



The Agricultural Digital Divide: Impact of Internet Penetration on Mechanization Adoption and Labor Productivity in Rural Areas

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ABSTRACT

The agricultural sector faces a structural divide between traditional practices and data-driven digitalization. This research investigates the influence of rural internet penetration on the adoption of modern agricultural machinery and its impact on labor productivity in Indonesia. Utilizing a quantitative framework, the study synthesizes official secondary data from national labor, digital development, and agricultural databases covering 38 provinces. Results demonstrate a significant positive correlation, where high-connectivity regions exhibit a 63.46% higher productivity index compared to digitally isolated areas. Path analysis reveals that internet penetration serves as a critical enabler, where gains in labor efficiency are predominantly mediated by the adoption of physical mechanization. However, low digital literacy in Eastern Indonesia remains a structural constraint. The study concludes that while rural internet penetration plays an important role in accelerating mechanization adoption, its effectiveness in improving agricultural productivity is highly dependent on digital literacy and the integration of digital infrastructure with mechanization practices.

Keywords: agricultural digital divide; internet penetration; mechanization adoption; labor productivity; agriculture 4.0; rural development.

1. Introduction

The global agricultural sector is currently undergoing a critical structural transformation at the intersection of traditional mechanization and data-driven digitalization [1]. In the Indonesian context, the primary challenge has shifted from land availability to production efficiency, which is increasingly constrained by a declining interest among the youth in farming and technological stagnation in rural territories. The phenomenon known as the "Agricultural Digital Divide" has emerged as a pivotal issue where access to digital information is unevenly distributed, subsequently hindering the adoption of modern, precision-based agricultural

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machinery [2]. This gap creates a tangible barrier to the structural transformation of the agrarian sector at the rural level.

While data from the Indonesian Central Bureau of Statistics (BPS) indicates a rising trend in rural internet penetration reaching over 62% of rural households this surge has not yet shown a direct, proportional correlation with an increase in aggregate labor productivity among farmers [3]. This disparity has fostered a new socio-economic stratification within the farming community: a divide between those capable of integrating Smart Farming technologies through digital connectivity and those remains entrenched in subsistence methods due to limited technical information [4]. Consequently, the mere presence of digital infrastructure is insufficient without a corresponding increase in the technical capacity of the users.

According to the Indonesia Digital Society Index (IMDI) released by the Ministry of Communication and Informatics (Ministry of Communication and Information Technology of the Republic of Indonesia), the digital infrastructure and ecosystem pillars in rural areas still lag by approximately 15-20 points compared to urban centers [5]. This gap is not merely a technical connectivity issue; it encompasses a deficit in digital literacy that prevents farmers from mastering the operation of sensor-based machinery or GPS-guided systems. Such disparities directly result in the sluggish dissemination of mechanization knowledge, which is essential for reducing production costs and optimizing output per unit area [6].

The significance of internet penetration in modern mechanization is intrinsically linked to the "Agriculture 4.0" paradigm. Contemporary mechanization transcends the use of simple hand tractors, evolving into integrated systems involving automation, pesticide-spraying drones, and harvesters synced with real-time weather and market databases. In regions where rural internet access is throttled, advanced equipment distributed through government subsidy schemes such as those monitored via the Ministry of Agriculture's SITAN (Agricultural Application Technology and High Value Information System) system often remains underutilized due to a lack of real-time data support [7]. This indicates that the effectiveness of agricultural machinery is highly dependent on the stability of the information network in the field.

Empirical evidence suggests that farmers with consistent internet access are 45% more likely to adopt innovative mechanization technologies than their digitally isolated counterparts [8]. This confirms that the internet serves as a vital informational conduit that mitigates information asymmetry between technology providers and rural end-users.

Regarding labor productivity, the Indonesian agricultural sector faces a daunting challenge in the form of an aging farmer population. National Labor Force Survey (Sakernas) conducted by Statistics Indonesia (BPS) data reveals that over 70% of the agricultural workforce is aged 45 or older, typically with lower formal education levels. In this setting, the internet should ideally



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function as a medium for knowledge transfer to bolster work capacity. However, current trends suggest a "usage gap" where internet penetration is dominated by entertainment consumption rather than productive agricultural utility. The weak correlation between device ownership and actual productivity gains highlights a significant divide in how digital tools are utilized. Meaningful improvements in labor efficiency, measured by the ratio of gross value added to total hours worked, can only be achieved if mechanization is adopted on a large scale, which fundamentally necessitates robust digital literacy [9].

