Beyond Digital Adoption: Digital Ecosystem Embeddedness and Food Security Resilience among Millennial Farmers in Island Communities

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Strengthening food security resilience in island regions requires a deeper understanding of how millennial farmers' embeddedness in digital ecosystems contributes to agricultural productivity and food security resilience. This study examines the direct effect of Digital Ecosystem Embeddedness on Food Security Resilience and its indirect effect through Agricultural Productivity in South Nias Regency, Indonesia. An explanatory quantitative research design was employed, using primary data collected through a structured questionnaire administered to 75 millennial farmers across five villages in South Nias Regency. The data were analyzed using partial least squares structural equation modeling (PLS-SEM). The results indicate that Digital Ecosystem Embeddedness has a positive and statistically significant effect on Agricultural Productivity ($\beta = 0.249$, $t = 2.921$, $p = 0.004$) and Food Security Resilience ($\beta = 0.254$, $t = 4.309$, $p < 0.001$). However, the indirect effect of Digital Ecosystem Embeddedness on Food Security Resilience through Agricultural Productivity is not statistically significant ($\beta = 0.108$, $t = 1.950$, $p = 0.051$), indicating that Agricultural Productivity does not significantly mediate this relationship at the 5% significance level. These findings suggest that digital ecosystem embeddedness is directly associated with enhanced agricultural productivity and stronger food security resilience among millennial farmers, although the productivity-mediated pathway remains statistically unsupported. The study highlights the importance of strengthening digital agricultural ecosystems by expanding farmers' access to information, markets, business networks, and productive resources to support food security resilience in geographically dispersed island communities.

Keywords: Digital Ecosystem Embeddedness; Agricultural Productivity; Food Security Resilience; Millennial Farmers; Island Regions; PLS-SEM

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1. Introduction

Food security can no longer be understood solely in terms of ensuring adequate food availability; it must also encompass the capacity of food systems to withstand, adapt to, and recover from disruptions [1]. Climate change, price volatility, supply chain disruptions, and economic uncertainty have made Food Security Resilience increasingly important, particularly in regions facing geographical and infrastructural constraints [2]. Recent literature emphasizes that food security resilience depends not only on agricultural production capacity but also on resource allocation efficiency, information accessibility, stakeholder connectivity, and adaptive capacity to manage emerging risks [3].

These challenges are particularly relevant to South Nias Regency, Indonesia, an island region where geographical constraints can increase distribution costs, restrict market access, and intensify dependence on interregional supply networks. Under such conditions, disruptions in agricultural production or distribution may directly affect food availability, affordability, and stability. Consequently, food security challenges in South Nias extend beyond agricultural output to encompass the capacity of local agricultural

systems to maintain essential functions and withstand disruptions under changing and uncertain conditions.

Digital technologies offer opportunities to mitigate some of these challenges. Mobile applications, social media, e-commerce, digital agricultural extension services, weather information systems, digital payments, and agricultural platforms can enhance farmers' access to information, markets, production inputs, financing, and knowledge. [4] demonstrate that digital technologies can support smallholder farmers' production and marketing decisions, while [5] highlight the potential of e-commerce platforms to expand market access and improve information flows. However, these benefits do not arise automatically from technology ownership or adoption. Inadequate infrastructure, limited digital literacy, financial constraints, and insufficient institutional support remain significant barriers to effective agricultural digitalization [6].

These conditions highlight the limitations of approaches that assess agricultural digitalization solely through device ownership, frequency of use, or technology adoption [7]. Farmers may use smartphones and social media without necessarily establishing productive relationships with buyers, input suppliers, financial institutions, agricultural extension agents, or business communities [8]. Evidence from Indonesian millennial farmers indicates that successful digitalization depends not only on technology adoption but also on infrastructure readiness and the dynamics of the surrounding business ecosystem [9]. Therefore, agricultural digitalization should be conceptualized as a process of integrating farmers into interconnected networks of stakeholders and resources within a broader digital ecosystem.

Accordingly, this study adopts the Digital Ecosystem Embeddedness perspective, which refers to the extent to which farmers are embedded in digital networks connecting them to information, markets, input suppliers, financial services, agricultural extension services, institutions, and other actors within the agricultural value chain. This perspective distinguishes technology use from digital embeddedness. While technology use reflects whether farmers adopt particular devices or platforms, digital embeddedness captures the extent to which such engagement fosters sustained relationships, resource accessibility, valuable information exchange, and opportunities for transactions and collaboration [10]. Previous research on digital platforms and digital innovation ecosystems suggests that the value of digitalization emerges primarily through stakeholder coordination and resource exchange rather than isolated individual technology use [11].

