

Empowering Farmers Through Agripreneurship for Sustainable Food Security in West Sumatra

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ABSTRACT

Sustainable food security has become an important issue in agricultural development. Although previous studies have examined food access, food production, agripreneurship, and information technology separately, limited research has integrated these factors within an agripreneurship-based food security framework. **This study examines** the roles of food access, food production, agripreneurship, and information technology in shaping sustainable food security among farming households in West Sumatra Province, Indonesia. **A total** of 400 farming households were selected using a multi-stage random sampling technique across six districts. Data were collected through structured surveys from May to July 2025 and analyzed using PLS-SEM. **The results** show that food access, agripreneurship, and information technology significantly improve sustainable food security. In contrast, food production has no significant direct effect, indicating that higher output alone does not ensure sustainability. This highlights a shift from production-oriented to system-oriented food security approaches. Further analysis confirms that agripreneurship and information technology mediate the relationships between food access, food production, and sustainable food security. Agripreneurship strengthens innovation and income diversification, while information technology improves access to information and decision-making efficiency. **This study contributes** a novel integrated model of agripreneurship-based sustainable food security in rural Indonesia. The findings emphasize that sustainable food security depends on the synergy of market access, entrepreneurial capacity, and digital transformation. Policy implications highlight the need to strengthen farmer entrepreneurship, expand digital infrastructure, and improve food distribution systems.

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1. INTRODUCTION

Sustainable food security has become a critical issue in global agricultural development. Pressure on natural resources threatens long-term food availability and productivity. Agriculture must produce sufficient food while maintaining resource sustainability. Unsustainable practices reduce soil fertility and disrupt agricultural systems. These conditions weaken resilience and threaten future food security [1, 2]. Farmers face increasing challenges in balancing production and sustainability goals. Climate change and environmental degradation further intensify these challenges. Therefore, sustainable food systems are essential for long-term agricultural development. This study aligns with global Sustainable Development Goals. It supports SDG

2, SDG 9, and SDG 12. SDG 2 focuses on food security and sustainable agriculture. Food production and food access directly support this goal. SDG 9 promotes innovation and infrastructure in agricultural systems. Information technology enhances efficiency and knowledge sharing among farmers. SDG 12 encourages responsible resource use in production systems. These goals strengthen the relevance of this study. They also connect local agricultural issues with global development priorities.

Food production plays a key role in sustainable food security systems. Global demand increases due to population growth and consumption changes. This condition intensifies agricultural production in many developing countries. However, intensive practices may damage ecosystems if poorly managed. Monoculture farming reduces biodiversity and increases environmental risks [3, 4]. Excessive chemical use also harms soil quality and productivity. Sustainable practices improve productivity while maintaining ecological balance. Crop diversification and organic inputs support long-term agricultural sustainability. These approaches also enhance farmers' resilience to environmental and market risks. Food access is another important factor in sustainable food security. It reflects the ability to obtain safe and nutritious food. Food access depends on markets, infrastructure, and purchasing power. These factors determine effective distribution and consumption patterns [5, 6]. Limited access reduces farmer income and restricts market participation. Farmers may prioritize short-term gains over sustainable practices. This condition may increase pressure on natural resources. Improved access supports sustainable agricultural practices and better resource management. Strong market systems also enhance farmers' economic stability.

Information technology increasingly supports agricultural decision-making processes. Digital tools provide access to market prices and climate information. Farmers can improve production and marketing strategies using these tools. Technology increases productivity and reduces information gaps in supply chains [7, 8]. It also promotes knowledge sharing and innovation among farmers. Digital platforms connect farmers with markets and agricultural services. Information technology strengthens farmers' capacity in modern agricultural systems. It also supports more efficient and sustainable resource use. Technology adoption becomes essential for improving agricultural performance and resilience. Agripreneurship plays a key role in strengthening sustainable food systems. It encourages innovation, efficiency, and market-oriented farming practices. Agripreneurship improves value creation and income diversification in agriculture. It also supports the adoption of sustainable farming practices.

Agripreneurial capacity depends on social interaction and institutional support [9]. Strong networks improve farmers' ability to innovate and collaborate. Government policies also influence agripreneurship development in rural areas. Institutional support improves access to inputs, training, and technologies [10, 11]. Agripreneurship empowers farmers to respond to changing economic conditions. It also enhances their competitiveness in agricultural markets. Previous studies examine production, access, and technology separately. Some studies analyze sustainability in agricultural systems. However, few studies integrate these variables within agripreneurship frameworks. Limited research examines their combined effects on sustainable food security. The role of agripreneurship remains underexplored in integrated analytical models. This creates a gap in understanding complex agricultural systems. Farmers must balance productivity, market access, and sustainability goals simultaneously.

