

Rice Production and Food Poverty Vulnerability in North Sulawesi

Maya Hendrietta Montolalu^{1*}, Ellen Grace Tangkere¹, David P. Rumambi², Putri Septiani Narwastu Tangka³

¹Department of Agribusiness, Faculty of Agriculture, Universitas Sam Ratulangi, Manado, Indonesia

²Agricultural Engineering Study Program, Department of Agricultural Technology, Faculty of Agriculture, Universitas Sam Ratulangi, Manado, Indonesia

³Undergraduate Student, Department of Agribusiness, Faculty of Agriculture, Sam Ratulangi University, Manado, Indonesia

Received: February 12, 2026

Revised: March 10, 2026

Accepted: March 25, 2026

Published: March 31, 2026

Corresponding Author:

Maya Hendrietta Montolalu

mayahmr2000@gmail.com

DOI: [10.29303/jppipa.v12i3.15886](https://doi.org/10.29303/jppipa.v12i3.15886)

 Open Access

© 2026 The Authors. This article is distributed under a (CC-BY License)



Abstract: Food security remains a major challenge in developing countries, particularly in relation to the vulnerability of food consumption among low-income households. Rice plays a central role in Indonesia's food system as the main staple food and a key determinant of food availability and access. However, increasing rice production does not necessarily guarantee adequate food consumption if economic access to food remains limited. This study aims to analyze the relationship between rice production, food access factors, and the prevalence of food consumption inadequacy as an indicator of food poverty vulnerability. The analysis employs a Two-Stage Least Squares (2SLS) econometric approach using secondary data from the Indonesian Central Bureau of Statistics and related institutions for the period 2018–2023. The first-stage estimation shows that paddy harvested area is the most significant factor influencing rice production, highlighting the importance of land utilization in determining food availability. In the second stage, the number of poor population emerges as the most influential factor affecting food consumption inadequacy, while income per capita and average rice production contribute to reducing the prevalence of inadequate food consumption. These findings indicate that food insecurity is driven not only by the availability of staple food but also by households' economic ability to access food. Therefore, strengthening food security requires integrated policies that simultaneously support agricultural production, protect agricultural land, and reduce poverty to improve household access to food

Keywords: Food access; Food security; Poverty; Rice; 2SLS econometric model.

Introduction

Food security remains one of the most important challenges in economic development, particularly in developing countries that continue to face poverty and inadequate food consumption. Ensuring that all individuals have access to sufficient and nutritious food is a fundamental responsibility of governments (Anzaini et al., 2022; Montolalu et al., 2024). In this context, food security is determined not only by food supply but also by the ability of households to access food economically and physically (FAO, 2019); (Sulaiman, 2024). Therefore, food security involves multiple dimensions, including

food availability, food access, and food utilization (Kac et al., 2012; Headey & Ecker, 2013).

The agricultural sector plays a strategic role in supporting national food security by providing staple food commodities for the population (Mukhlis et al., 2024). In Indonesia, rice is the primary staple food consumed by the majority of the population and therefore becomes a key determinant of food availability and food stability. Although the contribution of agriculture to the national economy has gradually declined, the sector remains an important source of livelihood and food supply for many households (BPS, 2023). Food security challenges are also closely related to

How to Cite:

Montolalu, M. H., Tangkere, E. G., Rumambi, D. P., & Tangka, P. S. N. (2026). Rice Production and Food Poverty Vulnerability in North Sulawesi. *Jurnal Penelitian Pendidikan IPA*, 12(3), 808–815. <https://doi.org/10.29303/jppipa.v12i3.15886>

poverty conditions. Low-income households tend to allocate a large proportion of their income to food consumption, making them highly vulnerable to fluctuations in food prices and food supply instability. When economic access to food is limited due to low income or rising food prices, the risk of inadequate food consumption increases and may lead to food poverty (FAO, 2019; Soedarto & Hendrarini, 2019).

Previous studies have highlighted the importance of staple food production in strengthening food security and stabilizing food access for vulnerable populations (Timmer, 2010; Li et al., 2026). Rice production, as the main staple food supply in Indonesia, plays an important role in determining the stability of food availability. Higher production levels can increase food supply and potentially improve food accessibility, while declining production may increase pressure on food prices and reduce the ability of households to obtain adequate food. However, food security outcomes are not determined solely by production factors. Economic access variables such as income, household expenditure, and poverty levels also play an important role in determining whether households are able to meet their food needs. The interaction between food availability and food access therefore becomes a crucial mechanism in explaining the prevalence of inadequate food consumption (Xin & Li, 2018; Wu et al., 2024).

