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The Impact Of Rice Field Productivity On Changes In Paddy Field Areas (LBS) In Indonesia

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ABSTRACT

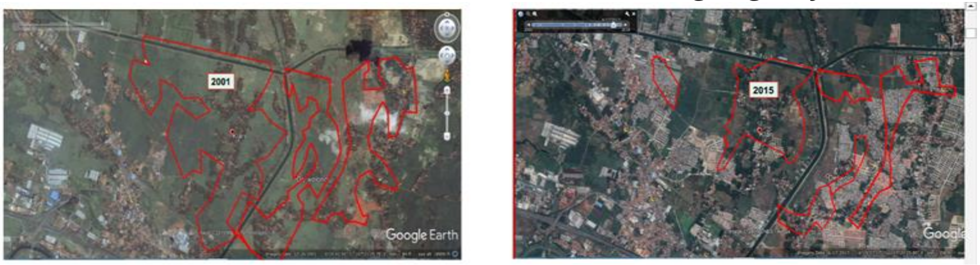
This study analyzes the impact of rice field productivity and other factors on changes in paddy field area (LBS) at the regency/city level in Indonesia. Using panel data from 364 regencies/cities (2010–2022), LBS changes are measured as the average annual percentage change over two periods: 2013–2019 and 2019–2023. To address endogeneity in rice productivity, a two-stage Instrumental Variable (IV) method with fixed effects is applied. The first stage instruments productivity with rainfall and previous productivity, while the second stage assesses its impact alongside control variables, including the agricultural, real estate, and construction sectors, population density, and a Dummy Policy Variable for LP2B protection with lag effects up to three years. Results indicate that rice productivity and other factors are not significant predictors of LBS changes, likely due to land ownership inequality and measurement errors. A restricted sample further suggests that LP2B protection is ineffective in preserving LBS. Using Local Average Treatment Effect (LATE), the IV method estimates policy impacts for regions aligned with instrument variation. The study recommends accelerating land redistribution, certification, technical support, and stricter enforcement at both central and regional levels to safeguard paddy fields.

INTRODUCTION

Agricultural land plays a crucial role in ensuring food security by supporting sustainable food production. As the global population grows, maintaining sufficient farmland is essential to meet increasing food demands. However, various pressures from urbanization, industrialization, and infrastructure expansion have posed significant threats to the sustainability of food production in many countries, including Indonesia. In Indonesia, agricultural land, particularly rice fields, has been undergoing large-scale conversion. Between 2000 and 2015, an average of 96,512 hectares of rice fields was converted annually. If this trend continues, the total agricultural land area is projected to shrink to only 5.1 million hectares by

2045 (Mulyani et al., 2016). For instance, Klari District, Karawang Regency, experienced significant agricultural land conversion between 2001 and 2015 (Figure 1.1). Key drivers of this conversion include population growth, urban expansion, and increasing demand for infrastructure, industry, and housing (Firman, 2004; Long et al., 2021; Putri, 2020).

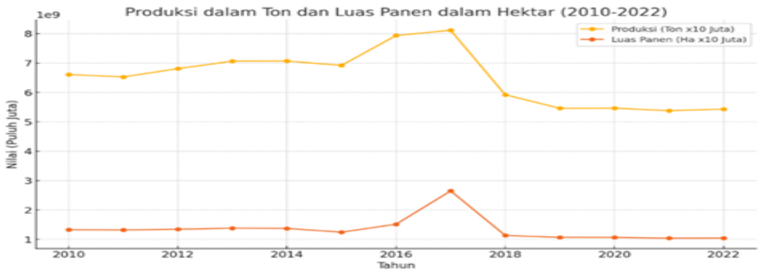
Figure 1 Land Use Conversion in Klari District, Karawang Regency (2001 vs 2015)



Source: Presentation by the Head of the Agricultural Land Resource Research and Development Center, 2015

As Indonesia's population reached 278.7 million in 2023 and is projected to grow to 318.9 million by 2045 (BPS, 2018; BPS, 2024), the pressure on national food demand, particularly for rice, continues to escalate. However, data indicates a fluctuating trend in rice production and harvested area from 2010 to 2022, with a general decline (Figure 1.2). This decline presents a significant challenge to maintaining production stability amid rising food demand. Rice field productivity is a key factor in addressing this challenge. Higher productivity provides economic incentives for farmers to retain land for agricultural use, reducing the likelihood of conversion. Conversely, lower productivity increases economic pressures, making agricultural land more susceptible to conversion into non-agricultural sectors. Previous studies indicate that highly productive land is less likely to be converted than land with lower productivity (Fang et al., 2024; Lanz et al., 2018).

Figure 2 Trend of Rice Production (in Tons) and Harvested Area (in Hectares) in Indonesia (2010-2022)



Source: https://bdsp2.pertanian.go.id/bdsp/id/, data reprocessed.