Therefore, this study develops an integrated analytical framework. It examines food production, food access, and information technology relationships. It also highlights agripreneurship as a key strengthening factor. This study focuses on farming households in West Sumatra. The findings provide insights for policy design and agricultural development strategies. This study contributes to agripreneurship-based sustainable food security systems. This integrated approach offers a novel perspective on agripreneurship-based food security.

2. LITERATURE REVIEW

2.1. Food Production

Food production represents a fundamental component of agricultural systems and plays a central role in sustaining rural livelihoods and economic development in agrarian societies. In modern agriculture, food production refers to the cultivation of crops and the raising of livestock for human consumption through various farming practices, including both conventional and environmentally friendly agricultural systems. Historically, food production evolved from hunter-gatherer societies into sedentary agricultural communities that laid the foundation for contemporary agricultural practices [12]. The transition toward settled agriculture occurred

around 13,000–10,000 years ago with the domestication of plants and animals. Early centers of agricultural domestication include the Fertile Crescent, where wheat and barley were first cultivated, and Mesoamerica, where maize, beans, and chili peppers became staple crops [13, 14]. Agricultural land remains one of the most critical resources influencing food production capacity. The availability, quality, and management of land significantly affect crop yields and agricultural productivity. In many regions, including West Sumatra, agricultural production systems face challenges such as land degradation, limited land availability, and climate variability [15]. Sustainable land management strategies are therefore essential for maintaining soil fertility and ensuring long-term productivity.

Water management also plays a vital role in supporting food production systems. Irrigation systems help farmers maintain crop growth stability, particularly in areas exposed to irregular rainfall and climate fluctuations. Studies show that cooperative irrigation institutions can improve farmers' access to water resources and increase agricultural productivity [16]. In addition, technological innovations such as Internet of Things (IoT)–based irrigation systems have been shown to increase water-use efficiency by up to 70 percent [17]. Agricultural productivity is another key element of food production systems. Productivity reflects farmers' ability to convert inputs such as land, labor, capital, and technology into agricultural outputs. Improvements in productivity contribute to higher agricultural efficiency and better economic outcomes for rural communities [18].

However, agricultural production systems are frequently exposed to risks such as extreme weather events, pest outbreaks, and production instability that may reduce yields and create uncertainty in farming systems [19–21]. Technological advancements in agricultural machinery and mechanization further contribute to improving agricultural production efficiency. Modern technologies such as precision farming, drones, and automated agricultural equipment enable farmers to conduct planting, crop monitoring, and harvesting more effectively [22]. These technological developments optimize resource utilization and reduce losses, making innovation an essential driver of modern food production systems.

2.2. Food Access

Food access refers to the ability of individuals or households to obtain sufficient food through physical, economic, and institutional mechanisms. In agricultural systems, food access is closely related to market structures, food distribution networks, and the economic capacity of rural households. Even in regions with high agricultural productivity, limited access to markets and infrastructure can restrict farmers' ability to distribute agricultural products and obtain necessary farming inputs. Several theoretical frameworks help explain the concept of food access. The capability approach emphasizes that individuals must possess the capacity and resources required to achieve well-being and participate in economic activities [23]. Similarly, the Right to Food perspective highlights the importance of equitable access to food through inclusive economic and institutional systems [24]. These perspectives underline the importance of structural conditions that enable farmers to participate in agricultural markets and food systems.

Empirical research demonstrates that food access is influenced by various socio-economic and market factors. Market accessibility, food prices, and household income significantly determine farmers' participation in agricultural markets [25]. Research conducted in rural Scotland also shows that informal food economies contribute to maintaining local food access, although large retail chains continue to dominate food distribution systems [26]. In Sub-Saharan Africa, diversified local food markets have been associated with improved dietary patterns and healthier food consumption behavior [23]. Infrastructure development also plays an important role in facilitating food access. Rural roads, transportation systems, and market facilities enable the efficient movement of agricultural products from farms to markets. Improved infrastructure strengthens supply chains, reduces transportation costs, and minimizes post-harvest losses.

In addition, financial stability among farmers influences their ability to purchase agricultural inputs and participate in markets. Farmers' financial security depends on stable income, agricultural subsidies, and investment opportunities in farming activities [22]. External economic conditions can also affect farmers' access to food systems and markets. Fluctuations in global oil prices, exchange rates, and agricultural credit availability influence farmers' purchasing power and profitability. Research in Indonesia shows that currency depreciation can weaken farmers' terms of trade, while improved access to credit can strengthen farmers' economic resilience [26].

2.3. Agripreneurship

Agripreneurship supports agricultural development and strengthens rural community resilience. It reflects farmers' ability to combine farming with business activities. Agripreneurship also includes innovation, efficiency, and market orientation. It helps farmers improve productivity and increase income. Farmers' participation in agripreneurship depends on socio-economic and environmental factors. Studies in Indonesia show these factors influence community empowerment participation [27]. Research in Malawi highlights women's roles in farming and household management [28]. These findings show the importance of social dimensions in agriculture.