Based on these considerations, it is important to analyze the relationship between rice production and vulnerability to food poverty by examining how food availability and food access jointly influence food consumption adequacy. This study aims to analyze the relationship between rice production and the prevalence of inadequate food consumption by integrating indicators of food availability (rice production, harvested area, and productivity) with economic access variables (income, household expenditure, and poverty).

Using secondary data obtained from the Indonesian Central Bureau of Statistics (BPS) and the National Logistics Agency (BULOG) for the period 2018–2023, this study employs an econometric approach using the Two-Stage Least Squares (2SLS) method to estimate the relationships among variables. This approach allows the study to capture the simultaneous relationship between food availability and food access in influencing food consumption adequacy. This study contributes to the literature by integrating agricultural production indicators and socio-economic access variables within a simultaneous econometric framework to better explain the prevalence of inadequate food consumption. Understanding these relationships is expected to provide empirical insights for designing policies aimed at strengthening food security and reducing vulnerability to food poverty.

To clarify the analytical pathway of the study, a conceptual framework is developed to illustrate the relationship between rice availability, food access, and the prevalence of inadequate food consumption.

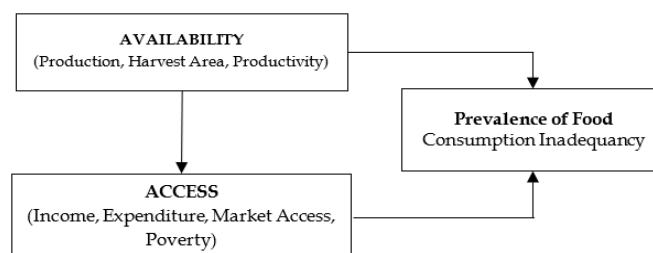


Figure 1. Conceptual rice availability, food access, and food consumption inadequacy

The conceptual framework illustrates that rice availability, represented by production-related variables, influences food supply conditions, while food access variables determine households' ability to obtain food. The interaction of these two dimensions ultimately affects the prevalence of inadequate food consumption.

Method

Research Design, Location, and Period

This study employs a quantitative approach using econometric analysis to examine the relationship between food availability, food access, and vulnerability to food poverty. The analysis focuses on the relationship between rice production and the prevalence of inadequate food consumption through the two main dimensions of food security, namely food availability and food access.

The data used in this study are secondary data (Sugiyono, 2022; Mukhlis et al., 2022; Ogari et al., 2026) obtained from official publications of government institutions, particularly the Indonesian Central Bureau of Statistics (BPS) and the National Logistics Agency (BULOG) Regional Office of North Sulawesi and Gorontalo. The dataset covers the period 2018–2023 and includes various indicators of agricultural production and socio-economic variables related to food security.

This study examines the interaction between rice production as a representation of food availability and socio-economic indicators representing food access, and their influence on the prevalence of inadequate food consumption.

Data collection was conducted through documentation and compilation of statistical reports published by the Indonesian Central Bureau of Statistics (BPS) and food statistics from the National Logistics Agency (BULOG). The collected data include several indicators of agricultural production and household economic conditions that are relevant to food security

analysis. The variables used in this study consist of three main groups: food availability variables, food access variables, and food security indicators.

Data analysis

Data analysis was conducted using an econometric approach through regression analysis and the Two-Stage Least Squares (2SLS) estimation method. This approach is applied to identify the simultaneous relationship between rice production and the prevalence of inadequate food consumption while considering explanatory variables related to food availability and food access.

The data processing and statistical analysis were performed using IBM SPSS Statistics version 26 (Ghozali & Latan, 2015). Time-series data covering the period 2018–2023 were utilized according to the availability of each research variable. The econometric model used in this study consists of two estimation stages.