Recognizing the importance of maintaining rice field productivity and agricultural sustainability, the Indonesian government has implemented strategic measures to ensure food availability through land protection policies. One of the key initiatives is Law Number 41 of 2009 on the Protection of Sustainable Food Agricultural Land (LP2B). This policy aims to prevent the conversion of productive agricultural land to non-agricultural sectors, preserve agricultural land, and support national food security. However, the implementation of this policy faces various challenges. Weak coordination among government agencies has hindered effective enforcement, as observed in Pandeglang (Octavianti & Nurikah, 2021). Additionally, the lack of detailed regulations and the presence of intermediaries or land brokers have rendered the policy ineffective in Sukoharjo (Permono et al., 2020). Furthermore, inadequate land protection incentives have been a common concern among farmers in Surakarta (Sutrisno & Setiawan, 2018). Globally, land protection has become a critical issue with diverse policy approaches. In China, strict regulations have proven effective in protecting high-productivity farmland, although they are only enforced within certain periods (Li, 2014). Meanwhile, OECD countries have successfully combined incentives and regulatory frameworks to maintain food security (DeBoe, 2020). However, subsidy-based policies such as the Common Agricultural Policy (CAP) in the European Union often fail to achieve their objectives due to inadequate adaptation to local conditions (Alig & Ahearn, 2006; Ustaoglu & Williams, 2017).

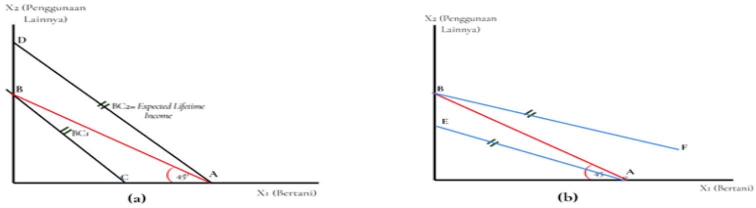
The weaknesses in land protection policy implementation across various countries, including Indonesia, underscore the need for an in-depth analysis of the factors influencing agricultural land changes. Existing studies in Indonesia have largely focused on measuring overall land conversion rates, while research on the specific drivers of Paddy Field Potential Area (LBS) changes at the district/city level remains limited. This study aims to fill this research gap by analyzing the impact of rice field productivity and other contributing factors on LBS changes at the district/city level. The findings will provide an empirical foundation for designing more effective policies to mitigate land conversion. Ultimately, this research is expected to make a significant contribution to understanding the patterns of LBS changes in Indonesia, particularly concerning rice field productivity and food security.

LITERATURE REVIEW

Relative Return Theory and Expected Lifetime Income

In resource economics theory, land-use decisions involve a trade-off between maintaining land for agriculture or converting it to other more profitable uses. These decisions are influenced by the relative returns of both options, which determine the economic incentives for individuals to maximize their lifetime income. The following graph illustrates the expected lifetime income between agricultural use (X_1) and other uses (X_2), which heavily depend on the relative return of the two sectors (productivity and land prices in alternative uses).

Figure 3 Expected Lifetime Income Curve: Agricultural Use (X_1) vs. Other Uses (X_2)



Based on Figure 3, line AB represents the total area of land. In graph (a), line AD reflects the higher expected income resulting from an increase in land prices for alternative uses. Along this line, farming becomes the optimal choice because point A intersects with the initial constraint line, indicating that farming provides a relatively good return compared to land conversion. On the other hand, in graph (b), line BF represents a higher expected income compared to the previous scenario, making farming no longer the optimal choice. Point B, which intersects with the initial constraint line, shows that converting land to the non-agricultural sector is more profitable. The shift from point A to point B indicates that land conversion has become a more profitable option than maintaining the land for farming.

LP2B And LBS: Integrated Land Protection For Food Security

Indonesia safeguards agricultural land through the Protection of Sustainable Food Agricultural Land (LP2B) and Paddy Field Potential Area (LBS) policies, both aimed at preventing land conversion and ensuring food security. LP2B provides a regulatory framework for land protection, while LBS functions as an official database for monitoring paddy fields. Governed by Law No. 41 of 2009, LP2B regulates land conversion and offers incentives such as property tax reductions, technical assistance, and infrastructure support. However, its effectiveness relies on strong coordination between central and regional governments, as enforcement gaps allow land conversion to persist. One major challenge is its overlap with spatial zoning policies, regulated by Law No. 26 of 2007. While Regional Spatial Planning (RTRW) designates land functions in line with LP2B, frequent amendments for strategic projects and investments create loopholes that facilitate conversion, underscoring the need for stricter regulatory oversight.