Agripreneurship development depends on access to knowledge and innovation. Extension services help farmers gain technical and business skills. Farmer groups provide access to credit and training programs. These supports improve farmers' performance and agribusiness participation [29]. Government policies influence agripreneurship development in rural areas. Subsidies and regulations affect access to inputs and technologies. Policy support can improve efficiency and reduce excessive input use [17].

Institutional Theory explains the role of regulations in shaping farmer behavior. Social Capital Theory highlights trust and networks within farming communities. These factors strengthen farmers' agripreneurship capacity [28, 29].

2.4. Information Technology

Information technology has increasingly transformed agricultural systems by enabling farmers to access digital information and decision-support tools. Digital technologies allow farmers to obtain real-time information about weather conditions, market prices, agricultural inputs, and crop management practices, thereby improving agricultural decision-making and production efficiency. Technology adoption in agriculture can be explained through the Unified Theory of Acceptance and Use of Technology (UTAUT2), which emphasizes factors such as perceived usefulness, ease of use, social influence, and facilitating conditions as determinants of technology adoption. In agricultural contexts, these factors influence farmers' willingness to adopt digital applications and agricultural information platforms.

Despite the potential benefits, technology adoption among farmers remains uneven in many developing countries. Studies in Bangladesh indicate that limited digital infrastructure and insufficient digital training hinder farmers' adoption of digital technologies [30]. Similar challenges have been observed in several African countries, where low digital literacy and limited internet access restrict the effective use of information technology in agriculture [31].

Mobile-based agricultural applications have emerged as important tools for connecting farmers with markets and financial services. These platforms provide real-time market information and facilitate communication between farmers and buyers [32]. However, the effectiveness of digital technologies often depends on farmers' access to mobile devices and stable internet networks. Social and economic factors also influence technology adoption. Awareness, perceived benefits, and social influence encourage farmers to adopt digital applications, while financial constraints may limit technology use [33]. More recent studies indicate that agricultural digitalization and data-driven farming systems can significantly improve agricultural efficiency and sustainability when supported by appropriate policies and institutional frameworks [34].

2.5. Sustainable Food Security (SFS)

Sustainable Food Security (SFS) at the household level is an evolving concept that extends beyond traditional food security by emphasizing long-term sustainability in food availability, access, utilization, and stability. Unlike conventional approaches that focus primarily on food quantity, SFS integrates nutritional quality, economic affordability, and the resilience of household food systems in the face of economic and environmental changes [30, 31].

Conceptually, SFS consists of five key dimensions: food availability, food access, food utilization, food stability, and economic sustainability. Food availability refers to the continuous presence of adequate food throughout the year, derived from both household production and external sources. Food access reflects the physical and economic ability of households to obtain food, including affordability and market accessibility. Food utilization emphasizes dietary quality and diversity, ensuring that households consume nutritious and balanced diets that support long-term health outcomes [3, 17].

Food stability is a critical dimension of SFS, representing the ability of households to maintain consistent food consumption despite seasonal fluctuations or economic shocks. This includes coping strategies such as food storage, income diversification, and reliance on multiple food sources to mitigate uncertainty [26]. In

addition, economic and agricultural sustainability plays a fundamental role in ensuring continuous food security, where agricultural income and farming activities serve as the backbone of household food consumption continuity [11]. From a theoretical perspective, SFS can be explained through Engel's Consumption Theory, which highlights the relationship between household income and food expenditure patterns, as well as institutional and social capital theories that influence food access, distribution, and information flow within rural communities [15, 24].

These theoretical lenses emphasize that SFS is not solely determined by production capacity, but also by broader socio-economic and institutional structures. Overall, Sustainable Food Security provides a comprehensive framework for understanding household-level food adequacy as a multidimensional and dynamic system influenced by economic, social, technological, and environmental factors, particularly in rural agricultural contexts.

2.6. Hypotheses Development

Based on theoretical foundations and previous studies, this study develops several hypotheses. These hypotheses explain the relationships among food production (FP), food access (FA), information technology (IT), agripreneurship (AP), and sustainable food security (SFS). The model reflects how agripreneurship strengthens sustainable food systems. Figure 1 presents the conceptual framework.