First Stage Equation:

The first stage model estimates the determinants of rice production as an indicator of food availability.

$$Y_1 = \beta_0 + \beta_1 PHA + \beta_2 TP + \beta_3 PP + \varepsilon \quad (1)$$

Second Stage Equation:

The second stage model analyzes the effect of rice production and food access factors on the prevalence of inadequate food consumption.

$$Y_2 = \beta_0 + \beta_1 Y_1 + \beta_2 IPC + \beta_3 PHE + \beta_4 NPP + \beta_5 PCFE + \beta_6 APP + \varepsilon \quad (2)$$

These equations indicate that the prevalence of inadequate food consumption is influenced by rice production as an indicator of food availability, as well as several socio-economic variables representing household food access. The variables included in the econometric model are defined as follows:

Table 1. Definition Of Research Variables

Variable	Symbol	Unit
Rice Production	Y_1	Tons
Prevalence of Inadequate Food Consumption	Y_2	Percent (%)
Paddy Harvested Area	PHA	Hectares (Ha)
Total Population	TP	Persons
Paddy Productivity	PP	Tons/Ha
Income per Capita	IPC	Indonesian Rupiah (Rp)
Percentage of Household Expenditure	PHE	Percent (%)
Number of Poor Population	NPP	Persons
Per Capita Food Expenditure	PCFE	Indonesian Rupiah (Rp)
Average Paddy Production	APP	Tons

Before estimating the regression model, classical assumption tests were conducted to ensure that the econometric model satisfies the statistical requirements for producing unbiased and efficient parameter estimates. The classical assumption tests performed in this study include normality test, multicollinearity test, heteroskedasticity test, and autocorrelation test.

The normality test is used to determine whether the residuals are normally distributed. The multicollinearity test aims to detect high correlations among independent variables by examining the Variance Inflation Factor (VIF) values. The heteroskedasticity test is conducted to identify unequal variance of residuals across observations, while the autocorrelation test is used to detect correlation among residuals across time periods in the time-series dataset.

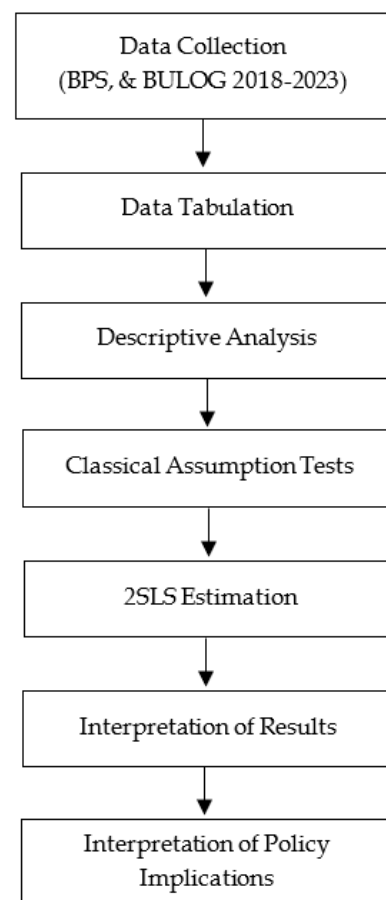


Figure 2. Research Analysis Procedure

Result and Discussion

Descriptive Statistics of Research Variables

Descriptive statistical analysis is conducted to provide an overview of the characteristics of the data used in this study. The descriptive statistics include the mean, standard deviation, minimum value, and maximum value of each research variable.

The variables analyzed represent the two main dimensions of food security, namely food availability and food access. Food availability is proxied by rice production, paddy harvested area, and paddy productivity. Meanwhile, food access is represented by income per capita, household expenditure, the number of poor population, and food expenditure per capita. The prevalence of food consumption inadequacy is used

as an indicator reflecting the level of food insecurity within the population.

Descriptive statistics help illustrate the variability and distribution of the observed variables during the study period. Variations in these variables reflect changes in agricultural production conditions as well as socio-economic dynamics that may influence food security outcomes.

Table 2. Descriptive Statistics of Research Variables

Variable	Mean	Min	Max	Std. Dev.
Rice Production (tons)	5,573333	1,38	11,12	2,188446
Paddy Harvest Area (ha)	12361,96	0	96150,51	22372,43
Paddy Productivity (tons/ha)	5770,912	0	39037	10339,3
Per Capita Income (Rp, constant)	585432,1	301827,8	851164	105477,4
Household Food Expenditure Share (%)	53,03063	40,77	67,61	5,913964
Number of Poor People	8,167111	5,03	13,6	2,358153
Prevalence of Inadequate Consumption (%)	30,79711	0	59,04	19,67038

Trend of Rice Production and Food Consumption Inadequacy

To provide a clearer overview of the relationship between food availability and food consumption conditions, a graphical trend analysis is presented. The figure illustrates the development of rice production and the prevalence of food consumption inadequacy during the study period.