LBS, designated by Coordinating Minister Regulation No. 18 of 2020 and integrated into the One Map Policy (Presidential Regulation No. 23 of 2021), tracks paddy field changes. Initially recorded at 7,750,999 hectares in 2013 (BPN Decree No. 3296 of 2013), LBS declined to 7,463,948 hectares in 2019 (Minister of ATR/BPN Decree No. 686), and further to 7,384,341 hectares in 2023 (SK LBS_446.1/SK-PG.03.03/V/2024) due to land conversion and data refinement. The 2023 Performance Report noted that by 2022, 374 districts/cities had adopted LP2B regulations covering 8,385,068 hectares. However, challenges such as spatial data inconsistencies, weak enforcement, and limited technical capacity persist. Strengthening LP2B and LBS integration through enhanced monitoring, adaptive policies, and cross-sectoral coordination is crucial for sustaining Indonesia's agricultural land. Table 1.1 summarizes LBS and LP2B implementation at the district/city level through 2022.

Table 1 Recap Of LP2B Designation In District/City RTRW Regional Regulations And Specific LP2B Regional Regulations Through 2022

No.	Category	The number of districts /cities	The area of designation (Ha)	LBS 2019 (Ha)	Details		
					LBS 2019 Established (Ha)	Designation outside LBS 2019 (Ha)	LBS 2019 Not Established (Ha)
1	**2**	**3**	**4 (=6+7)**	**5**	**6**	**7**	**8 (=5-6)**
1	Districts/cities that have established K/LP2B through RTRW/LP2B Regulations	**374**	**8,388,068**				
a	RTRW/LP2B with spatial data	228	5,605,204	5,303,771	4,119,963	1,485,241	1,183,808
b	RTRW/LP2B without spatial data	146	2,782,864	1,671,024	1,010,958	1,771,906	660,066
2	RTRW/LP2B without LP2B area designation	**118**		482,562			482,562
3	Districts/cities without RTRW/LP2B data	**14**		6,182			6,182
	Total	**506**	**8,388,068**	**7,463,539**	**5,130,921**	**3,257,147**	**2,332,618**

Source: Laporan Kinerja Direktorat Jenderal Prasarana dan Sarana Pertanian Tahun, 2023

Land Conversion and Previous Research

Rapid urban expansion and weak land regulations accelerate agricultural land conversion in many countries. In Nigeria and China, this has transformed farmland into non-agricultural zones, threatening food security and the environment (Braimoh & Onishi, 2007; He et al., 2014; Long et al., 2021). In Indonesia, particularly in West Java and DKI Jakarta, farmland has been rapidly converted into residential areas due to rising infrastructure and real estate demands (Mulyani et al., 2016), while industrial expansion in Majalengka has driven farmland conversion into commercial zones (Paramasatya & Rudiarto, 2019). Firman (2004) found that this trend is most pronounced in rapidly urbanizing cities, where weak local governance accelerates land conversion. Additionally, land productivity affects conversion trends—high-productivity land is preserved, while low-productivity land is more vulnerable to urban expansion (Lanz et al., 2018). Studies from Asia and Europe show that increasing agricultural productivity can help mitigate land conversion pressures despite urbanization (Fang et al., 2024). However, agricultural land continues to be repurposed for non-agricultural use.

To address these challenges, various countries have adopted land protection policies with different approaches. In Europe, subsidies and localized regulations have effectively curbed land conversion (Kristensen, 2016). Meanwhile, in China, land quota policies safeguard agricultural land from urban expansion (Wu et al., 2019). In Indonesia, the LP2B policy aims to maintain paddy field productivity; however, its implementation faces significant challenges, including weak inter-agency coordination and limited technical support. These issues, as observed in Sukabumi and Pandeglang, undermine the policy's effectiveness (Gafuraningtyas et al., 2024; Octavianti & Nurikah, 2021). Strengthening policy implementation is therefore essential to safeguarding agricultural land and ensuring long-term food security.

METHODS

Data Sources

This study uses panel data from 2010 to 2022 across 364 districts/cities. LBS change data were obtained from the Ministry of Agrarian Affairs and Spatial Planning/National Land Agency (ATR/BPN). Rice productivity data were sourced from https://bdsp2.pertanian.go.id/bdsp/id/. Sectoral GDP contributions (agriculture, real estate, construction) and population density data were accessed from BPS (https://bps.go.id). LP2B policy data came from the Ministry of Agriculture, while rainfall data, used as an instrumental variable, were obtained from CHRS (https://chrsdata.eng.uci.edu/) and processed using ArcGIS to calculate district/city-level averages.

