports the argument that increased production diversity enhances food security.

However, growing a larger number of crops typically leads to longer work hours, and as a result, crop productivity is likely to be lower than if the farmer focused on just one crop. In discussions on the relationship between production diversity and dietary diversity, the impact on crop output is rarely considered. In this analysis, we used this variable to examine the relationship between the diversity of rice production and yield, while considering the impact of reduced family labor caused by off-farm work. In the dataset used for this analysis, the average number of crops grown was two for households with only agricultural income and two for households with non-agricultural income. In addition to paddy rice, which is classified as a cereal, another category of crops is also grown.

ECONOMETRIC MODEL

Given the objective of this study, we specify three equations for the number of wage laborers, wage income, and agricultural production. We specify the functions from Equations (1) to (3) and provide a brief explanation of the variables in Table 2.

Number of Wage Laborers

The number of people working in wage employment (L) is expressed as a function of a household's social characteristics and capital (Z_L).

$$L = \gamma_0 + \gamma_1 Z_L + \varepsilon_L \ldots \quad (1)$$

Z_L includes household size, number of children, number of older people, gender of household head, age of household head and its squared value, education level of household head, region, number of livestock for agriculture, and area of owned land. Furthermore, recognizing that job accessibility is influenced by both the surrounding environment and educational background of household members, we included the percentage of individuals in the county working outside the agriculture sector and the highest number of years of education in the household as instrumental variables in the first stage of the 3-SLS estimation. If a higher percentage of the local population was employed in the non-agricultural sector, or if a household member had a higher level of education, it was likely that the environment was more conducive to off-farm employment, which may affect the number of individuals engaged in non-agricultural work. However, it is unlikely that the proportion of non-agricultural workers in the local area or the highest level of education in the household directly influence wage income

Table 2. Variable descriptions

Variable Category	Variable	Description
Dependent variable	Paddy yield	Rice yield per area (kg/ha)
Household's character	Household size	Number of family members
	Child	Number of children under 15 years old
	Old	Number of adults 65 years and older
	Gender of household head	Gender of the head of the household
	Age of household head	Age of the head of the household
	Age^2 of household head	Square of the age of the head of the household
	Education level of household head	Education level of the head of the household
	Economic state (base=same)	Dummy variable representing current economic conditions compared to economic conditions one year ago (four levels: significantly decrease, decrease, increase, significantly increase)
	Region (base=Java)	Dummy variables for five regions: Sumatra, Kepulauan, Nusa Tenggara, Kalimantan, Sulawesi, and Maluku and Papua
Agricultural production factors (farm assets)	Ratio of working irrigation	Area under cultivation with working irrigation in place.
	Livestock	Number of head of cattle and buffalo available for agricultural use
	Owned land area	Area of farmland owned
Agricultural production status	Dummy of using fertilizer	Dummy variable that takes 1 if fertilizer is used
	Production diversity	Agricultural crop count
Endogenous variable	Wage income	Household off-farm wage income (IDR 1,000)
	Family members with wage jobs	Number of family members employed off-farm as wage earners
Instrumental variable	Mean of per capita wage income in the country	Average per capita wage income by sampling unit (IDR 1,000)
	Percentage of people in the county working outside the agriculture sector	Percentage of the population working in the nonfarm sector by sampling unit
	Highest education in the household	Years of education of the most educated person in the household

from the nonfarm sector or rice yields. These instrumental variables were used by Tuladhar, Sapkota, and Adhikari (2014) with the same rationale.

Wage Incomes

Wage income is expressed as a function of the number of household members engaged in wage employment (L), the household's social characteristics, and human and capital variables (Z_W).

$$W=\partial_0 + \partial_1 L + \partial_2 Z_W + \varepsilon_W \ldots \quad (2)$$

Household characteristics comprising the variable set Z_w include the number of family members with wage jobs, number of children and older individuals, gender of the household head, and region of residence. In addition, the area of owned land was considered an asset. As a control variable, we used the mean per capita wage income in the county. It is anticipated that the mean per capita wage rate at the district level influences household wage income but does not have a direct effect on rice productivity.