Changes in rice production reflect fluctuations in agricultural output, which may influence the stability of food supply. Meanwhile, the prevalence of food consumption inadequacy reflects the ability of households to meet their food consumption needs.

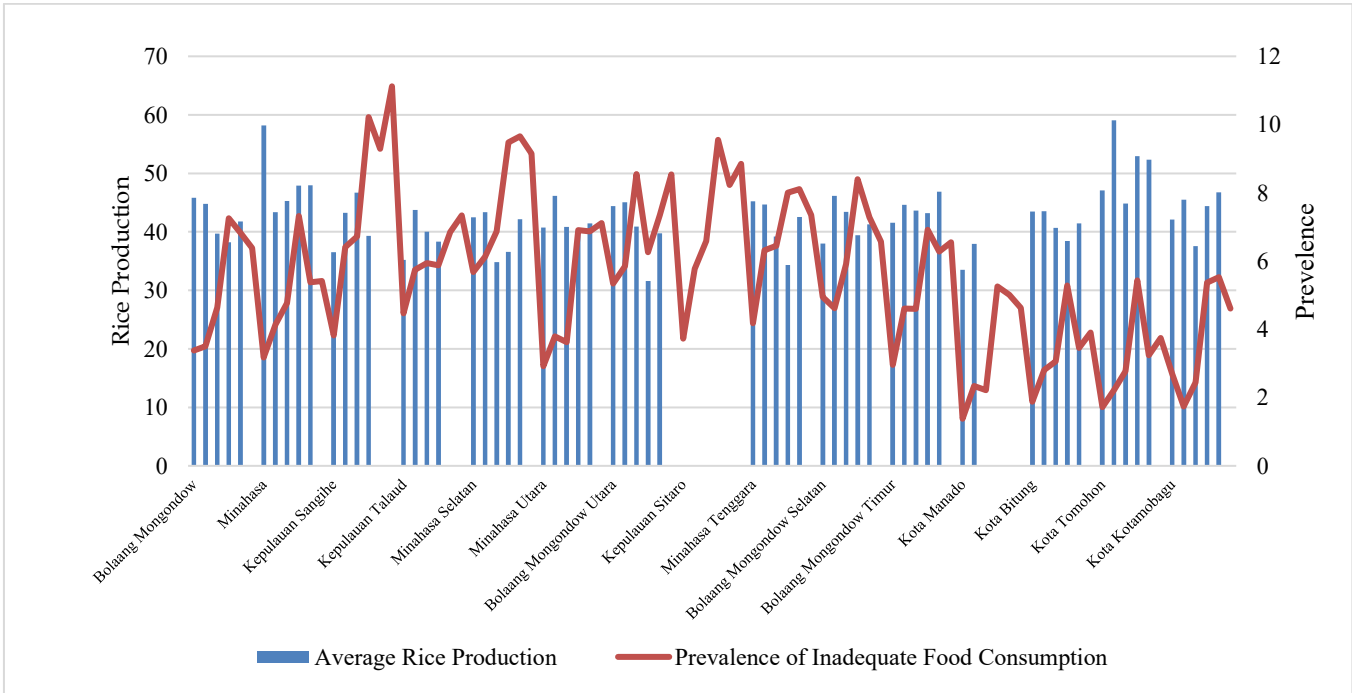


Figure 3. Trend of Rice Production and Food Consumption Inadequacy (2018–2023)

First-Stage Estimation Results (Determinants of Rice Production)

The first stage of the Two-Stage Least Squares (2SLS) estimation examines the determinants of rice production as a proxy for food availability. The

explanatory variables included in this model are paddy harvested area (PHA), population (NP), and paddy productivity (PP).