Theoretically, Digital Ecosystem Embeddedness can enhance Agricultural Productivity by enabling farmers to access timely information on market prices, weather conditions, crop diseases, cultivation techniques, market demand, and input availability. Such connectivity can reduce information asymmetry and search costs, improve decision-making accuracy, and enhance resource utilization efficiency. Recent evidence suggests that agricultural digitalization can improve productivity and farm performance through greater efficiency, knowledge dissemination, and informed decision-making [12].

Agricultural Productivity may subsequently strengthen Food Security Resilience by enhancing farmers' capacity to sustain production, maintain income, and withstand disruptions. However, productivity is not the only potential pathway. Digital Ecosystem Embeddedness may also directly enhance resilience by facilitating rapid access to weather information, price fluctuations, alternative buyers, financing, and agricultural extension services. [13] demonstrate that digital agriculture development is associated with improved agrifood system resilience, while [14] report that rural digital transformation can strengthen Food Security Resilience through technological advancement and more efficient resource allocation.

Despite these developments, several research gaps remain. First, agricultural digitalization studies have predominantly focused on technology adoption, digital literacy, and platform utilization, while farmers' embeddedness within digital ecosystems has received limited attention as an integrated construct. Second,

existing research has primarily examined productivity, income, efficiency, and market access as outcomes, whereas Food Security Resilience remains relatively underexplored in digital agriculture literature. Third, the mediating role of Agricultural Productivity in the relationship between Digital Ecosystem Embeddedness and Food Security Resilience has rarely been empirically investigated. Fourth, much of the existing evidence originates from China, Africa, and regions with geographical and agricultural characteristics that differ from those of the Indonesian archipelago, limiting its contextual applicability to millennial farmers in South Nias Regency.

Accordingly, this study addresses whether Digital Ecosystem Embeddedness enhances Food Security Resilience among millennial farmers and to what extent this relationship is mediated by Agricultural Productivity. By focusing on South Nias Regency, the study examines how digital connectivity translates into productive capacity and food security resilience within an island agricultural context. Theoretically, it extends digital agriculture research beyond technology adoption toward an ecosystem embeddedness perspective. Empirically, it investigates Agricultural Productivity as a potential mediating mechanism linking Digital Ecosystem Embeddedness to Food Security Resilience.

2. Literature Review and Problem Statement

Food Security Resilience

Food Security Resilience refers to the capacity of individuals, households, communities, and food systems to maintain essential food security functions, absorb shocks, adapt to changing conditions, and recover from disruptions [15]. Unlike static food security measures, resilience emphasizes adaptive capacity and long-term stability under uncertainty. Agricultural systems increasingly face multidimensional risks, including climate change, price volatility, supply chain disruptions, input shortages, and market instability. Resilient food systems must therefore sustain production, reallocate resources, and maintain food accessibility during crises. Recent evidence highlights technological innovation, resource allocation efficiency, and adaptive capacity as key determinants of agrifood resilience [16]. At the farm level, resilience extends beyond production output to encompass information accessibility, market connectivity, resource mobilization, and adaptive farming strategies. Digitalization strengthens these capabilities by facilitating information exchange and stakeholder collaboration [17], particularly in geographically isolated regions where physical access to agricultural resources remains constrained.

Agricultural Productivity

Agricultural Productivity reflects farmers' ability to generate agricultural output through the efficient utilization of productive resources, including land, labor, capital, technology, and knowledge. Beyond conventional inputs, productivity increasingly depends on information accessibility, resource allocation, and production decision-making [13]. Digital agriculture facilitates access to weather forecasts, market prices, cultivation techniques, input management, and market demand, thereby reducing uncertainty and information asymmetry. [18] highlights the potential of digital technologies to improve agricultural efficiency and productivity. Similarly, [19] demonstrate that digitalization contributes to the performance and productivity of Indonesian millennial farmers, although its effectiveness depends on infrastructure readiness and supportive ecosystems. Recent evidence further indicates that digitalization benefits smallholder farmers by expanding access to information, services, and markets [20]. Accordingly, Agricultural Productivity reflects farmers' capacity to effectively integrate conventional production inputs with informational, technological, and relational resources obtained through digital ecosystem embeddedness [21].