Agricultural Production

Assuming that farm households face liquidity constraints on their investments in agricultural inputs to maximize productivity, the scenario unfolds as follows:

(3)

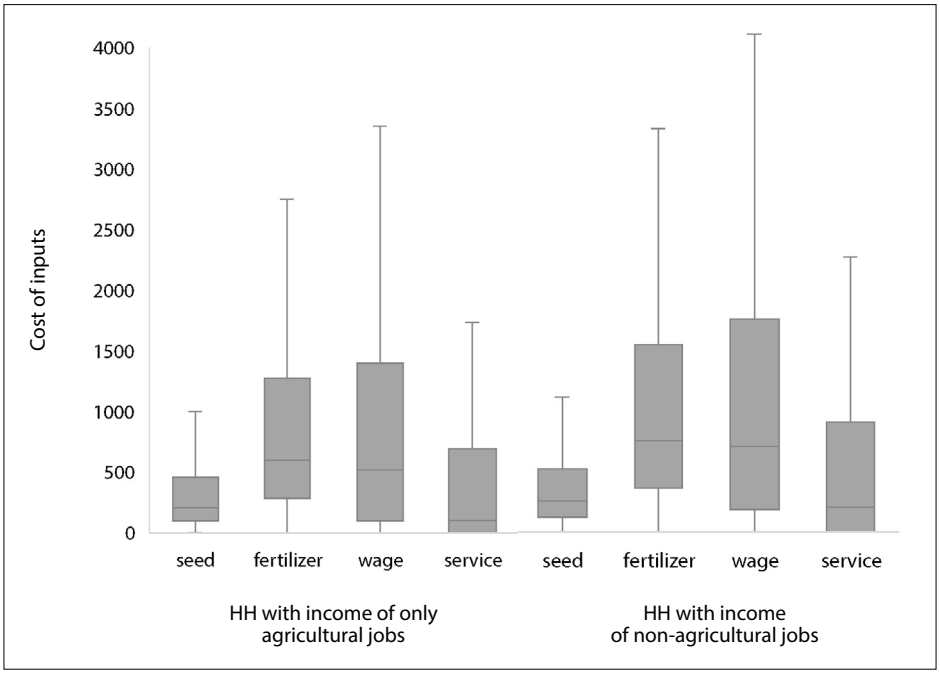
$$Q^C = \alpha + \beta_1 W + \beta_2 L + \lambda_3 Z_Q + \varepsilon_Q ...$$

where Q^C is the constrained production per hectare produced by a household under a given credit or liquidity constraint, W is the household wage income, and L is the number of household members engaged in wage labor, including agricultural- and non-agricultural labor not invested in homegrown agriculture. Q^C serves as a proxy variable for profit maximization in the agricultural production sector. Z_Q encompasses the socioeconomic characteristics of households, including the number of household members, number of children and older individuals, gender and age of the household head, level of education, economic status, and region. Additionally, variables reflecting asset characteristics and agricultural production factors were considered, such as the number of livestock used for farming, percentage of arable land equipped with operable irrigation facilities, and area of land owned. The analysis also incorporated variables related to the use of fertilizers and production diversity, which captured the range of crop types cultivated. After estimating L and W as endogenous variables using equations (1) and (2), equation (3) was simultaneously estimated.

RESULTS

Figure 3 illustrates the differences in agricultural expenditure patterns between households with only agricultural income and those with non-agricultural income. For seed and fertilizer expenses, there were no significant differences between the two types of households, as expenditures on these items remained relatively stable across both groups. Conversely, households with non-agricultural income exhibited greater expenditure on hired labor, with a broader distribution of these costs compared to households

Figure 3. Households that earn wages spend more on agricultural services



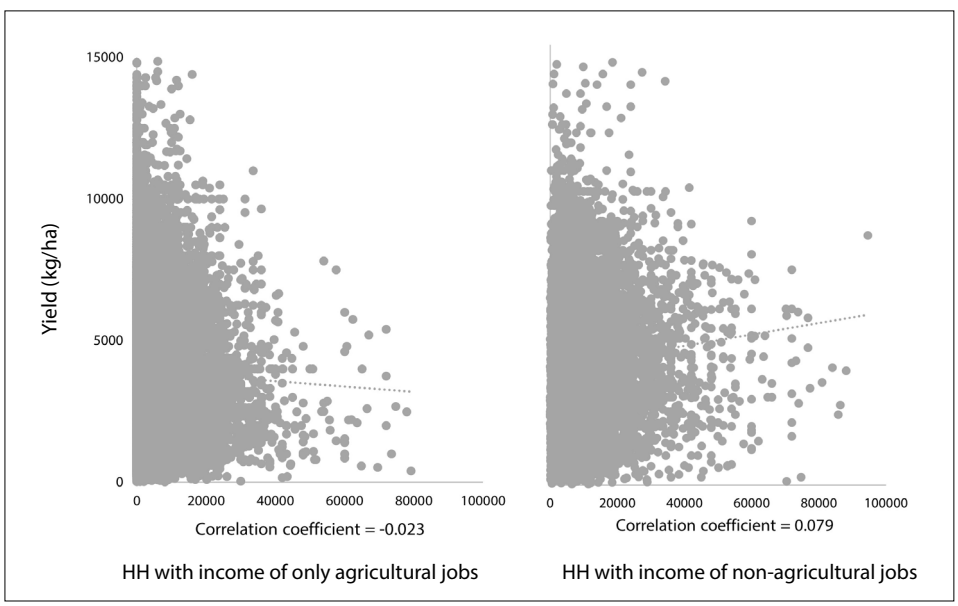
with only agricultural income. This suggests that households with non-agricultural income allocate more resources to agricultural labor. Additionally, expenditures on agricultural services are higher and vary more among households with non-agricultural income than among those with solely agricultural income. In summary, households with non-agricultural income tend to have slightly higher expenditures, particularly on hired labor and agricultural services than their counterparts relying solely on agricultural income.