Table 3. First Stage Regression Result

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-1225.384	1358.139		-.902	.369
1 PHA	2.277	.056	.972	40.823	.001
TP	2.651	4.157	.015	.638	.525
PP	16.587	28.216	.014	.588	.558

a. Dependent Variable: Y1 (Rice Production)

The estimated equation of the first-stage model is:

$$Y1 = -1225.384 + 2.277 \text{ PHA} + 2.65\text{TP} + 16.587\text{PP}$$

The estimation results indicate that paddy harvested area (PHA) has a positive and statistically significant effect on rice production at the 1% significance level ($p = 0.001$). The coefficient value of 2.277 suggests that an increase in harvested area is associated with an increase in rice production, holding other factors constant. This finding confirms the fundamental role of land availability in determining agricultural output. Larger harvested areas allow farmers to produce more rice, thereby increasing overall food supply.

In contrast, population (TP) does not show a statistically significant effect on rice production ($p = 0.525$). Although population growth may increase demand for staple food commodities, the result suggests that population size alone does not directly influence rice production during the study period. This may occur because production decisions are more strongly

influenced by agricultural resources and technological factors rather than demographic pressure.

Similarly, paddy productivity (PP) does not exhibit a statistically significant relationship with rice production ($p = 0.558$). This result may indicate that variations in productivity during the study period were relatively small or that improvements in productivity were not sufficient to significantly influence aggregate rice production.

Overall, the results highlight that land utilization through harvested area remains the most dominant factor influencing rice production, which aligns with agricultural production theory emphasizing land as a primary production factor in crop farming systems (Timmer, 2015).

Second-Stage Estimation Results (Determinants of Food Consumption Inadequacy)

The second stage of the 2SLS estimation evaluates the relationship between rice production, food access variables, and the prevalence of food consumption inadequacy.

Table 4. Second Stage Regression Result

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-.124	2.679		-.046	.963
Y ₁	2.007E-5	.000	.156	1.737	.086
IPC	-6.674E-5	.000	-.199	-2.041	.044
1 PHE	.007	.037	.018	.192	.848
NPP	.340	.107	.369	3.176	.002
PCFE	3.464E-6	.000	.167	1.423	.159
ARP	-.026	.010	-.236	-2,572	.012

a. Dependent Variable: Y2 (Food Consumption Inadequacy)

The estimated equation of the second-stage model is:

$$Y2 = -0.124 + 2.007Y1 - 6.674IPC + 0.007PHE + 0.340NPP + 3.464PCFE - 0.026ARP$$

The results indicate that rice production (Y1) has a positive but statistically insignificant effect on food consumption inadequacy ($p = 0.086$). Although higher rice production theoretically increases food availability, the result suggests that improvements in food supply

alone may not directly reduce food consumption inadequacy. This finding supports the concept that food security is multidimensional and depends not only on food availability but also on economic access to food (FAO, 2017).

Income per capita (IPC) shows a negative and statistically significant effect on food consumption inadequacy ($p = 0.044$). The negative coefficient indicates that higher income levels reduce the prevalence of food consumption inadequacy. This result

highlights the importance of household purchasing power in ensuring adequate food consumption. Higher income enables households to access food more easily and diversify their diets.

The variable household expenditure (PHE) does not show a statistically significant effect on food consumption inadequacy ($p = 0.848$). This may occur because total household expenditure does not necessarily reflect the proportion allocated specifically for food consumption.

Meanwhile, the number of poor population (NPP) has a positive and statistically significant effect on food consumption inadequacy ($p = 0.002$). The coefficient value of 0.340 indicates that higher poverty levels increase the prevalence of inadequate food consumption. This result confirms that poverty remains one of the main determinants of food insecurity because poor households face greater limitations in accessing adequate food.

The variable food expenditure per capita (PCFE) does not show a statistically significant effect ($p = 0.159$). Although food expenditure theoretically reflects food access, the insignificance of this variable may indicate variations in consumption patterns or differences in food price levels across regions.

Finally, average rice production (ARP) has a negative and statistically significant effect on food consumption inadequacy ($p = 0.012$). This finding suggests that improved rice production performance contributes to reducing food consumption inadequacy. Higher rice production may stabilize food supply and reduce the risk of food shortages in the market.

Linking Food Availability and Food Access

The findings of this study highlight the complex relationship between food availability and food access in determining food consumption conditions. While rice production represents the availability dimension of food security, the results suggest that improvements in production alone may not automatically lead to improved food consumption outcomes.

This result supports the multidimensional framework of food security proposed by the Food and Agriculture Organization, which emphasizes that food security is determined by four main pillars: availability, access, utilization, and stability (FAO, 2021).