Theoretically, the adoption of technology in rural landscapes follows a diffusion of innovation pattern that is heavily reliant on communication networks. The internet accelerates the stages of persuasion and decision-making regarding mechanization adoption. Without stable connectivity, the perceived risk of failing to implement new technologies remains prohibitively high for smallholder farmers. The integration of information access and physical tool adoption is the primary key to minimizing such technical failure risks.

Consequently, analyzing the nexus between internet penetration and mechanization is no longer optional but a prerequisite for designing effective rural transformation policies. The core objective of this study is to evaluate the extent to which government-led digital infrastructure has successfully reshaped rural mechanization and whether these interventions have effectively boosted labor productivity rates that have historically remained stagnant [10].

This research anchors its analysis on official secondary data harvested from national surveys to ensure the precision of population and sample representations, covering millions of farmers across all provinces. By deconstructing the myth that "digitalization automatically yields prosperity," this article argues that without integration with physical mechanization, rural internet remains a hollow infrastructure that fails to address the root causes of national food productivity issues. Subsequent analytical sections will employ econometric approaches to validate the significance of digital variables on mechanization and productivity outcomes.

2. Materials and Method

The present study utilizes a quantitative explanatory framework designed to assess the causal links between internet penetration, the adoption of agricultural machinery, and labor productivity. Given the study's focus on macro-level dynamics across Indonesia's rural landscapes, the analysis relies exclusively on officially sanctioned secondary data accessible via public domains, ensuring a high degree of transparency and replicability. To strengthen the global relevance of this research, the methodology aligns with international benchmarks for digital agriculture, facilitating comparison with high-impact cross-country studies on the socio-economic impacts of rural digitalization.



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2.1. Data Acquisition and Research Period

The longitudinal and cross-sectional data utilized in this study were compiled from three official institutional databases representing national-level agricultural, labor, and digital development indicators across Indonesia:

- Statistics Indonesia (BPS): Data were obtained from the National Labor Force Survey (Sakernas) and Telecommunication Statistics of Indonesia. The indicators include the percentage of rural households with internet access and the demographic composition of the agricultural labor force. The Sakernas dataset was specifically used to derive labor structure and working-hour estimates relevant to productivity measurement [11].
- Ministry of Communication and Informatics (Kominfo): Data were sourced from the Indonesia Digital Society Index (IMDI) reports. The analysis focuses on two primary dimensions: digital infrastructure and digital literacy, which reflect both access quality and the capacity of rural populations to utilize digital technologies effectively.
- Ministry of Agriculture of the Republic of Indonesia (Kementan): Data on agricultural mechanization were retrieved from the Sistem Informasi Alat dan Mesin Pertanian (Alsintan), which records the distribution and utilization of agricultural machinery, including tractors, combine harvesters, and agricultural drones at the provincial level.

2.2. Population and Sampling

The research population encompasses all agricultural households across the 38 provinces of Indonesia. Given the national scope of this study, province-level aggregate data were employed as a proxy for the overall agricultural population, which is estimated at approximately 29.3 million individuals based on the 2023 Agricultural Census Long Form.

This study adopts a census-based sampling approach (total population sampling), in which all provinces ($N = 38$) are included in the analysis. This approach eliminates regional selection bias and ensures full coverage of the national agricultural landscape. The dataset represents a wide range of rural clusters across the archipelago, providing a comprehensive and statistically representative depiction of the agricultural digital divide from western to eastern Indonesia.

2.3. Operational Definition of Variables

The analysis incorporates three distinct categories of variables:

- Independent Variable (Internet Penetration): Measured as the percentage of rural households within each province that have accessed the internet within the preceding six months. This indicator serves as a proxy for digital accessibility and the potential for real-time agricultural information dissemination.



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- **Mediating Variable (Mechanization Adoption):** Represented by the density of agricultural machinery, measured as the number of machinery units per hectare of agricultural land (specifically rice fields), as well as the frequency of digitally assisted maintenance and operational support. This standardized “per hectare” metric enables consistent comparison of mechanization intensity across provinces with varying land sizes.
- **Dependent Variable (Labor Productivity):** Calculated as the ratio of the agricultural sector’s Gross Value Added (GVA) to the total effective working hours of the agricultural labor force within a given region.

2.4. Analytical Procedures and Modeling

Data processing involved a rigorous synchronization of disparate ministerial databases. The analytical technique employed is Path Analysis within a Multiple Linear Regression framework to examine the mediating effects of mechanization adoption. The governing equation is formulated as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \epsilon$$

Where:

Y = Agricultural Labor Productivity

X_1 = Rural Internet Penetration Rate

X_2 = Mechanization Adoption Index

β = Regression Coefficients

ϵ = Stochastic Error Term

All raw data were tabulated to capture post-pandemic digital acceleration anomalies. Data validity was verified through triangulation, such as cross-referencing rural electrification data from the State Electricity Company (PLN) with BPS internet penetration metrics to ensure infrastructural consistency [12, 13].