Digital Ecosystem Embeddedness and *Food Security Resilience*

Digital Ecosystem Embeddedness refers to farmers' integration into digital networks connecting information, markets, technologies, institutions, and economic resources. Grounded in embeddedness theory, economic activities are shaped by interconnected social and economic relationships [12]. Previous studies demonstrate that digital embeddedness enhances farmers' social networks, resource accessibility, entrepreneurial learning, and performance [22]. Within agrifood ecosystems, digital value creation emerges through connectivity, resource exchange, and stakeholder collaboration [11]. Such embeddedness may strengthen Food Security Resilience by improving access to weather information, market prices, alternative markets, and institutional support, thereby enhancing farmers' adaptive capacity [23]. However, these benefits depend on infrastructure quality, digital literacy, information reliability, and institutional support [24][25]. Thus, food security resilience depends not merely on technology adoption but also on farmers' effective integration into productive and collaborative digital ecosystems.
H1: Digital Ecosystem Embeddedness has a positive and significant effect on Food Security Resilience.

Digital Ecosystem Embeddedness and *Agricultural Productivity*

Digital Ecosystem Embeddedness enhances Agricultural Productivity by expanding farmers' access to production-related information, technologies, and resources. Digital connectivity facilitates timely information on agricultural inputs, cultivation practices, weather, market prices, and crop diseases, reducing information asymmetry and improving decision-making. Connections with suppliers, buyers, extension services, and farming communities further strengthen resource accessibility and knowledge exchange. [25] highlight the contribution of digital platforms to market access, knowledge dissemination, and adaptive agricultural practices. Similarly, [22] demonstrate that digital ecosystem embeddedness improves farmers' performance through social networks, continuous learning, and resource management. However, productivity gains depend on farmers' digital capabilities, technological readiness, and supportive ecosystems [11][12]. Thus, digital embeddedness strengthens productivity when connectivity translates into effective resource utilization.
H2: Digital Ecosystem Embeddedness positively and significantly influences Agricultural Productivity.

Agricultural Productivity and *Food Security Resilience*

Agricultural Productivity contributes to Food Security Resilience by strengthening farmers' productive and economic capacities to withstand disruptions [26]. Higher productivity generates production surpluses, increases household income, and improves farmers' ability to manage price volatility, rising input costs, and production shocks [27]. However, productivity and resilience are conceptually distinct; productivity reflects output generation, whereas resilience involves maintaining essential functions, adapting to disturbances, and recovering from shocks [28]. Thus, productivity alone cannot ensure resilience without adaptive capacity, resource diversification, information accessibility, and market flexibility. [13] demonstrate that digital agriculture enhances climate resilience in agrifood systems, while [29] identify technological advancement and resource allocation efficiency as mechanisms strengthening Food Security Resilience. These findings suggest that productive capacity and operational efficiency support farmers' ability to maintain food availability and economic stability under uncertainty.
H3: Agricultural Productivity positively and significantly influences Food Security Resilience.

The Mediating Role of Agricultural Productivity

Agricultural Productivity may mediate the relationship between Digital Ecosystem Embeddedness and Food Security Resilience by transforming digital resources into productive capacity [30]. Digital embeddedness facilitates access to information, technology, markets, social networks, and agricultural

resources, while productivity reflects farmers' ability to convert these advantages into improved production outcomes. [14] demonstrate that digital ecosystem embeddedness influences farmers' entrepreneurial performance through social networks, learning, and resource management, supporting the potential role of intermediary mechanisms. Similarly, digital technologies enhance agricultural decision-making, resource utilization, and productivity [19]. Improved productivity may subsequently strengthen farmers' capacity to maintain food availability and economic stability during disruptions. Furthermore, [31] emphasize technological advancement and resource allocation efficiency as mechanisms linking digital transformation to agrifood resilience.

H4: Agricultural Productivity significantly mediates the relationship between Digital Ecosystem Embeddedness and Food Security Resilience.