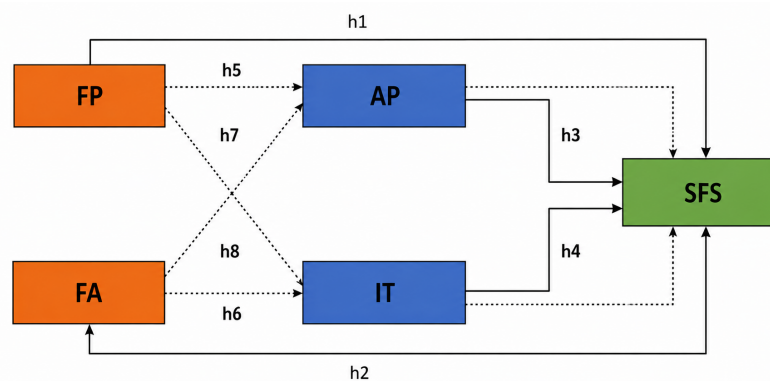


Figure 1. Conceptual Framework

Based on the proposed conceptual framework, the following hypotheses are formulated:

- H1: FP has a significant effect on SFS.**
- H2: FA has a significant effect on SFS.**
- H3: IT has a significant effect on SFS.**
- H4: AP has a significant effect on SFS.**
- H5: IT mediates the relationship between FP and SFS.**
- H6: IT mediates the relationship between FA and SFS.**
- H7: AP mediates the relationship between FP and SFS.**
- H8: AP mediates the relationship between FA and SFS.**

3. METHODS

3.1. Population and Sample

The population of this study includes all agricultural households in West Sumatra Province. The total population is 769,045 households. A multi-stage random sampling technique was used in this study. This approach ensures representation across diverse socio-economic and agroecological conditions.

In the first stage, six regencies Agam, Lima Pulu Kota, Solok, Padang, West Pasaman, and Sijunjung were selected using the Probability Proportional to Size (PPS) method based on their contribution to the agricultural sector. In the second stage, farming households were randomly selected from each regency in proportion to the number of households. The required sample size was determined using the Slovin formula [8], which is widely applied when population variance is unknown due to its simplicity and efficiency.

Compared to Cochran and Krejcie–Morgan methods, Slovin is more practical. It does not require detailed assumptions about population variability. Therefore, it is appropriate for large and heterogeneous populations. The Slovin formula is expressed as follows:

$$n = \frac{N}{1 + N(e)^2} \quad (1)$$

Where:

n : Number of samples

N : Total population

e : Margin of error

$$n = \frac{755,877}{1 + 755,877(0.05)^2} = 399.8 \approx 400$$

Six regencies were selected using the PPS method. These include Agam, Lima Puluh Kota, Solok, Padang, Pasaman Barat, and Sijunjung. The selected regions include 365,190 agricultural households. The sample was distributed proportionally across regencies, as shown in Table 1. This process resulted in a total of 400 respondents.

Table 1. Distribution of Population and Samples

Regency	Number of agricultural households (N)	Proportion (%)	Number of samples (n)
Agam	86,060	23.56	94
Lima Puluh Kota	74,064	20.28	81
Solok	75,257	20.61	82
Padang	21,205	5.81	23
West Pasaman	61,544	16.86	67
Sijunjung	47,060	12.89	53

Table 1 presents the distribution of agricultural households and the corresponding sample allocation across the six selected regencies. The total population comprises 365,190 agricultural households, with Agam contributing the largest proportion (23.56%; 86,060 households), followed by Solok (20.61%; 75,257 households) and Lima Puluh Kota (20.28%; 74,064 households). In contrast, Padang accounts for the smallest proportion of agricultural households (5.81%; 21,205 households). Accordingly, the sample was proportionally allocated based on the population size of each regency, resulting in 94 respondents from Agam, 82 from Solok, 81 from Lima Puluh Kota, 67 from West Pasaman, 53 from Sijunjung, and 23 from Padang. As shown in Table 1, this proportional allocation ensures that each regency is represented according to its share of the agricultural household population, thereby improving the representativeness and reliability of the survey findings.

3.2. Respondent Characteristics

The description of respondent characteristics aims to provide an overview of the socio-economic profile of the participants in the context of the empirical analysis. Table 2 presents information on the respondents' educational level, cultivated land area, monthly income, and household size, which serve as key categories describing the characteristics of the farming households that participated in this study.