2.5. Ethical Approval and Data Availability

This research adheres to ethical standards for secondary data analysis. Since the study utilizes anonymized, aggregated datasets provided by public institutions (Statistics Indonesia, the Ministry of Communication and Informatics, and the Ministry of Agriculture), it does not involve direct intervention with human or animal subjects. Consequently, no specific ethical approval code from an Institutional Review Board (IRB) was required, as the data contains no personally identifiable information (PII) and is categorized as open-access public domain data.



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All materials and protocols used in this study are available through the following official repositories:

BPS Data Portal: <https://www.bps.go.id>

IMDI Kemenkominfo: <https://imdi.kominfo.go.id>

SITAN Kementan: <https://sitan.pertanian.go.id>

3. Result

This section presents the empirical findings derived from the integration of datasets from Statistics Indonesia (BPS) - including the National Labor Force Survey (Sakernas)—the Ministry of Communication and Informatics (Kominfo) through the Indonesia Digital Society Index (IMDI), and the Ministry of Agriculture (Kementerian Pertanian Republik Indonesia) via the agricultural machinery information system database [11]. The analysis focuses on regional disparities and the role of digital integration in accelerating agricultural modernization.

3.1. Landscape of Rural Internet Penetration and Digital Literacy

Recent data indicate a substantial increase in rural internet accessibility; however, a significant “usage gap” persists in terms of productive digital literacy. The Indonesia Digital Society Index (IMDI) shows that while the infrastructure pillar reached a national average score of 45.20, the empowerment pillar—reflecting the effective use of digital tools for economic activities—remains lower at 34.15.

Table 1. Comparative Analysis of Rural Internet Penetration and Digital Literacy Index (2022-2023)

Region (Province)	Rural Internet Penetration (%)	Digital Literacy Index (Scale 1-5)	4G/LTE Network Availability (%)
West Java	72.45	3.65	98.20
East Java	68.12	3.52	96.45
South Sulawesi	58.34	3.12	84.10
East Nusa Tenggara	41.20	2.85	62.30
Papua	26.15	2.10	45.15
National Average	62.10	3.42	88.40

Source: Synthesized from *Telecommunication Statistics of Indonesia (BPS, 2023)* and *IMDI Report (Kominfo, 2023)*.

The data in Table 1 suggest that although 4G/LTE infrastructure is widely available, internet penetration in eastern regions such as Papua and East Nusa Tenggara remains significantly



below the national average. This disparity constitutes a structural barrier to the adoption of data-driven agricultural technologies.

3.2. Correlation Between Internet Access and Mechanization Adoption

Regression analysis reveals a statistically significant positive relationship between internet accessibility and the adoption of agricultural machinery. Provinces with internet penetration rates exceeding 60% exhibit substantially higher mechanization intensity compared to regions with limited connectivity.

Table 2. Modern Mechanization Adoption Ratios Classified by Internet Access Levels

Internet Access Category	Machinery Units (Units/1,000 Ha)	Drone Adoption Rate (%)	Frequency of Online-Assisted Maintenance
High (>70%)	12.45	15.20	65.40
Medium (50-70%)	8.12	5.34	32.15
Low (<50%)	3.45	0.85	10.20
Total/Average	8.01	7.13	35.92

Source: Summarized from the *Agricultural Information System - SITAN* (Ministry of Agriculture, 2023).

To formally assess this relationship, a multiple linear regression analysis was conducted. The results indicate that the model is statistically significant (F – test, $p < .001$), suggesting that internet penetration and mechanization variables jointly explain variations in mechanization adoption. The effect size, measured using Partial Eta Squared $\eta^2 = .42$, indicates that approximately 42% of the variance in mechanization adoption is associated with differences in digital accessibility.

3.3. Impact on Labor Productivity

Labor productivity was measured using Gross Value Added (GVA) per working hour in the agricultural sector. The findings indicate that higher digital connectivity contributes to improved productivity, primarily through more efficient input allocation and reduced labor intensity.



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Table 3. Analysis of Agricultural Labor Productivity (GVA/Working Hour)

Economic Indicator	Digital Group (High Connectivity)	Traditional Group (Low Connectivity)	Variance (%)
Output per Hectare (Tons)	6.45	4.82	33.82
Working Hours per Cycle	320.00	450.00	-28.89
Productivity Index	.85	.52	63.46

Source: Processed from the National Labor Force Survey - Sakernas (BPS, 2023) and OECD efficiency indicators (2020).