Variable Types

The dependent variable is the average annual percentage change in LBS at the district/city level, calculated by comparing LBS areas in 2013, 2019, and 2023 over two periods: 2013–2019 and 2019–2023, using the following formula:

$$\text{Average change in LBS} = \begin{cases} \frac{(LBS_{2019} - LBS_{2013})}{LBS_{2013}} \times \left(\frac{100}{6}\right), & \text{for the period 2013-2019} \\ \frac{(LBS_{2023} - LBS_{2019})}{LBS_{2019}} \times \left(\frac{100}{4}\right), & \text{for the period 2019-2023} \end{cases}$$

The independent variable, average rice productivity, is predicted using instrumental variables to address endogeneity: average annual rainfall (mm/year) and previous-period rice productivity (quintals/hectare) at the district/city level. This variable is calculated with three lag periods for each LBS change period: lag 1 (2012–2018, 2018–2022), lag 2 (2011–2017, 2017–2021), and lag 3 (2010–2016, 2016–2020). Control variables include the average contribution of the agricultural, real estate, and construction sectors to regional GDP (%), average population density (people/km^2), and the LP2B policy dummy variable. The dummy is coded as 1 if changes in LBS occur in or after the policy year and 0 otherwise. All control variables are calculated with three lag periods: lag 1 (2012–2018, 2018–2022), lag 2 (2011–2017, 2017–2021), and lag 3 (2010–2016, 2016–2020), representing lag effects before LBS changes.

Analysis Method

This study applies a quantitative two-stage Instrumental Variable (IV) panel method to address endogeneity in rice productivity, using rainfall and previous rice productivity as instruments. Rainfall patterns influence groundwater availability, which is crucial for rice cultivation (Asada & Matsumoto, 2009; Beding et al., 2021). In the first stage, rice productivity is estimated using rainfall and previous productivity, with rainfall data processed in ArcGIS to calculate district/city-level averages. The second stage examines the effect of rice productivity on LBS changes, incorporating control variables with and without the LP2B policy dummy variable, while accounting for lag effects.

Model Analysis

This study employs two regression models to estimate the effect of rice productivity and other factors on LBS changes. To systematically analyze these influences, the following analytical specifications are applied. The first model, without the LP2B policy dummy variable or sample restrictions, analyzes general land conversion patterns and key factors influencing LBS changes. The second model, which includes the LP2B policy dummy variable, is restricted to regions where LBS is within the designated policy area, ensuring the analysis focuses on protected land. This approach minimizes measurement errors and evaluates the policy's effectiveness in reducing land conversion.

First Model:

1stStage:

Average predicted rice productivity$_{it-k}$ = α_0 + α_1. Average rainfall$_{it-k}$ + α_2. Average rice productivity$_{it-(k+1)}$ + γ_i + θ_t + νit

2nd Stage:

Changes in LBS$_{it}$ = β_0 + β_1. Average predicted rice productivity$_{it-k}$ + β_2. Average contribution of the agricultural sector to total GDP$_{it-k}$ + β_3. Average contribution of the real estate sector to total GDP$_{it-k}$ + β_4. Average contribution of the construction sector to total GDP$_{it-k}$ + β_5. Average population density$_{it-k}$ + μ_i + λ_t + ϵ_{it}

Second Model:

1stStage:

Average predicted rice productivity$_{it-k}$ = α_0 + α_1. Average rainfall$_{it-k}$ + α_2. Average rice productivity$_{it-(k+1)}$ + γ_i + θ_t + νit

2nd Stage:

Changes in LBS$_{it}$ = β_0 + β_1. LP2B Protection Policy Dummy + β_2. Average predicted rice productivity$_{it-k}$ + β_3. Average contribution of the agricultural sector to total GDP$_{it-k}$ + β_4. Average contribution of the real estate sector to total GDP$_{it-k}$ + β_5. Average contribution of the construction sector to total GDP$_{it-k}$ + β_6. Average population density$_{it-k}$ + μ_i + λ_t + ϵ_{it}

Robustness Check

This study employs control variables with lagged effects ranging from one to three years to ensure the reliability of the analysis results. Additionally, a fixed effects model with clustered standard errors at the regional level is applied to account for unobserved time-invariant factors (Wooldridge, 2016). The consistency of regression results across different lagged periods will serve as an indicator that the analysis is sufficiently robust.

RESULTS AND DISCUSSION

The descriptive statistics table provides an overview of the characteristics of all the variables used in this study. The descriptive results indicate that the majority of regions have implemented the LP2B protection policy, as reflected in the policy dummy variable. In addition, the average contribution of the agricultural sector to the regional Gross Domestic Product (PDRB) is higher compared to the contributions from the real estate and construction sectors, emphasizing the significant role of the agricultural sector in the regional economy. The average rice productivity is approximately 47 quintals per hectare. All variables have 721 observations, as presented in Table 2, which offers an initial overview of the patterns and characteristics of the data.