Economic access variables such as income and poverty show stronger relationships with food consumption inadequacy compared to production variables. This indicates that economic inequality and poverty play a critical role in shaping food consumption patterns, even when food supply at the aggregate level is relatively sufficient.

These findings are also consistent with previous studies highlighting that household income and poverty

status are key determinants of food access and nutritional adequacy (Timmer, 2015).

Implications for Food Security Policy

The results imply that policies aimed at improving food security should not focus solely on increasing agricultural production. While increasing rice production remains important to ensure food availability, policies must also address the economic barriers that limit household access to food.

Programs aimed at poverty reduction, income improvement, and social protection can play a significant role in reducing food consumption inadequacy. At the same time, improving agricultural productivity and expanding harvested areas can strengthen food supply stability.

Therefore, integrated policies that simultaneously address food availability and food access are essential for reducing vulnerability to food poverty.

Study Limitations and Future Research

This study has several limitations that should be acknowledged. First, the analysis relies on secondary macro-level data, which may not fully capture household-level food consumption behavior. Second, the relatively limited observation period may constrain the ability to capture long-term structural changes in food security dynamics.

Future research could incorporate longer time-series data or panel datasets to provide a more comprehensive analysis of the relationship between agricultural production and food security. In addition, including variables such as food price volatility, climate variability, and distribution systems may further enrich the analysis of food consumption vulnerability.

Conclusion

This study aims to analyze the relationship between rice production, food access factors, and the prevalence of food consumption inadequacy as indicators of food security vulnerability. Using the Two-Stage Least Squares (2SLS) estimation approach, the results highlight the interaction between food availability and economic access in shaping food consumption conditions.

The first-stage estimation shows that paddy harvested area (PHA) is the most influential factor in determining rice production. The variable has a positive and statistically significant effect on rice production, indicating that land utilization remains the dominant driver of rice output during the study period. This finding emphasizes the importance of maintaining and optimizing agricultural land use to sustain rice production and ensure adequate food availability. In

contrast, population size and paddy productivity do not exhibit statistically significant effects, suggesting that variations in land utilization play a more critical role than demographic pressure or productivity fluctuations in determining aggregate rice production levels.

The second-stage estimation reveals that the number of poor population (NPP) is the most influential factor affecting the prevalence of food consumption inadequacy. The positive and statistically significant coefficient indicates that higher poverty levels substantially increase the risk of inadequate food consumption. This result highlights that food insecurity is closely associated with economic vulnerability, where households with limited income face greater difficulties in accessing sufficient food. In addition, income per capita (IPC) and average rice production (ARP) show negative and significant effects, indicating that improvements in household income and agricultural production performance contribute to reducing the prevalence of food consumption inadequacy.

These findings confirm that food security is not determined solely by food availability but also by the economic capacity of households to access food. Even when food production increases, food consumption inadequacy may persist if economic access remains limited. Therefore, strengthening food security requires an integrated policy approach that simultaneously supports agricultural production and improves household economic welfare. Policies aimed at protecting agricultural land, increasing productivity, and strengthening the stability of rice supply are essential for maintaining food availability. At the same time, poverty reduction strategies, income improvement programs, and social protection policies are crucial to enhance household access to food.

Acknowledgments

We would like to thank all parties involved in the completion of this research.

Author Contributions

M.H.M.: Developing ideas, analyzing, writing, reviewing, responding to reviewers' comments; E.G.T., D.P.R., P.S.N.T.: analyzing data, overseeing data collection, reviewing scripts, and writing.

Funding

This research received no external funding.

Conflicts of Interest

The authors declare no conflict of interest.

References

Anzaini, B. K., Gantini, T., & Srimenganti, N. (2022). Analisis Ketahanan Pangan Berdasarkan Proporsi