Table 2. Socio-Economic Characteristics of Respondents

Characteristics	Category	Frequency	%
Education	Elementary school	132	33.00
	Junior high school	116	29.00
	Senior high school	104	26.00
	Bachelor's degree	48	12.00

Land area cultivated	< 0.5 ha	148	37.00
	0.5–1 ha	150	37.05
	> 1 ha	102	25.05
Monthly income	< USD 100	162	40.05
	USD 100–200	160	40.00
	> USD 200	78	19.05
Household size	≤ 3 persons	102	25.05
	4–5 persons	196	49.00
	≥ 6 persons	102	25.05

Table 2 shows that most respondents have a basic to intermediate education level (elementary–junior high school), accounting for 62%, while only 12% have completed higher education. This condition indicates limited access to formal education, which in turn may affect farmers' ability to manage their farms efficiently and adopt agricultural innovations. In terms of cultivated land area, about 37% of farmers own less than 0,5 ha, and only 25,5% manage more than 1 ha, reflecting the dominance of smallholders with relatively limited production capacity. Furthermore, based on income levels, the majority of households (80,05%) earn less than USD 200 per month, indicating low welfare levels and high dependence on seasonal agricultural income. Regarding household size, around 49,00% of respondents have 4–5 family members a medium-sized household structure typical of rural areas which may increase food consumption needs under limited household resources. Overall, these characteristics suggest that the majority of farmers in the study area are low-educated, low-income, and small-scale producers, which provides an important contextual basis for analyzing the level of FS in West Sumatra Province.

3.3. Data Collection and Variable Measurement

Data were collected through field surveys using structured questionnaires administered directly to farming households across six districts in West Sumatra Province between May and July 2025. The primary respondents were household heads or family members actively involved in agricultural activities and decision-making related to food management. The research instrument was developed based on an extensive review of relevant literature and previous empirical studies. Furthermore, Table 3 presents the operationalization of research variables, summarizing 33 indicators used to measure the five main variables examined in this study.

Table 3. Variable Types and Measurement Indicators

Variable	Measurement items	Source
FP	Nine items	[8, 9, 13, 31, 34]
AP	Seven items	[15, 21, 22, 33]
FA	Six items	[14, 16, 24]
IT	Five items	[6, 7]
SFS	Six items	[6, 11, 17, 23]

3.4. Data Analysis Technique

Data analysis in this study was conducted in several stages to ensure both model adequacy and the robustness of the relationships among variables. The Partial Least Squares Structural Equation Modeling (PLS-SEM) approach was employed, as it is well-suited for analyzing complex causal relationships among latent variables, accommodates medium-to-large sample sizes, and does not require data normality assumptions. The analysis consisted of two main stages: evaluation of the measurement model and hypothesis testing.

The first stage, measurement model evaluation, was conducted to assess the validity and reliability of the variables. Convergent validity was evaluated based on the loading factor (LF) (≥ 0.70) and Average Variance Extracted (AVE) (≥ 0.50). Reliability was assessed using Composite Reliability (CR) and Cronbach's Alpha (CA), both of which should exceed 0.70. Furthermore, discriminant validity (DV) was verified using the

Heterotrait–Monotrait Ratio (HTMT) criterion, ensuring that the values were below 0.85 to confirm adequate variable discrimination.

The second stage, hypothesis testing, employed a two-tailed test with a 5% significance level. The relationships among variables were considered statistically significant when $p\text{-value} \leq 0,05$. This stage included testing for direct effects, indirect (mediating) effects, and moderating effects. The results of the hypothesis testing provide empirical evidence regarding the strength and direction of relationships among variables, thereby validating the conceptual model developed in this study.

4. RESULT AND DISCUSSION

4.1. Measurement Model Evaluation Results

The results of the measurement model analysis, including the values of LF, AVE, CR, and CA for each variable, are presented in Table 4. These results illustrate the strength of the indicators in reflecting their respective variables, as well as the overall level of validity and reliability of each variable.

Table 4. Results of Measurement Model Evaluation Analysis (Food Access)

Indicator	LF	CA	CR (rho.a)	CR (rho.c)	AVE
Food Access		0.902	0.905	0.923	0.631
The distance to markets or grocery stores is not too far.	0.797				
Roads leading to the market are easy to pass and not difficult to access.	0.776				
Staple foods such as rice, eggs, and cooking oil can be purchased weekly without incurring debt.	0.806				
Food prices remain affordable given the current household income.	0.830				
Nearby shops or small stores provide the food items needed.	0.765				
Food can still be purchased during the rainy season or periods of scarcity.	0.769				
Food prices in the market remain relatively stable and do not change drastically.	0.815				
Food Production		0.933	0.945	0.943	0.648
The available land is sufficient for cultivating the crops needed.	0.800				
Agricultural land is managed properly to ensure optimal and sustainable harvests.	0.782				
Water availability for crops is sufficient during each planting season in fields or farms.	0.754				
Irrigation systems function well to support crop growth and maintain plant health.	0.764				
During the dry season, sufficient water can still be provided for agricultural land.	0.819				
Crop yields are generally sufficient to meet household food needs.	0.795				
Cultivated crops grow well and produce satisfactory harvests each season.	0.845				
Farming equipment is sufficient to support agricultural activities.	0.841				