Table 2 Descriptive Statistics of Variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Changes in LBS (%/year)	721	0.963	13.187	-16.183	91.599
LP2B Protection Policy Dummy (0: Before, 1: After)	721	0.677	0.468	0	1
Average contribution of the agricultural sector to total GDP (%)_*lagged*1	721	26.493	14.532	0.102	71.927
Average contribution of the real estate sector to total GDP (%)_*lagged*1	721	2.508	1.631	0.02	9.982
Average contribution of the construction sector to total GDP (%)_*lagged*1	721	9.958	4.23	1.341	30.707
Average Rice Productivity (quintals/ha) _*lagged*1	721	47.64	10.509	17.879	103.335
Average Population Density (people/km^2)_*lagged*1	721	784.435	1629.517	1.872	14801.55
Average Rainfall (mm/year)_*Lagged*1	721	3347.988	975.327	1103.338	5080.466

Source: Data processed, 2024

Analysis of Changes in LBS Without the LP2B Protection Policy Dummy Variable

This analysis examines the impact of paddy productivity on LBS changes while identifying broader patterns of change. At this stage, the LP2B protection policy dummy variable is excluded to provide an unbiased perspective on the factors influencing LBS. Table 1.3 presents the estimation results, using a significance threshold of $p<0.05$ to indicate reliable causal relationships. The findings show that paddy productivity and other variables do not significantly impact LBS changes across all tested specifications. Given the IV method's focus on Local Average Treatment Effect (LATE), these results reflect the impact of paddy productivity only on regions affected by instrument variation. The lack of significance underscores the need for a deeper understanding of factors driving farmers' decisions on land use changes.

Table 3 Analysis of Changes in LBS without LP2B Protection Policy Dummy Variable with One to Three-Year Lag Effects

VARIABLE	Dependent Variable: Changes in LBS (%/Year)		
	One-Year Lag Effect	**Two-Year Lag Effect**	**Three-Year Lag Effect**
	(1)	(2)	(3)
Average Rice Productivity (quintals/ha)	0.0849	0.273*	0.336*
	(0.159)	(0.160)	(0.202)
Average contribution of the agricultural sector to total GDP (%)	0.399	0.435	0.395
	(0.402)	(0.355)	(0.343)
Average contribution of the real estate sector to total GDP (%)	-4.095	-5.601*	-5.983*
	(3.476)	(3.234)	(3.147)
Average contribution of the construction sector to total GDP (%)	-0.251	-0.113	-0.171
	(0.754)	(0.977)	(1.160)
Average Population Density (people/km^2)	-0.00326	-0.00418*	0.00178

VARIABLE	Dependent Variable: Changes in LBS (%/Year)		
	One-Year Lag Effect	**Two-Year Lag Effect**	**Three-Year Lag Effect**
	(1)	(2)	(3)
	(0.00235)	(0.00250)	(0.00321)
Constant	1.659	-5.219	-7.554
	(16.58)	(16.74)	(18.23)
Observations	721	721	721
R-squared	0.006	0.007	0.020
Number of districts/cities	364	364	364
Fixed Effects: Time & Regional FE	YES	YES	YES
Clustered Standard Errors at TheRegency/City Level	YES	YES	YES

Note: Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

Lagged 1: The average rice productivity_lag1 is instrumented with the average rainfall_lag1 & average rice productivity_lag2.
The IV test results show that the specification is well-identified (Kleibergen-Paap LM Statistic: 126.296 p-value < 0.05), the instrument is strong (Kleibergen-Paap rk Wald F Statistic: 4073.884>19.93 (Stock-Yogo, 10%)), and valid (Hansen's J Statistic: 0.674 p-value > 0.05).
Lagged 2: The average rice productivity_lag2 is instrumented with the average Rainfall_lag2 & average rice productivity_lag3.
The IV test results show that the specification is well-identified (Kleibergen-Paap LM Statistic: 105.2 p-value < 0.05), the instrument is strong (Kleibergen-Paap rk Wald F Statistic: 10,000>19.93 (Stock-Yogo, 10%)), and valid (Hansen's J Statistic: 0.853 p-value > 0.05).
Lagged 3: The average rice productivity_lag3 is instrumented with the average rainfall_lag3 & average rice productivity_lag4.
The IV test results show that the specification is well-identified (Kleibergen-Paap LM Statistic: 106.05 p-value < 0.05), the instrument is strong (Kleibergen-Paap rk Wald F Statistic: 13,000>19.93 (Stock-Yogo, 10%)), and valid (Hansen's J Statistic: 1.045 p-value > 0.05).

Analysis of Changes in LBS With the LP2B Protection Policy Dummy Variable

This analysis evaluates the impact of LP2B protection policies on LBS changes, considering rice productivity, population density, and economic sector contributions to GDP, with lag effects of one to three years. Significance thresholds are set at p<0.01 or p<0.05, while p<0.1 is deemed unreliable. Table 4 shows that LP2B policy has no significant effect on LBS changes across all specifications. However, in Specification (3), the construction sector's contribution negatively impacts LBS, where a 1% GDP increase in construction correlates with a decline in LBS. Under the Local Average Treatment Effect (LATE) framework, the IV method estimates policy effects for those whose treatment is influenced by instrument variation.