Statistical analysis further shows a strong positive correlation between mechanization adoption (X_2) and labor productivity (Y) is robust, with $r = .724$; $p = .002$, indicating a robust association between increased mechanization and higher labor efficiency. Path analysis results demonstrate that internet penetration does not exert a statistically significant direct effect on labor productivity. Instead, its influence is indirectly transmitted through mechanization adoption, confirming its role as an enabling factor rather than a direct driver of productivity gains.

4. Discussion

This study provides empirical evidence that the relationship between internet penetration, agricultural mechanization, and labor productivity operates as an integrated system rather than as isolated variables. The findings demonstrate that digital connectivity alone does not directly translate into productivity gains; instead, its impact is mediated through the adoption of agricultural machinery, reinforcing the importance of digital–physical integration in rural transformation.

The results indicate that regions with higher levels of internet access tend to exhibit significantly greater mechanization intensity, which subsequently leads to improved labor productivity. This supports the argument that digital infrastructure functions as a form of knowledge-enabling capital, reducing information asymmetry and facilitating access to technical guidance, operational support, and innovation diffusion among farmers [14]. In this context, the internet enhances farmers' capacity to adopt advanced technologies—such as automated irrigation systems and precision agriculture tools—by lowering perceived risks and increasing access to real-time problem-solving resources.

However, the study also reveals that the benefits of digital connectivity are conditional upon the presence of sufficient digital literacy and institutional support. The observed productivity



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gap—reaching over 60% between high-connectivity and low-connectivity regions—confirms that digital tools only become economically meaningful when they are effectively utilized in conjunction with mechanized farming practices. This finding aligns with previous research emphasizing that information and communication technologies (ICT) contribute to productivity primarily through their complementarities with physical capital and human skills [9].

A critical dimension emerging from this analysis is the persistent regional disparity, particularly in eastern Indonesia. Provinces such as East Nusa Tenggara and Papua continue to lag behind in both internet penetration and digital literacy, limiting their capacity to benefit from modern agricultural systems. While infrastructure expansion—such as the development of Base Transceiver Stations (BTS)—has improved connectivity, this alone is insufficient to drive structural transformation. Without parallel investments in digital literacy and agricultural extension services, there is a substantial risk that internet usage remains concentrated in non-productive activities. This concern is consistent with broader findings from the OECD, which highlight that technological diffusion without integration into production systems may exacerbate regional inequalities rather than reduce them [10].

From a policy perspective, the findings underscore the necessity of transitioning from fragmented interventions toward a coordinated development strategy. The effectiveness of agricultural modernization depends on the synchronization of digital infrastructure expansion, mechanization programs, and human capital development. In practical terms, this implies that government initiatives—such as machinery distribution programs—should be strategically aligned with regional connectivity levels and supported by targeted training programs. Furthermore, integrating national databases on digital development and agricultural machinery deployment would enable more precise monitoring and evaluation of policy outcomes.

Finally, this study highlights several avenues for future research. Given the reliance on aggregated provincial data, further investigation using micro-level or household data is necessary to capture behavioral and socio-economic heterogeneity among farmers. Additionally, future studies should explore the role of emerging digital ecosystems—including agricultural e-commerce, fintech services, and AI-based advisory systems—in facilitating access to mechanization and improving production efficiency. Longitudinal approaches are also needed to assess the long-term impact of digitalization on rural labor dynamics, particularly in relation to youth participation and rural–urban migration patterns.



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5. Conclusions

This study demonstrates that rural internet penetration plays a crucial role in accelerating mechanization adoption and improving agricultural labor productivity, primarily by reducing information asymmetry and enabling more efficient use of modern agricultural machinery. However, the findings also indicate that the effectiveness of digital infrastructure is highly dependent on the level of digital literacy, as increased internet access alone does not automatically translate into higher Gross Value Added (GVA) in the agricultural sector. The study further confirms that mechanization acts as a key mediating variable linking digital connectivity to productivity gains, highlighting the importance of integrating digital and physical technologies in rural development. Despite the robustness of national-level data, the analysis is limited by its reliance on aggregated provincial datasets, which may not fully capture micro-level variations among farmers. Therefore, it is recommended that policymakers strengthen the alignment between agricultural mechanization programs and rural digital infrastructure development, prioritize digital literacy initiatives in underserved regions—particularly in eastern Indonesia—and encourage future research using primary data to explore household-level dynamics as well as the potential role of emerging technologies such as AI and IoT in enhancing agricultural efficiency.

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