Farming equipment is easily available and relatively affordable.	0.839				
Agripreneurship		0.904	0.918	0.924	0.634
Agricultural training improves farmers' business and production skills.	0.837				
Farmers actively participate in capacity-building and entrepreneurship programs.	0.717				
Farmers can easily access support when facing farming or business problems.	0.829				
Farmers actively share market and production information with peers.	0.749				
Farmers frequently discuss business strategies during group activities.	0.804				
Farmers utilize government support to improve farming performance.	0.857				
Farmers use available resources to increase income and business opportunities.	0.771				
Information Technology		0.878	0.884	0.910	0.670
Mobile phones are used as the main communication tool and source of information.	0.810				
Internet signal quality in the area is relatively good.	0.754				
WhatsApp and social media are utilized to obtain agricultural information.	0.822				
Agricultural information is accessed through radio, television, mobile phones, or digital platforms.	0.857				
Information on market prices, fertilizer availability, and cultivation techniques is obtained via WhatsApp or social media.	0.847				
Sustainable Food Security (SFS)		0.908	0.909	0.924	0.576
Households have sufficient food availability throughout the year.	0.736				
Food produced by households meets daily consumption needs.	0.747				
Households can access food easily from markets or own production.	0.789				
Food prices are affordable for household consumption.	0.782				
Households consume diverse and nutritious food regularly.	0.817				
Food consumption remains stable during economic or seasonal changes.	0.761				
Households maintain food reserves for uncertain conditions.	0.744				
Agricultural income supports continuous food consumption.	0.712				
Farming activities ensure long-term food security for households.	0.738				

The results presented in Table 4 indicate that all indicators have LF values above 0.70, confirming their validity in representing the respective latent constructs. The highest LF value is observed in Social Institutions (0.857) and Information Technology (0.857), while the lowest is found in Agripreneurship (0.717), which remains within the acceptable threshold. Furthermore, all AVE values exceed 0.50, indicating satisfactory convergent validity. Among the constructs, Information Technology shows the highest AVE value (0.670), while Sustainable Food Security (SFS) records the lowest (0.576), yet both meet the required validity criteria. In addition, reliability testing using Cronbach's Alpha and Composite Reliability demonstrates strong internal consistency across all constructs, as all values exceed 0.70. Therefore, the measurement model can be considered valid and reliable. To further ensure discriminant validity, the HTMT approach was applied, as presented in Table 5, to verify that each construct is empirically distinct from the others.

Table 5. The Results of VD Test (HTMT)

	FA	SFS	FP	AP	IT
FA					
SFS	0.718				
FP	0.485	0.390			
AP	0.468	0.711	0.430		
IT	0.395	0.696	0.342	0.684	

Based on the information in Table 5, all variables have HTMT values below 0.85, indicating that discriminant validity is achieved. This means that each variable is clearly distinguishable from the others, and the indicators validly represent their respective constructs. Model fit was assessed using SRMR. The saturated model shows SRMR of 0.093 (original sample) and 0.039 (mean), while the estimated model shows 0.113 (original sample) and 0.041 (mean), with narrow confidence intervals (0.043–0.048). Although the estimated SRMR slightly exceeds the conventional threshold of 0.08, such values are still acceptable in complex PLS-SEM models. The results indicate a moderate model fit with stable estimates across resampling. Given the multidimensional nature of Sustainable Food Security (SFS), the model is considered adequate and statistically robust. Therefore, it is appropriate to proceed with structural model evaluation and hypothesis testing.

Table 6. SRMR

	Original Sample (O)	Sample Mean (M)	95%	99%
Saturated model	0.093	0.039	0.043	0.046
Estimated model	0.113	0.041	0.046	0.048

The effect size (f^2) analysis indicates that Food Availability exerts a large effect on Sustainable Food Security (SFS) ($f^2 = 0.352$), confirming it as the most dominant predictor in the model. Information Technology ($f^2 = 0.164$) and Social Institutional Capital ($f^2 = 0.147$) show medium effects, highlighting their substantive roles in shaping SFS outcomes. In contrast, Food Production demonstrates a negligible direct effect on SFS ($f^2 = 0.003$), suggesting that its influence is primarily indirect. Overall, the findings confirm that SFS is more strongly driven by access, institutional, and technological factors than by production alone, consistent with multidimensional food security frameworks in contemporary literature.

Table 7. Effect Size (f^2)

Relationship	f^2 (Original Sample)	t-value	p-value
FA → SFS	0.352	4.006	0.000
FA → AP	0.109	2.830	0.005
FA → IT	0.080	2.426	0.015
FP → SFS	0.003	0.330	0.742
FP → AP	0.081	2.887	0.004

FP → IT	0.037	1.690	0.091
AP → SFS	0.147	3.071	0.002
IT → SFS	0.164	3.418	0.001

4.2. Hypothesis Testing Results

The hypothesis testing in this study comprises three categories. Hypotheses 1 to 4 represent direct effects, Hypotheses 5 to 8 represent indirect (mediating) effects, which examines the extent to which a specific variable strengthens or weakens the relationship among the main constructs. The results of all hypothesis tests are presented in Table 8, providing a comprehensive overview of the direction and significance of relationships among variables in the research model.