Table 4 Analysis of Changes in LBS with LP2B Protection Policy Dummy Variable with One to Three-Year Lag Effects

VARIABLE	Dependent Variable: Changes in LBS (%/Year)		
	One-Year Lag Effect	**One-Year Lag Effect**	**One-Year Lag Effect**
	(1)	(2)	(3)
LP2B Protection Policy Dummy (0: Before, 1:	-11.02	-3.491	-0.572

VARIABLE	Dependent Variable: Changes in LBS (%/Year)		
	One-Year Lag Effect	**One-Year Lag Effect**	**One-Year Lag Effect**
	(1)	(2)	(3)
After)			
	(10.24)	(10.23)	(10.58)
Average Rice Productivity (quintals/ha)	0.151	0.914	0.491
	(0.776)	(1.007)	(0.794)
Average contribution of the agricultural sector to total GDP (%)	-1.164	0.121	-0.553
	(1.963)	(3.021)	(2.609)
Average contribution of the real estate sector to total GDP (%)	-21.46	-13.40	-17.75
	(19.66)	(24.37)	(24.53)
Average contribution of the construction sector to total GDP (%)	-2.493	-4.229*	-4.414**
	(3.895)	(2.210)	(1.933)
Average Population Density (people/km^2)	0.0209	0.000756	-0.00855
	(0.0497)	(0.0165)	(0.0136)
Constant	107.3	35.36	84.97
	(122.3)	(189.6)	(164.7)
Observations	129	129	129
R-squared	0.145	0.140	0.189
Number of districts/cities	100	100	100
Fixed Effects: Time & Regional FE	*YES*	YES	YES
Clustered Standard Errors at TheRegency/City Level	*YES*	YES	YES

Note: Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

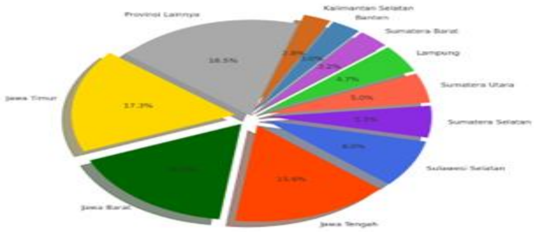
Lagged 1: The average rice productivity_lag1 is instrumented with the average rainfall_lag1 & average rice productivity_lag2.
The IV test results show that the specification is well-identified (Kleibergen-Paap LM Statistic: 8.92 p-value < 0.05), the instrument is strong (Kleibergen-Paap rk Wald F Statistic: 2829.36 > 19.93 (Stock-Yogo, 10%)), and valid (Hansen's J Statistic: 0.179 p-value > 0.05).

Lagged 2:
The average rice productivity_lag2 is instrumented with the average rainfall_lag2 & average rice productivity_lag3.
The IV test results show that the model is well-identified (Kleibergen-Paap LM Statistic: 9.05 p-value < 0.05), the instrument is strong (Kleibergen-Paap rk Wald F Statistic: 569.82 > 19.93 (Stock-Yogo, 10%)), and valid (Hansen's J Statistic: 0.075 p-value > 0.05).
Lagged 3: The average rice productivity_lag3 is instrumented with the average rainfall_lag3 & average rice productivity_lag4.
The IV test results show that the model is well-identified (Kleibergen-Paap LM Statistic: 9.93 p-value < 0.05), the instrument is strong (Kleibergen-Paap rk Wald F Statistic: 937.86 > 19.93 (Stock-Yogo, 10%)), and valid (Hansen's J Statistic: 0.076 p-value > 0.05).

Heterogeneity Analysis

This analysis examines the impact of the LP2B protection policy on LBS changes across Java and Non-Java regions, as well as differences between rice production center and non-center regions. Production centers are defined as districts/cities within the 10 provinces with the highest rice production from 2010 to 2022. Figure 1.4 illustrates the dominance of major rice-producing provinces, while contributions from other provinces remain relatively smaller.

Figure 4 Average Rice Production Proportion in Indonesia (2010-2022): Top 10 Provinces vs Others



Source: https://bdsp2.pertanian.go.id/, reprocessed.

Findings indicate that the LP2B policy has not significantly influenced LBS changes in either Java or Non-Java regions, nor between production center and non-center regions. These results underscore the need to evaluate and refine the LP2B policy to enhance its effectiveness by considering regional characteristics. Strengthening the policy is essential to support sustainable agriculture in Indonesia. Tables 1.5 and 1.6 present a detailed comparison of Java and Non-Java regions, as well as production center and non-center regions, incorporating lag effects of one to three years.