3. Method

Proposed Research Model

The proposed research model examines the relationships among Digital Ecosystem Embeddedness, Agricultural Productivity, and Food Security Resilience among millennial farmers in South Nias Regency, Indonesia. Digital Ecosystem Embeddedness serves as the exogenous construct, Agricultural Productivity as the mediating construct, and Food Security Resilience as the endogenous construct. Four hypotheses are proposed: Digital Ecosystem Embeddedness influences Food Security Resilience (H1) and Agricultural Productivity (H2); Agricultural Productivity influences Food Security Resilience (H3); and Agricultural Productivity mediates the relationship between Digital Ecosystem Embeddedness and Food Security Resilience (H4).

Data were collected using structured questionnaires administered to millennial farmers across five villages selected to capture diverse farming conditions and agricultural environments. Participation was voluntary, and responses were used exclusively for research purposes. Following data completeness screening, 75 valid questionnaires were retained for PLS-SEM analysis.

Research Design and Data Collection

This study employed a quantitative cross-sectional survey design involving 75 millennial farmers actively engaged in agricultural production across five villages in South Nias Regency, Indonesia. Primary data were collected through directly administered questionnaires measuring farmers' perceptions of Digital Ecosystem Embeddedness, Agricultural Productivity, and Food Security Resilience, particularly their capacity to maintain food security under changing or disruptive conditions. Digital ecosystem embeddedness encompasses not only technology adoption but also access to information, business networks, markets, and productive resources. Previous studies indicate that farmers' digital embeddedness is associated with network access and performance, while digital transformation depends on interactions among technology, infrastructure, and business ecosystems. The sample size was considered in relation to the parsimonious model comprising three latent constructs and a maximum of two predictors for an endogenous construct. Sample adequacy in PLS-SEM should account for model complexity, statistical power, and anticipated effect sizes rather than relying solely on indicator-based rules. Accordingly, PLS-SEM was employed to examine the explanatory and predictive relationships among the constructs.

Measuring Instruments

Table 1. Measurement Scales for Variables

Variable	Code	Measurement Items
Digital Ecosystem Embeddedness (X)	DE1	I am connected with other farmers through digital platforms or media to support my agricultural activities.
	DE2	I regularly exchange agricultural information and knowledge through digital networks.
	DE3	Digital platforms help me connect with suppliers of agricultural inputs and production materials.
	DE4	Digital networks help me connect with buyers or markets for my agricultural products.
	DE5	Digital networks make it easier for me to access information or services from agricultural extension agents, government agencies, financial institutions, and other agricultural support organizations.
	DE6	The relationships I establish through digital ecosystems help me obtain the information and resources needed to manage my farming activities.
	DE7	[Proposed] My participation in digital agricultural networks creates opportunities for sustained collaboration with other stakeholders in the agricultural value chain.
Agricultural Productivity (Z)	AP1	My farming activities generate agricultural output commensurate with the resources used.
	AP2	I am able to utilize land, labor, and agricultural production inputs efficiently.
	AP3	The use of agricultural inputs in my farming operations is becoming increasingly effective.
	AP4	I am able to complete agricultural production activities within the planned timeframe.
	AP5	The quality of my agricultural products continues to improve.
	AP6	I am able to maintain agricultural productivity despite changes in production or market conditions.
	AP7	[Proposed] I am able to minimize production losses through effective management of agricultural activities.
	AP8	[Proposed] My farming operations have become more productive in terms of agricultural output relative to the resources utilized.
Food Security Resilience (Y)	FR1	My household is able to maintain food availability when agricultural activities are disrupted.

Variable	Code	Measurement Items
	FR2	My household can continue to obtain the food it needs despite changes in economic or production conditions.
	FR3	I am able to adapt my farming activities to changes in weather, production conditions, or market circumstances.
	FR4	I have alternative options available when agricultural production declines.
	FR5	I am able to restore my farming operations and meet household food needs after experiencing disruptions.
	FR6	I can access the information or resources needed when facing challenges that threaten continued food security.
	FR7	My household is able to maintain relatively stable food security conditions over time.

Data Analysis

Data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) with SmartPLS software. This approach was selected for its suitability in explaining and predicting relationships among latent constructs and examining direct and mediating effects within a structural model.

The analysis involved two stages. First, the measurement model was assessed for reliability and validity using outer loadings (≥ 0.708), Cronbach's alpha and composite reliability (CR > 0.70), average variance extracted (AVE > 0.50), and the heterotrait–monotrait ratio (HTMT < 0.90) to establish discriminant validity. Second, the structural model was evaluated using the variance inflation factor (VIF) to assess collinearity, path coefficients (β) to estimate relationships among constructs, the coefficient of determination (R^2) to assess explanatory power, effect size (f^2) to determine individual predictor contributions, and predictive relevance (Q^2) to evaluate the model's predictive relevance.