Figure 4 depicts the relationship between wage income and rice yield for both household types, as presented in Table 4. For households with only agricultural income, the correlation coefficient is -0.023, whereas for households with non-agricultural income, the coefficient is 0.079, indicating a minimal correlation. Notably, the negative correlation for households with only agricultural income contrasted with the positive correlation for households with non-agricultural income, suggesting different relationships between the two groups.

There was no significant difference in wage income between households with only agricultural income and those with non-agricultural income. However, a statistically significant difference in rice yield per area was observed, with yields being higher for households with non-agricultural income at a level satisfying the one percent significance threshold. This finding implies that households with non-agricultural income may be more inclined to invest in productivity-enhancing agricultural inputs as the liquidity constraints associated with wage income are alleviated. To further investigate this relationship, we used an econometric model that controls for wage income and other relevant factors.

Table 3 presents the estimation results of the effects of labor migration on paddy rice productivity. The coefficients presented in Table 3 represent the marginal products, which indicate an incremental change in the dependent variables for a one-unit increase in the independent variables. This interpretation sheds light on the drivers of wage income and employment in the context of labor out-migration in Indonesia. Columns (1) and (2) show the first-stage regressions explaining family members' job wages and household income. Column (3) illustrates that wage income

Figure 4. Relationship between wage income and yield per area of paddy rice



Note: Regarding yield, a 1% significance level difference was identified between households with non-agricultural income and those without. However, no significant difference was found concerning wage income.

Table 3. Three-stage least squares regression results: Effects of incomes from farm diversification and labor out-migration on rice productivity, Indonesia, 2013

Variables	(1) Family Member with Wage Jobs	(2) Household's Wage Income	(3) Yield
Wage income			0.282**
			(0.0838)
Family members with wage jobs		13,660***	-3,140**
		(427)	(1,110)
Household size	0.0641***		-55.2**
	(0.00141)		(18.6)
Child	-0.0570***	51.8***	-7.00
	(0.00188)	(16.2)	(16.7)
Old	-0.0271***	-215***	55.2**
	(0.00260)	(34.8)	(25.1)
Ratio of working irrigation			384***
			(13.8)
Livestock	0.000839		8.91**
	(0.000529)		(3.39)
Dummy of using fertilizer			668***
			(33.4)
Production diversity			-72.3***
			(9.77)
Gender of household head	-0.0195***	-256***	203***
	(0.00343)	(67.9)	(32.7)
Age of household head	-0.00162***		12.5***
	(0.0000985)		(2.58)
Age^2 of household head			-0.0920**
			(0.0265)
Education level of household head	0.00365***		34.1***
	(0.000422)		(3.36)
Economic state (base=same)			
Significant decrease			-270***
			(61.0)
Decrease			-190***
			(15.4)
Increase			106***
			(14.4)
Significant increase			100
			(39.1)
Region (base = Java)			
Sumatra	-0.0109***	1,178***	-983***
	(0.00305)	(55.0)	(81.6)
Kepulauan Nusa Tenggara	0.00842*	-804***	-859***
	(0.00463)	(54.6)	(78.1)
Kalimantan	-0.0237***	1,397***	-1,881***
	(0.00434)	(100)	(89.7)
Sulawesi	0.00702	-642***	-1,077***
	(0.00434)	(57.4)	(75.0)
Maluku and Papua	-0.00481	371	-1,881***
	(0.0157)	(265)	(95.8)