Table 5 Heterogeneity Analysis of the Relationship between LP2B Protection Policy and Changes in LBS: Comparison of Java and Non-Java Regions

	Dependent Variable: Changes in LBS (%/Year)					
VARIABLES	Java Region	Non- Java Region	Java Region	Non- Java Region	Java Region	Non- Java Region
	(1)	(2)	(3)	(4)	(5)	(6)
	Panel A: With 1-Year Lag Effect		**Panel B: With 2-Year Lag Effect**		**Panel C: With 3-Year Lag Effect**	
LP2B Protection Policy Dummy (0: Before, 1: After)	.	-10.77	.	-2.173	.	1.185
	(omitted)	(10.25)	*(omitted)*	(10.13)	*(omitted)*	(10.65)
Control Variables	.	*YES*	.	*YES*	.	*YES*
Constant	.	116.2	.	45.26	.	89.36
		(126.1)		(191.2)		(169.6)
Observations	10	119	10	119	10	119
R-squared	.	0.148	.	0.154	.	0.202
Number of districts/cities	8	92	8	92	8	92
FE: Time & Regional FE	.	*YES*	.	*YES*	.	*YES*
Clustered Standard Errors at The Regency/City Level	.	*YES*	.	*YES*	.	*YES*

Note: Robust standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

The IV test results indicate that the model is well-identified (Kleibergen-Paap LM p-value < 0.05), the instruments are strong (Kleibergen-Paap F-statistic > Stock-Yogo critical value), and valid (Hansen J p-value > 0.05), making the results reliable. The regression is conducted by including the variables of rice productivity (Quintals/Ha), the average contribution of the agricultural sector to total GDP (%), the average contribution of the real estate sector to total

GDP (%), the average contribution of the construction sector to total GDP (%), and the average population density (people/km²).

Table 6 Heterogeneity Analysis of the Relationship between LP2B Protection Policy and Changes in LBS: Rice Production Center and Non-Center Regions

	Dependent Variable: Changes in LBS (%/Year)					
VARIABLES	Production center	Non-Production center	Production center	Non-Production center	Production center	Non-Production center
	(1)	(2)	(3)	(4)	(5)	(6)
	Panel A: With 1-Year Lag Effect		**Panel B: With 2-Year Lag Effect**		**Panel C: With 3-Year Lag Effect**	
LP2B Protection Policy Dummy (0: Before, 1: After)	2.068	-11.55	1.729	-6.381	5.026	-11.61
	(4.233)	(11.87)	(5.014)	(13.33)	(3.495)	(19.35)
Control Variables	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*
Constant	-0.453	65.82	-79.56	-3.156	-11.68	132.9
	(28.75)	(168.8)	(54.38)	(249.8)	(76.89)	(218.1)
Observations	34	95	34	95	34	95
R-squared	0.914	0.255	0.696	0.319	0.638	0.378
Number of districts/cities	26	74	26	74	26	74
FE: Time & Regional FE	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*
Clustered Standard Errors at The Regency/City Level	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*

Note: Robust standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

The IV test results show that the model is well-identified (Kleibergen-Paap LM p-value < 0.05), the instrument is strong (Kleibergen-Paap F-statistic > critical value from Stock-Yogo), and valid (Hansen J p-value > 0.05), making it reliable. The regression was conducted by including the variables of rice productivity (Quintals/Ha), average contribution of the agricultural sector to total GDP (%), average contribution of the real estate sector to total GDP (%), average contribution of the construction sector to total GDP (%), and average population density (people/km²).

DISCUSSION

The Insignificance Of Rice Field Productivity On The Changes In LBS

Farmer's decision to retain or convert land depends on relative returns; farming provides limited income, while selling land for non-agricultural use offers higher immediate gains but sacrifices long-term potential. This study uses rice productivity as a proxy for farming returns and real estate sector contribution for land prices, yet findings show no significant effect of rice productivity on LBS changes, reflecting the structural limitations of Indonesian farmers. Most Indonesian farmers cultivate small plots (≤0.5 hectares), limiting productivity and economies of scale. The 2023 Agricultural Census (BPS) recorded 17.25 million smallholder farmers (62% of agricultural households), many of whom lack land ownership and work as laborers, tenants, or sharecroppers, restricting investment in better farming practices. With profits concentrated among landowners, farmers have little incentive to improve productivity.

Land ownership inequality has persisted for decades. Bachriadi & Wiradi (2011) found that despite a rise in agricultural households from 1973 to 2003, average land per household remained below 1 hectare. Figure 1.7 illustrates the continued growth of small-scale farmers (≤0.5 hectares), exacerbating land distribution disparities. With yields barely sufficient for household consumption, most farmers struggle to expand production. Moeis et al. (2020) found that many rely on non-agricultural income to survive, making land retention decisions driven by short-term financial pressures, such as debt repayment and education costs, rather than long-term productivity gains.