Hypotheses were tested using a bootstrapping procedure with 5,000 resamples at a 5% significance level ($t > 1.96$; $p < 0.05$) for two-tailed tests. The mediating effect of Agricultural Productivity on the relationship between Digital Ecosystem Embeddedness and Food Security Resilience was examined through the specific indirect effect. Mediation was considered statistically significant when the indirect effect was significant and its bootstrapped confidence interval excluded zero.

4. Results And Discussion

Respondent Profile

Table 2. Respondent Demographics

	Scale	N	Percentage (%)
Gender	Male	43	57.33%
	Female	32	42.67%
Age	20–25 Years	17	22.67%
	26–30 Years	23	30.67%
	31–35 Years	20	26.67%

	Scale	N	Percentage (%)
	36–40 Years	15	20.00%
Education	Junior High School	8	10.67%
	Senior High School	39	52.00%
	Diploma	8	10.67%
	Bachelor's Degree	20	26.67%
Total Respondents		75	100%

Source: Data processed by the authors, 2026.

Table 2 presents the demographic characteristics of the 75 millennial farmers participating in this study. Male respondents represented 57.33% of the sample, while female respondents accounted for 42.67%. The largest age group was 26–30 years old (30.67%), followed by respondents aged 31–35 years (26.67%), 20–25 years (22.67%), and 36–40 years (20.00%). Regarding education, most respondents had completed senior high school (52.00%), followed by respondents holding a bachelor's degree (26.67%). Junior high school and diploma graduates represented 10.67% each. Overall, the sample was dominated by productive-age millennial farmers with senior high school educational backgrounds.

Measurement Model Assessment

The measurement model was evaluated based on indicator reliability, internal consistency, and convergent validity using outer loadings, Cronbach's alpha, composite reliability (rho_A and rho_C), and Average Variance Extracted (AVE). The recommended thresholds were outer loadings > 0.708, reliability coefficients > 0.70, and AVE > 0.50 (Hair et al., 2022; Hair & Alamer, 2022). As shown in Table 3, all indicators exhibited satisfactory outer loadings (0.877–0.930), with values ranging from 0.905–0.930 for Digital Ecosystem Embeddedness, 0.899–0.923 for Agricultural Productivity, and 0.877–0.904 for Food Security Resilience. The AVE values were 0.842, 0.826, and 0.795, respectively, exceeding the recommended threshold. Cronbach's alpha (0.957–0.970), rho_A (0.957–0.970), and rho_C (0.965–0.974) also demonstrated strong internal consistency. Overall, these findings confirm satisfactory indicator reliability, internal consistency, and convergent validity across all constructs.

Table 3. Reliability and Convergent Validity

Variable	Item	Outer Loading	Cronbach's Alpha	rho_A	rho_C	AVE
Digital Ecosystem Embeddedness (X)	DE1	0.92	0.969	0.971	0.974	0.842
	DE2	0.93				
	DE3	0.916				
	DE4	0.912				
	DE5	0.905				
	DE6	0.917				
	DE7	0.922				
Agricultural Productivity (Z)	AP1	0.923	0.97	0.972	0.974	0.826
	AP2	0.9				
	AP3	0.899				
	AP4	0.915				
	AP5	0.913				
	AP6	0.901				
	AP7	0.905				
	AP8	0.915				

Variable	Item	Outer Loading	Cronbach's Alpha	rho_A	rho_C	AVE
Food Security Resilience (Y)	FR1	0.885	0.957	0.957	0.965	0.795
	FR2	0.902				
	FR3	0.877				
	FR4	0.904				
	FR5	0.881				
	FR6	0.901				
	FR7	0.893				

Source: Authors' SmartPLS output.

Overall, the measurement model demonstrates satisfactory reliability and convergent validity. All indicators exceeded the recommended outer loading threshold, while all AVE values were substantially above 0.50. The reliability coefficients also exceeded 0.70, confirming strong internal consistency across the three constructs. Although several reliability coefficients were above 0.95, suggesting that some indicators may contain closely related content, the consistently high outer loadings and AVE values support retaining the indicators for subsequent analysis. Therefore, the measurement model was considered adequate for further assessment of discriminant validity and the structural model.