Continued on next page

Table 3 continued

Variables	(1) Family Member with Wage Jobs	(2) Household's Wage Income	(3) Yield
Owned land area	0.104e-06	-0.0199**	
	(2.23e-07)	(0.00611)	
Mean of per capita wage income in the country		0.136**	
		(-0.0522)	
% of people in the county working outside the agriculture sector	1.028***		
	(0.0388)		
The highest years of education in the household	0.000545		
	(-0.000515)		
Constant	-0.0755***		3,183***
	(0.00840)		(117)

Note: The numbers in parentheses are bootstrap standard errors. ***p<0.01, ** p<0.05, * p<0.1. 3-SLS estimates were conducted using STATA's reg3 command.

gains result in higher paddy rice yields. The effect is that an IDR 1,000 increase in household wage income (where one unit of wage income equals IDR 1,000) leads to a 0.28 kg/ha increase in rice yields. This suggests that wage income is a means of alleviating the liquidity constraints of farmers, and that they use inputs and invest in agricultural technology to increase agricultural productivity.

Conversely, the loss of labor due to nonfarm wage labor employment had a negative impact of 3,140 kg/ha on rice productivity. In the dataset used, the average nonfarm wage income per person is approximately IDR 6.66 million. If one new wage worker is added from the household, the effect of the increased wage on rice yield would be an increase of 1,865 kg/ha, multiplied by 0.28 kg/ha of average per capita nonfarm wage income. This only covers approximately 60 percent of the yield reduction effect (3,140 kg/ha) owing to labor loss. Therefore, it can be said that in Indonesia, there are pathways that can improve yields through increased wage income, but they are not sufficient to compensate for the losses caused by reduced labor input.

Additionally, paddy rice yields tend to be lower for farmers who have many other crops (e.g., horticultural crops) and livestock production. Therefore, it is not surprising that paddy rice productivity declines with increasing crop numbers and distribution of the labor force invested in paddy rice. In other words, although securing staple food and dietary or nutritional diversity are part of the same food security issue, the results suggest that there may be a trade-off relationship at the farmer's production stage. However, an increase in one crop type resulted in a decrease in rice yield by 72 kg/ha. While a direct comparison is not feasible within this analysis, at the farmer decision-making level, there is a significant likelihood that farmers will cultivate high-value-added crops that can offset the 72 kg decrease in rice yield. To further understand these dynamics, it is essential to analyze the impact of crop diversification on farm income, though the extent of this impact is a subject of debate (Pellegrini and Tasciotti 2014).

Regarding yield, notable regional differences exist. The average yield on Java Island, Indonesia's rice production hub (4,595 kg/ha), was higher by 1 to 2 tons compared to other regions. This variance is attributed to Java Island's more favorable land conditions for paddy rice cultivation. However, Java Island also hosts the political and economic capital, Jakarta, alongside other major cities, leading to ongoing population shifts. The conversion of farmland into residential areas suggests a weaking in the stability of the food production base. Conversely, regions such as Sumatra and Kepulaun Nusa Tenggara have the potential to elevate their rice yields to match those of Java Island. Enhancing agriculture in these less advantaged areas could mitigate the risk of agricultural production concentration on Java Island.

Moreover, economic growth has led to increased workers' wages, necessitating a shift toward more commercial and specialized agriculture. The wage income from diversified income sources compensated for only 60 percent of the yield impact caused by the migration of family labor to off-farm sectors. The comparative advantage of rice production is diminishing as farmers adopt mechanization to conserve labor and shift to producing higher value-added crops. Farmers on Java Island are increasingly moving from rice production to cultivating more lucrative crops such as vegetables, fruits, and livestock to maximize profits. Meanwhile, the nation's overall food security, particularly concerning rice, becomes more vulnerable. Thus, immediate enhancements in rice yield and fertilizer supply systems in Sumatra and Kepulaun Nusa Tenggara are imperative. Conversely, in regions like Maluku and Papua, where daily access to water and food is challenging, ensuring adequate food and nutrition becomes a top priority. In remote areas still facing market failures, prioritizing self-sufficiency appears desirable.

In particular, households whose economic situation was worse than the previous years tended to have lower yields than those whose economic situation was similar to that of previous years. Farmers who had better economic conditions than in previous years had a similar impact on rice yields; however, the worse the economic conditions, the lower the rice yield. If the economic situation is "significantly decreased," it means that the economic conditions were better than usual last year but have worsened compared to the usual conditions this year. This might be due to decreased income, which resulted in decreased application of recurring inputs such as fertilizers. Thus, the worse the economic situation, the more it will affect the rice yield in the following year, which may lead to a further decline in income, difficulty in securing food, and on to a downward spiral.