Table 7 Land Ownership of Agricultural Households in Indonesia 1973-2003

Census Year	1973*)	1983	1993	2003
Total number of farmer households (million)	21.6	23.8	30.2	37.7
'Absolute-landless' (million households)	7.1 (33%)	5.0 (21%)	9.1 (30%)	13.4 (36%)
Farmer households using land (million households)	14.5 (67%)	18.8 (79%)	21.1 (70%)	24.3 (64%)
Total land ownership by farmer households using land (million hectares)	14.2	16.8	17.1	21.5
Average land ownership by farmers (hectares)	0.99	0.89	0.81	0.89
Land ownership gini ratio	**0.7**	**0.64**	**0.67**	**0.72**

Source: Research by Bachriadi & Wiradi, 2011

Beyond economic constraints, methodological limitations may also explain why rice productivity has no significant effect on LBS changes. This study uses the real estate sector as a proxy for land prices, which may not fully capture actual land values. Additionally, rice productivity is endogenous, influenced by factors such as irrigation access, which were not accounted for in the model. Adriansyah & Gultom (2023) highlight that limited access to technology and infrastructure has further hindered productivity growth among small farmers. These structural disparities reinforce why rice productivity does not drive LBS changes. Farmers with small plots or insecure land tenure prioritize immediate financial survival over long-term productivity gains. Short-term pressures—such as selling land to cover expenses—limit the impact of productivity improvements on land retention. Urbanization accelerates this trend, as rising land prices and increasing demand for non-agricultural development offer stronger incentives for conversion. In this context, policy interventions must extend beyond productivity enhancements to address land ownership inequality, financial security, and economic diversification for farmers. Without these measures, LP2B protections and productivity gains alone will not be enough to sustain Indonesia's agricultural land.

The Insignificance Of The LP2B Protection Policy On The Changes In LBS

The LP2B Protection Policy has not significantly influenced LBS changes, reflecting challenges in policy implementation. One major issue is limited socialization and technical support, which reduce farmer participation and awareness of the policy's benefits (Gafuraningtyas et al., 2024). Additionally, weak coordination among local agencies has hindered enforcement, making it difficult to implement protective measures effectively (Octavianti & Nurikah, 2021). As a result, farmers lack sufficient motivation to retain their land, particularly because existing land protection incentives are inadequate (Sutrisno & Setiawan, 2018).

Beyond the LP2B policy, other key factors—such as rice productivity, agricultural sector contribution, real estate sector contribution, and population density—do not significantly influence LBS changes. This may be due to measurement errors in estimating relative returns, as real estate sector contribution is used as a proxy for land prices but does not fully capture actual land values. Additionally, rice productivity is endogenous, influenced by external factors like irrigation availability, which were not accounted for in this study. However, the construction sector's contribution to GDP shows a significant negative impact on LBS, indicating growing pressure on agricultural land sustainability. This supports Othman et al. (2021), who highlight that urbanization and infrastructure expansion accelerate land conversion, creating short-term economic incentives for farmers to sell their land.

These findings highlight the urgent need to strengthen LP2B enforcement. Policy improvements should focus on enhancing inter-agency coordination, increasing compliance monitoring, and imposing stricter land-use regulations. Additionally, enforcement mechanisms must ensure that land protection measures are upheld at both local and national levels, with clear legal consequences for unauthorized land conversion. Without these measures, LP2B will remain ineffective in curbing agricultural land loss, ultimately threatening food security and sustainability.

CONCLUSION

The empirical test results using all observations show that rice productivity and all other variables do not have a significant impact on changes in LBS. This insignificance may be caused by potential land ownership inequality, the limited capacity of smallholder farmers, and measurement errors in calculating relative return. Furthermore, the empirical test results with a restrictive sample show that the LP2B protection policy is not significant for changes in LBS, indicating that this policy has not been effective in protecting LBS from conversion. Additionally, in the heterogeneity analysis, the LP2B protection policy does not have a significant impact, either in Java and Non-Java regions, or in rice production center and non-center areas. In the context of LATE, the IV method only estimates the impact on the relevant regional groups with instrument variation.

SUGGESTION

The government needs to accelerate land redistribution accompanied by ownership certification and technical assistance to empower smallholder farmers in improving productivity and reducing land ownership inequality. To strengthen the impact of the LP2B protection policy, stricter enforcement of regulations regarding compliance is required, both by the central and local governments. Future research could use spatial analysis to better understand the impact of the LP2B policy in more depth and specificity at the geographical level.

LIMITATION

This study has several limitations. First, LBS changes are measured using 2013, 2019, and 2023 data from ATR/BPN, covering only two periods (2013–2019 and 2019–2023). Second, the analysis is limited to districts/cities with LBS data and designated LP2B areas, excluding those without such data. Third, aggregate LP2B data restricts detailed spatial analysis of LBS areas under protection. Fourth, rainfall data, used as an instrument, is available only until 2021, missing recent climate variations. Fifth, irrigation data could not be included due to lack of relevant records, such as paddy field irrigation flows. Sixth, the analysis assumes uniform LBS characteristics within districts/cities, potentially overlooking local variations.

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