Discriminant Validity

Discriminant validity was assessed using the Fornell–Larcker criterion, which requires the square root of each construct's Average Variance Extracted (AVE) to exceed its correlations with other constructs. As presented in Table 4, the square roots of AVE were 0.917 for Digital Ecosystem Embeddedness, 0.909 for Agricultural Productivity, and 0.892 for Food Security Resilience. The inter-construct correlations were 0.396 between Digital Ecosystem Embeddedness and Agricultural Productivity, 0.547 between Digital Ecosystem Embeddedness and Food Security Resilience, and 0.812 between Agricultural Productivity and Food Security Resilience. Although the latter exhibited the strongest correlation, all values remained below the corresponding square roots of AVE, confirming satisfactory discriminant validity according to the Fornell–Larcker criterion.

Table 4. Discriminant Validity Based on the Fornell–Larcker Criterion

Constructs	Digital Ecosystem Embeddedness	Agricultural Productivity	Food Security Resilience
Digital Ecosystem Embeddedness	0.917		
Agricultural Productivity	0.396	0.909	
Food Security Resilience	0.547	0.812	0.892

Discriminant validity was further evaluated using the Heterotrait–Monotrait Ratio (HTMT), a sensitive criterion for assessing construct distinctiveness, with recommended thresholds of 0.90 and a more conservative 0.85 (Hair et al., 2022; Hair & Alamer, 2022). As presented in Table 5, all HTMT values were below both thresholds: 0.406 between Digital Ecosystem Embeddedness and Agricultural Productivity, 0.566 between Digital Ecosystem Embeddedness and Food Security Resilience, and 0.841 between Agricultural Productivity and Food Security Resilience. Although the highest value (0.841) approached the conservative threshold, it remained acceptable, supporting satisfactory discriminant validity and confirming that the constructs are empirically distinguishable.

Table 5. Discriminant Validity Based on the HTMT Ratio

Constructs	Digital Ecosystem Embeddedness	Agricultural Productivity	Food Security Resilience
Digital Ecosystem Embeddedness	–		
Agricultural Productivity	0.406	–	
Food Security Resilience	0.566	0.841	–

The Fornell–Larcker and HTMT assessments consistently supported the discriminant validity of Digital Ecosystem Embeddedness, Agricultural Productivity, and Food Security Resilience, despite the relatively strong association between the latter two constructs. The measurement model also demonstrated satisfactory indicator reliability, internal consistency, and convergent validity, with all outer loadings exceeding 0.70, AVE values above 0.50, and reliability coefficients meeting the recommended thresholds. Collectively, these findings confirm adequate psychometric properties and support proceeding with structural model evaluation and hypothesis testing.

Structural Model Assessment and Hypothesis Testing

Following the assessment of the measurement model, the structural model was evaluated to examine the hypothesized relationships among Digital Ecosystem Embeddedness, Agricultural Productivity, and Food Security Resilience. Hypothesis testing was conducted using the bootstrapping procedure by examining the original sample coefficient (β), sample mean, standard deviation, T-statistics, and P-values. A relationship was considered statistically significant when the T-statistic exceeded 1.96, and the P-value was below 0.05.

Table 6. Structural Path and Hypothesis Testing

Hypothesis	Structural Relationship	Original Sample (β)	Sample Mean	STDEV	T-statistics	P-values	Decision
H1	Digital Ecosystem Embeddedness → Food Security Resilience	0.254	0.247	0.059	4.309	<0.001	Supported
H2	Digital Ecosystem Embeddedness → Agricultural Productivity	0.249	0.245	0.085	2.921	0.004	Supported
H3	Agricultural Productivity → Food Security Resilience	0.433	0.442	0.104	4.173	<0.001	Supported
H4	Digital Ecosystem Embeddedness → Agricultural Productivity → Food Security Resilience	0.108	0.112	0.055	1.95	0.051	Not Supported

Table 6 presents the direct and indirect effects among the constructs. Digital Ecosystem Embeddedness positively and significantly influenced Food Security Resilience ($\beta = 0.254$, $t = 4.309$, $p < 0.001$) and Agricultural Productivity ($\beta = 0.249$, $t = 2.921$, $p = 0.004$), supporting H1 and H2, respectively. Agricultural Productivity also positively influenced Food Security Resilience ($\beta = 0.433$, $t = 4.173$, $p < 0.001$), supporting

H3 and exhibiting the strongest direct effect. These findings suggest that digital ecosystem integration enhances agricultural productivity and food security resilience, while higher productivity contributes to farmers' capacity to maintain food availability and withstand disruptions. However, the indirect effect of Digital Ecosystem Embeddedness on Food Security Resilience through Agricultural Productivity was not statistically significant ($\beta = 0.108$, $t = 1.950$, $p = 0.051$), leading to the rejection of H4. Thus, despite the positive indirect coefficient, Agricultural Productivity was not confirmed as a significant mediator at the 5% significance level.