Other results show that yields decreased as the number of household members increased. Households with more members tend to have a higher proportion of children and older adults. In addition, the percentage of irrigation used, number of buffaloes, and use of fertilizers resulted in higher yields. All regions tend to have lower unit yields than Java, especially in the northern islands where the yield is more than 100 kg lower.

The analysis presented above reveals several significant findings. First, although there are mechanisms through which wage income can enhance farmers' cash flows and subsequently increase rice yield, these mechanisms are insufficient to fully compensate for the losses incurred because of reduced labor availability. Second, crop diversification, although recommended to enhance household food security, may lead to decreased rice yields. Third, to address the overreliance on rice production in Java, where regional disparities in rice yields are pronounced and urbanization is increasing, efforts should be made to improve rice yields in Sumatra and Nusa Tenggara, along with strengthening the fertilizer supply system. Finally, households that experienced deterioration in their economic conditions compared to the previous year tended to exhibit lower yields, indicating the need for targeted policy support to assist these households.

DISCUSSION AND CONCLUSIONS

This paper analyzed the impact of employment, wage labor, and income on agricultural output in Indonesia using cross-sectional data from the country's 2013 Census of Agriculture. The study found that Indonesian farmers actively channeled wage income into spending on agricultural inputs to improve yields. However, agricultural production continued to depend on human labor, and the effect of labor force loss due to wage labor employment was observed. In comparison with the magnitude of the effect, the effect of productivity gains due to labor force loss was larger and was not compensated for by the impact of wage income. This calls for interventions that would increase farm productivity in the face of lower labor use on the farms. Given the significant regional disparities in rice yields and the fact that other regions lag behind the yield levels of high-yielding areas, this situation poses a critical

challenge to national food security, necessitating urgent government intervention.

There are several types of interventions that could address the situation. A potential policy response is to promote more efficient fertilizer use to enhance yields. Currently, the government subsidizes fertilizers in response to rising prices and rigid distribution networks. However, the coexistence of two types of fertilizers, subsidized low-cost fertilizers and unsubsidized fertilizers, complicates the availability of these essential inputs, making it challenging for farmers to access affordable fertilizers when needed.

In the dataset utilized for this analysis, only 31 percent of the households benefited from fertilizer subsidies. Redundancies in distribution channels, which often result from bureaucratic procedures, need to be rectified. There is also a need for greater investments in research and development, and wider availability of agricultural machinery to address labor shortages. As noted in the previous section, only 1.3 percent of the households in the dataset utilized subsidies for machinery, highlighting a clear opportunity for improvement. Only around one quarter of farmers participated in agricultural extension programs. Therefore, it is necessary to widen participation therein to help raise farm productivity and raise their utilization by user associations.

While Indonesia has succeeded in reducing poverty and hunger in recent years with its remarkable economic growth, the country's farm sector remains biased toward rice monocropping, and child malnutrition is a persistent issue (Mehraban and Ickowitz 2021). However, rice monocropping is not an appropriate strategy from a food security perspective. In addition, rice production is concentrated in Java, where the capital is located, and where rice yields are significantly higher than in other regions. Efforts to decentralize rice-growing areas and improve productivity on remote islands are desirable. Agricultural development must be strategically advanced in each region, focusing on the establishment of specialized rice-growing areas in Sumatra and Nusa Tenggara, while promoting the cultivation of subsistence crops in remote regions, such as Maluku and Papua.

The study further revealed that despite overall economic growth, households find it challenging to recover from adverse economic conditions due to economic downturns. In these instances, it is essential to provide temporary income subsidies and emergency assistance grants to enable them to continue purchasing fertilizer and farm equipment. Such measures would effectively mitigate short-term shocks and help prevent declines in harvest yields.

Additionally, expanding income insurance for farmers is crucial to cover crop damage resulting from natural disasters and the impacts of climate change. Disaster insurance and insurance products designed to address climate-related risks can help compensate for the losses caused by such events, thereby stabilizing farmers' livelihoods and production activities. In conjunction with stabilizing farmers' incomes and securing the necessary funds and materials, a multifaceted approach including technical assistance and infrastructure development is essential for mitigating the negative effects of declining economic conditions on agricultural production.

This analysis has limited its focus to paddy rice production. The impact of income source diversification on overall agricultural production also warrants examination under a more comprehensive evaluation, in terms of its effects on utilization of agricultural inputs and decision-making on cropping patterns and farm practices.

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