- Pengeluaran Dan Konsumsi Energi (Suatu Kasus Pada Rumah Tangga Petani Buruh Di Desa Gunungmanik Kecamatan Tanjungsari Kabupaten Sumedang). *Orchid Agri*, 2(2), 76–85. <https://doi.org/http://dx.doi.org/10.35138/orchidagri.v2.i2.441> Analisis
- BPS. (2023). *Indonesia dalam Angka*. Badan Pusat Statistik Indonesia.
- FAO. (2019). *The State of Food Security and Nutrition in the World 2019*. Food and Agriculture Organization.
- FAO. (2021). *Sustainable agriculture and food security*. Food and Agriculture Organization.
- Ghozali, I., & Latan, H. (2015). *Partial Least Squares Konsep, Teknik dan Aplikasi Menggunakan Program SmartPLS 3.0* (Ed. Ke-2). Badan Penerbit Universitas Diponegoro.
- Headey, D., & Ecker, O. (2013). Rethinking the measurement of food security : from first principles to best practice. *International Food Policy Research Institute (IFPRI)*, 5, 327–343. <https://doi.org/10.1007/s12571-013-0253-0>
- Kac, G., Vela'squez-Melendez, Schlusell, M. M., Segall-Correa, A. M., Silva, A. A., & Pe'rez-Escamilla, R. (2012). Severe food insecurity is associated with obesity among Brazilian adolescent females. *Public Health Nutrition*, 15(10), 1854–1860. <https://doi.org/10.1017/S1368980011003582>
- Li, S., Zhang, Z., Xu, J., Han, J., Zhuang, H., Cui, X., Cai, H., Xiao, C., Yang, S., & Tao, F. (2026). Global food security under a sustainability perspective: Assessment, challenges, and strategies. *Geography and Sustainability*, 100495. <https://doi.org/10.1016/j.geosus.2026.100495>
- Montolalu, M. H., Tangkere, E. G. J., Timban, F. J., & Kaban, M. A. (2024). Analisis Sektor Pertanian dan Kemiskinan Studi Kasus Prevalensi Stunting di Sulawesi Utara. *Jurnal Manajemen STIE Muhammadiyah Palopo*, 10(2), 393–407. <https://journal.stiem.ac.id/index.php/jurman/article/view/2235/949>
- Mukhlis, Hendriani, R., Sari, R. I. K., & Sari, N. (2022). Analisis Produksi dan Faktor Produksi Usaha Tani Terpadu Tanaman Padi dan Ternak Sapi di Nagari Taram Kecamatan Harau. *Jurnal Penelitian Pertanian Terapan*, 22(2), 104–110. <https://doi.org/10.25181/jppt.v22i2.2581>
- Mukhlis, M., Ismawati, I., Sillia, N., Fitrianti, S., Ukrita, I., Wisra, R. F., Rafli, H., Hendriani, R., Hanum, L., Ibrahim, H., Nofianti, S., Marta, A., & Sari, N. (2024). Characteristics of Production Factors and Production of Zero Tillage System Rice Farming. *Jurnal Penelitian Pendidikan IPA*, 10(8), 6013–6019. <https://doi.org/10.29303/jppipa.v10i8.8542>
- Ogari, P. A., Lastinawati, E., Ritonga, U. S., Oktarina, Y., Sari, R. N., & Mukhlis. (2026). Evaluating Tiered

- Facilitation as a Contextual Learning Approach for CPPOB Adoption in Food MSMEs. *Jurnal Penelitian Pendidikan IPA*, 12(1), 593–599. <https://doi.org/10.29303/jppipa.v12i1.13882>
- Soedarto, T., & Hendrarini, H. (2019). Pengembangan Perilaku Petani Dalam Mewujudkan. *SCAN*, XIV(2), 45–48. <https://doi.org/https://doi.org/10.33005/scan.v14i2.1486>
- Sugiyono. (2022). *Metode Penelitian Kuantitatif, Kualitatif, dan R&D*. Alfabeta.
- Sulaiman, N. A. A. B. (2024). *Understanding Food Security Challenges*. <https://doi.org/https://doi.org/10.13140/RG.2.2.17967.14245>
- Timmer, C. P. (2010). Reflections on food crises past. *Food Policy*, 35(1), 1–11. <https://doi.org/10.1016/j.foodpol.2009.09.002>
- Wu, H., Zhang, Z., Xu, J., Song, J., Han, J., Zhang, J., & Mei, Q. (2024). Food consumption away from home had divergent impacts on diet nutrition quality across urban and rural China. *Food Security*, 0123456789. <https://doi.org/10.1007/s12571-024-01514-4>
- Xin, L., & Li, P. (2018). Food consumption patterns of Chinese urban and rural residents based on CHNS and comparison with the data of national bureau of statistics. *Journal of Natural Resources*, 33(1), 75–84. <https://doi.org/10.11849/zrzyxb.20161207>