Discussion

The Impact of Digital Ecosystem Embeddedness on Food Security Resilience

The findings demonstrate that Digital Ecosystem Embeddedness positively and significantly influences Food Security Resilience ($\beta = 0.254$, $t = 4.309$, $p < 0.001$), supporting H1. This result aligns with previous studies highlighting the contribution of digital connectivity to farmers' access to information, social networks, market opportunities, and external resources that enhance adaptive capacity [32]. Similarly, [33][34] emphasize the potential of digital transformation to strengthen agricultural resilience through improved resource allocation, market integration, and responses to uncertainty.

In South Nias Regency, where geographical isolation and infrastructure limitations may restrict agricultural opportunities, digital ecosystem embeddedness offers an alternative means of overcoming spatial barriers. Digital connections enable millennial farmers to interact with suppliers, buyers, extension services, and financial institutions, potentially improving their ability to anticipate and respond to production and market disruptions. This suggests that digital embeddedness contributes to resilience not merely through technology adoption but through access to informational, relational, and institutional resources.

Nevertheless, these benefits depend on adequate digital infrastructure, technological literacy, information quality, and institutional support. Previous research identifies infrastructure deficiencies and limited digital capabilities as persistent barriers to agricultural digitalization [35]. Consequently, strengthening Food Security Resilience requires an integrated digital agricultural ecosystem that combines technological accessibility with reliable information, market connectivity, and institutional collaboration.

The Impact of Digital Ecosystem Embeddedness on Agricultural Productivity

Digital Ecosystem Embeddedness positively and significantly influences Agricultural Productivity ($\beta = 0.249$, $t = 2.921$, $p = 0.004$), supporting H2. This finding is consistent with studies demonstrating that digital integration facilitates agricultural knowledge acquisition, resource coordination, and production-related decision-making [36]. Through digital platforms and networks, farmers can obtain timely information regarding cultivation practices, weather conditions, agricultural inputs, and market demand, potentially reducing information asymmetry and improving resource utilization.

From a resource-based perspective, digital information and network relationships constitute complementary resources that can strengthen traditional agricultural production capabilities. [37] highlight the contribution of digital platforms to market access and information exchange, while [38] emphasize the potential of digital technologies to support agricultural knowledge, climate-smart practices, and productivity. These perspectives suggest that digital ecosystem embeddedness may enhance productivity by improving farmers' ability to access, coordinate, and utilize relevant resources.

However, digital connectivity alone cannot ensure productivity improvements. Agricultural outcomes remain dependent on land quality, financing, infrastructure, production inputs, technological capabilities, and environmental conditions. Evidence concerning Indonesian millennial farmers further suggests that digital transformation requires supportive infrastructure and business ecosystems [39]. Therefore,

agricultural digitalization initiatives should integrate digital connectivity with extension services, productive financing, infrastructure development, and farmer capacity building to translate informational advantages into measurable production improvements.

The Impact of Agricultural Productivity on Food Security Resilience

Agricultural Productivity positively and significantly influences Food Security Resilience ($\beta = 0.433$, $t = 4.173$, $p < 0.001$), supporting H3. This relationship exhibits the strongest direct effect in the structural model, suggesting that productive capacity is particularly important for strengthening food security resilience among millennial farmers. The finding is consistent with previous research linking agricultural productivity and resource efficiency to food availability, household income, and resilience to disruptions [40].

Higher agricultural productivity may strengthen resilience through two interconnected mechanisms. First, increased agricultural output supports food availability and production continuity. Second, improved farm performance can enhance household income and purchasing capacity, providing additional resources to manage input price fluctuations, market uncertainty, and temporary production disruptions. Thus, agricultural productivity represents both a productive and an economic foundation for maintaining food security under changing conditions.