Table 8. The Direct and Mediation Effects on Variables

Hypothesis	Relationship	Coefficient	p-value	Decision
H1	FA influences SFS	0.417	0.000	Accepted
H2	FP influences SFS	-0.037	0.381	Rejected
H3	AP influences SFS	0.305	0.000	Accepted
H4	IT influences SFS	0.304	0.000	Accepted
H5	AP mediates the relationship between FA and SFS	0.097	0.000	Accepted
H6	IT mediates the relationship between FA and SFS	0.088	0.000	Accepted
H7	AP mediates the relationship between FP and SFS	0.084	0.000	Accepted
H8	IT mediates the relationship between FP and SFS	0.060	0.001	Accepted

The hypothesis testing in this study comprises three categories. Hypotheses 1 to 6 represent direct effects, Hypotheses 7 and 8 represent indirect (mediating) effects, which examines the extent to which a specific variable strengthens or weakens the relationship among the main constructs. The results of all hypothesis tests are presented in Table 8, providing a comprehensive overview of the direction and significance of relationships among variables in the research model.

Food access has a significant positive effect on sustainable food security in rural households. Improved access strengthens the stability of household food consumption and reduces pressure on natural resource exploitation. When farmers can easily access markets and inputs, they tend to manage agricultural resources more efficiently and avoid excessive land use. In West Sumatra, local nagari markets play an important role in stabilizing food distribution and ensuring affordability of both food and agricultural inputs. These conditions support household resilience and reduce dependence on unsustainable farming practices. The findings are consistent with recent studies after 2021 [2, 25], which confirm that improved market access enhances rural food security outcomes [24]. Overall, better food access creates a more stable and balanced rural food system. Food production, however, does not show a significant direct effect on sustainable food security. This indicates that increasing production alone is not sufficient to ensure long-term food security outcomes. In many cases, higher production is achieved through intensification practices such as fertilizer use and continuous cropping. Although these strategies increase short-term yields, they often lead to soil degradation and ecological imbalance. Farmers also tend to prioritize income stability over environmental considerations, reflecting survival-oriented decision-making in smallholder systems. Similar findings have been reported in recent studies after 2021 [19, 27], which highlight that agricultural intensification may weaken long-term sustainability. These results suggest that production must be supported by institutional and technological mechanisms to contribute effectively to food security.

Information technology has a significant positive influence on sustainable food security. Farmers increasingly use mobile phones, digital platforms, and messaging applications such as WhatsApp to access agricultural information. These tools provide real-time updates on weather conditions, market prices, and farming

techniques, which improve decision-making in agricultural activities. Digital technology also reduces uncertainty and enhances efficiency in rural farming systems. However, differences in digital literacy and infrastructure still limit equal access among farmers. These findings are consistent with studies after 2021 [7, 21], which emphasize the role of digital agriculture in strengthening rural food systems. Overall, information technology improves both productivity and resilience in farming households. Agripreneurship also plays an important role in improving sustainable food security. It encourages farmers to adopt innovative and market-oriented approaches in their farming activities. Through agripreneurship, farmers are able to diversify income sources and improve resource efficiency. Social networks and farmer organizations further support entrepreneurial development by facilitating knowledge sharing and collaboration. However, the level of agripreneurship development remains uneven across rural communities due to differences in capacity and access to training. These findings align with studies after 2021 [1, 14], which show that agripreneurship enhances rural sustainability outcomes. Therefore, strengthening entrepreneurial capacity through training and institutional support is essential for rural development.

Food access not only has a direct effect on sustainable food security but also works indirectly through agripreneurship. Better access to markets and resources encourages farmers to engage in value-added activities and entrepreneurial behavior. This transformation helps improve income diversification and strengthens household food security. Agripreneurship acts as a mechanism that converts access into economic resilience and sustainability outcomes. These results are supported by recent studies [4, 29], which confirm the mediating role of agripreneurship in rural food systems. Thus, FA contributes to SFS both directly and indirectly through AP. Information technology also mediates the relationship between food access and sustainable food security. Digital tools enhance market transparency, improve price information, and reduce transaction costs in agricultural activities. Farmers often combine physical market access with digital platforms to improve decision-making and reduce uncertainty. This integration strengthens the efficiency of food distribution systems in rural areas. These findings are consistent with studies after 2021 [28, 31], which highlight the importance of digital transformation in rural food systems. Therefore, IT strengthens the impact of food access on sustainable food security. Agripreneurship further mediates the relationship between food production and sustainable food security. Agricultural production creates opportunities for farmers to engage in entrepreneurial activities that add value to their outputs. Through innovation and market orientation, farmers can improve income and resource efficiency. Agripreneurship transforms production from subsistence-oriented farming into more commercial and sustainable practices. These findings are consistent with studies [20], which show that agripreneurship enhances productivity and resilience. Thus, FP influences SFS through the development of agripreneurship. Information technology also mediates the relationship between food production and sustainable food security. Digital tools help farmers access information on climate conditions, pest management, and production techniques. This improves adaptive farming strategies and increases production efficiency. Technology also reduces uncertainty and supports data-driven agricultural decision-making. These findings align with studies after 2021 [24, 32], which confirm that digital agriculture improves sustainability outcomes. Therefore, FP contributes to SFS through the role of information technology.