Nevertheless, productivity and resilience remain conceptually distinct. High agricultural output under favorable conditions does not necessarily guarantee resilience to climate variability, transportation disruptions, market instability, or resource shortages. As emphasized by [41][42][43], agricultural resilience also depends on adaptive capacity, market diversification, institutional support, and access to alternative resources. Accordingly, productivity improvements should be accompanied by broader risk-management strategies to ensure sustainable food security in geographically vulnerable island communities.

The Effect of Digital Ecosystem Embeddedness on Food Security Resilience through Agricultural Productivity

The findings reveal that Agricultural Productivity does not significantly mediate the relationship between Digital Ecosystem Embeddedness and Food Security Resilience ($\beta = 0.108$, $t = 1.950$, $p = 0.051$), indicating that H4 is not supported at the 5% significance level. Although both component relationships are statistically significant, the indirect effect does not meet the conventional significance threshold. Therefore, the proposed productivity-mediated mechanism cannot be statistically confirmed.

This finding provides an important distinction between the productive and resilience-related benefits of digital ecosystem embeddedness. Digital integration may strengthen farmers' adaptive capacity through mechanisms that extend beyond agricultural output, including access to timely information, alternative markets, institutional networks, financial resources, and social support. [44] identify social-network reconstruction, continuous learning, and resource management as relevant mechanisms associated with digital ecosystem embeddedness. Similarly, [29][26] highlight the importance of knowledge acquisition and sharing in digitally embedded entrepreneurial ecosystems, although their findings originate from a different empirical context.

The nonsignificant indirect effect should not be interpreted as evidence that Agricultural Productivity is irrelevant to Food Security Resilience. Agricultural Productivity remains the strongest significant direct predictor in the model. Rather, the findings indicate that Digital Ecosystem Embeddedness and Agricultural Productivity contribute independently to resilience within the estimated structural relationships. Digital embeddedness is associated with informational, relational, and adaptive advantages, whereas productivity contributes through agricultural output and economic capacity.

Importantly, the marginal nonsignificance of the indirect effect (p = 0.051) warrants cautious interpretation, particularly given the relatively small sample of 75 respondents. The result does not establish the absence of mediation under all conditions but indicates insufficient statistical evidence to confirm the proposed indirect pathway in this sample. Future research involving larger samples and longitudinal designs could examine whether productivity-related mediation becomes more apparent over time or under different agricultural conditions.

5. Conclusion

This study demonstrates that Digital Ecosystem Embeddedness positively and significantly influences Agricultural Productivity and Food Security Resilience among millennial farmers in South Nias Regency, Indonesia. Agricultural Productivity also significantly contributes to Food Security Resilience, exhibiting the strongest direct effect in the structural model. However, its mediating effect is not statistically significant, suggesting that the resilience benefits of digital ecosystem embeddedness may extend beyond productivity improvements to include information accessibility, market connectivity, institutional networks, and adaptive capacity.

These findings highlight the importance of understanding digital embeddedness as a relational and ecosystem-based resource rather than merely technology adoption. Agricultural development policies should integrate digital connectivity with improvements in productive resources, infrastructure, financing, and extension services to strengthen resilience in island communities. Future research should examine alternative mediating mechanisms, including digital literacy, knowledge sharing, social capital, market integration, and adaptive capacity, using larger samples and longitudinal designs to improve generalizability and clarify causal relationships.

Managerial Implications

The findings offer practical implications for local governments, agricultural institutions, farmer organizations, and digital-service providers in South Nias Regency. First, agricultural digitalization should prioritize integrated digital ecosystems connecting millennial farmers with buyers, input suppliers, extension services, financial institutions, and agricultural markets rather than focusing solely on technology provision. Second, accessible and reliable information on cultivation practices, weather, market prices, financing, and agricultural support programs should be integrated with farmer training and extension services.

Third, improving Agricultural Productivity remains essential through investments in quality inputs, infrastructure, production technology, financing, and agricultural skills. Fourth, strengthening digital market connectivity, alternative distribution channels, and regional partnerships can help mitigate geographical constraints and market disruptions in island communities. Finally, policy evaluation should extend beyond production indicators to include digital connectivity, information accessibility, market diversification, institutional support, and adaptive capacity, recognizing that digital embeddedness may contribute to resilience even without statistically confirmed productivity-mediated effects.

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