Overall, sustainable food security depends on the integration of food production, food access, agripreneurship, and information technology. Production alone is insufficient without supporting systems that enhance access, innovation, and information flow. These variables interact to shape resilient rural food systems and improve household food security. Integrated policy approaches are therefore essential to strengthen sustainability outcomes. From the authors' perspective, based on field engagement with farming households in West Sumatra, these dynamics reflect real challenges faced by smallholders in balancing income needs, market constraints, and environmental pressures. This contextual understanding strengthens the interpretation of empirical findings and supports the development of an agripreneurship-based sustainable food security framework.

5. MANAGERIAL IMPLICATIONS

The findings provide important implications for policymakers and agricultural practitioners. Strengthening food access should become a strategic priority in rural development. Improved infrastructure can support better distribution and reduce market inefficiencies. Expanding digital technology adoption is also essential for modern agriculture. Reliable internet access and farmer digital literacy must be improved. Information technology helps farmers make better production and marketing decisions.

Social institutions should be reinforced to support collective learning and coordination. Farmer groups

and cooperatives can act as innovation platforms. These institutions can accelerate the adoption of sustainable farming practices. Policymakers should integrate institutional, technological, and economic approaches. This integration can improve both productivity and environmental sustainability.

Agripreneurship development should also be promoted among farmers. This approach encourages innovation, value creation, and market orientation. Strong collaboration between government, academia, and communities is necessary.

6. CONCLUSIONS

This study confirms that sustainable food security depends on the interaction of economic, social, and technological factors. Food access, agripreneurship, and information technology play important roles in supporting sustainable food security in rural farming households. Food production alone does not significantly determine sustainable food security outcomes. Increasing production is not sufficient without supporting institutional and technological systems. Sustainable agriculture requires improved market access and stronger institutional capacity. Effective utilization of digital technologies is also essential for improving rural food systems. West Sumatra benefits from strong communal values and nagari-based institutions that support agricultural cooperation. These local institutional structures provide an important foundation for sustainable rural development.

Government policies should prioritize improving food access through better rural infrastructure and distribution systems. Digital transformation in agriculture must be expanded to strengthen farmers' access to information and markets. This effort requires not only infrastructure development but also improved digital literacy among farmers. Local institutions should be empowered as platforms for knowledge sharing, innovation, and collective learning. Environmentally friendly farming practices need to be continuously promoted across agricultural systems. These include organic fertilization, crop diversification, and soil conservation techniques. Incentive-based policies can encourage farmers to adopt more sustainable agricultural practices. Participation of youth and women in agripreneurship and digital agriculture should be further strengthened. This will support innovation, income diversification, and long-term rural resilience. Strengthening agripreneurship is essential for transforming traditional farming into more adaptive and market-oriented systems. Such transformation contributes to both economic improvement and environmental sustainability. It also enhances farmers' ability to respond to market and climate challenges effectively.

This study has limitations related to agroecological diversity across regions in West Sumatra. The quantitative approach used may not fully capture socio-cultural and behavioral dynamics of farming communities. Future research should adopt mixed-method approaches to explore these dimensions more comprehensively. Further studies may also examine the role of agripreneurship in strengthening sustainable food security systems. From the authors' perspective, based on field observations and engagement with farming households, these findings reflect real conditions faced by farmers in balancing productivity, market access, and sustainability pressures.

7. DECLARATIONS

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7.2. Author Contributions

Conceptualization: BM; Methodology: RR; Software: YY; Validation: RR and BM; Formal Analysis: YY and BM; Investigation: YY; Resources: RR; Data Curation: BM; Writing Original Draft Preparation: YY and RR; Writing Review and Editing: BM and YY; Visualization: RR; All authors, RR, YY, BM have read and agreed to the published version of the manuscript.

7.3. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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7.5. Declaration of Conflicting Interest

The authors declare that they have no conflicts of interest, known competing financial interests, or personal relationships that could have influenced the work reported in this paper.

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