Strengthening Farmer Resilience for Coconut Business Sustainability: Evidence from Aceh Besar

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Abstract

Coconut is an important commodity for people in Aceh Besar, serving as a source of food, income, industrial raw materials, and coastal conservation. However, its sustainability is vulnerable to strategic environmental changes such as declining cultivation areas and productivity, limited acces to technology, insufficient role of farmer organizations, limited extension services, and pest attacks. Allegedly, the sustainability of the coconut business is affected by the level of farmers' resilience, which underlies the development of farmer autonomy, enabling them to sustain their businesses in the long term. This research aims to analyze the factors that affect farmers' resilience, autonomy, and the sustainability of their coconut businesses, and to examine the interrelationships among these variables. The research was conducted through a survey involving 106 coconut farmers in June-July 2024. The data were analyzed descriptively and inferentially using the SEM PLS method. The results show that farmers exhibit low levels of resilience, autonomy, and business sustainability. Both farmer resilience and autonomy show a direct positive effect on business sustainability. Resilience is affected by farmer characteristics, the role of extension workers, and social capital. Farmer autonomy is affected by farmer characteristics. Developing sustainable coconut businesses is achieved by enhancing farmers' motivation, tailoring extension media to their needs, and strengthening their social networks.

Keywords: *Business Sustainability; Coconut Farmer; Estate Crops; Farmer Autonomy; Resilience.*

A. Introduction

Coconut is one of the vital estate crop commodities in Aceh Besar Regency, because it plays important roles in the economic, social, and ecological aspects as a source of food and income, a raw material for industry, and in coastal conservation. However, its existence is vulnerable to threats arising from strategic environmental changes, including reduced plantation area and low production and productivity. Uristiati et al., (2020) noted that the problems were caused by the dominance of aging trees, the use of uncertified seeds, lack of farmer knowledge, limited access to industrial partnerships and capital. The vulnerabilities can be overcome if coconut farmers possess a high level of resilience. Allegedly, farmers' resilience affects the sustainability of the coconut business by fostering farmer autonomy, and various factors affect both resilience and farmers' autonomy.

The area of coconut plantations in Aceh Besar declined from 14,800 hectares in 2020 to 12,400 hectares in 2023, accompanied by a drop in production from 7,800 tons to 5,500 tons. Productivity in 2023 was only 766 kilograms/ hectare, which is lower than the national average of 1.01 tons/hectare (Directorate General of Estate Crops, 2024). The drastic decline in coconut plantation area was driven by the 2004 tsunami, which damaged approximately 10,282 hectares of coconut plantations. The destruction of coastal ecosystems and increased soil salinity rendered much of the land unsuitable for cultivation (Tomasoa & Prasetyo, 2018). The disaster has caused significant ecological and economic losses for farmers (Syamsidik et al, 2019) and increased their vulnerability to poverty (Adji, 2011). The drastic reduction in coconut plantation area has led to a significant decline in production (Center for Plantation Research and Development, 2005).

Post the tsunami, the reduction in coconut plantation areas has persisted, primarily due to land-use changes and shifts in cultivated commodities. Land-use changes driven by the increasing demand for infrastructure, meanwhile, have also been affected by the massive expansion of other crops perceived as more profitable. Although both governmental bodies and local communities have undertaken replanting initiatives, these efforts have remained insufficient to compensate for the extensive damage and loss of coconut trees.

The use of uncertified seeds also leads to lower production and productivity. Generally, coconut farmers in Indonesia use seeds from mature coconuts, which are propagated independently for cultivation (Tarigans, 2015). The lack of access to technology has constrained coconut business management, keeping it largely traditional. Coconut

business management in Aceh remains traditional and has not yet been oriented toward a profitable industrial system, as its management is carried out in a non-integrated manner (Baihaqi and Hamid, 2015). This condition is exacerbated by the underperformance of farmer group institutions in developing the coconut business (Tarigans, 2015).

If this trend persists, coconut resources are at risk of extinction, potentially threatening food security, farmers' income, the limited availability of industrial raw materials, and environmental degradation, especially in coastal regions. In the long term, it poses a serious threat to the sustainability of the coconut business. In the face of threats to the sustainability of the coconut business, farmers, as key actors in the coconut business, must possess a high level of resilience.

Resilience refers to the capacity to withstand, adapt to, and transform in response to external pressures or environmental changes without altering the fundamental structure of their lives (Holling, 1973; Carver, 1998) and is affected by internal and external factors (Timmerman, 1981). The external pressure raised through disaster experience, proactive risk mitigation, and capacity building (OECD, 2020). Income sustainability is a primary focus in supporting post-shock recovery among rural communities, although vulnerable groups often lack access to such resources (Ellis, 1998). Implementing livelihood strategies requires considering both the sustainability of livelihoods and the preservation of their intrinsic values (Dharmawan, 2007).

Rural communities adopt two main strategies to sustain their livelihoods: survival strategies and asset accumulation strategies (Dharmawan 2007). Within Acehnese communities, their capacity to survive and sustain livelihoods in the aftermath of the tsunami was primarily attributed to strong kinship ties and a deeply rooted culture of cooperation among community members (Maliati & Chalid, 2021).

In the case of coconut farmers, a high level of resilience will lead them to better conditions. This is supported by Seriño et al., (2021), who found that coconut farmers with higher resilience are better equipped to cope with severe impacts, whereas those with lower resilience struggle even under less severe conditions. Resilience enables individuals to make autonomous decisions for survival (Sumardjo et al., 2019; Dumasari, 2020). Such decision-making is based on the farmer's action to seek and access relevant information according to their needs, evaluate that information, and apply it in managing their business efficiently, produce a qualified product, and establish mutually beneficial partnerships (Sumardjo, 1999).

Strengthening the resilience of farmers and the agricultural sector has become increasingly essential, given that agriculture is inherently exposed to multiple risks from production to marketing (Bahadur & Lovell, 2016; Muin & Mubarak, 2024). These risks include climate variability, production shocks, and market uncertainties that directly affect farmers' livelihoods and the stability of agricultural systems. The development of resilience is also aligned with Sustainable Development Goal 11, which is targeted for achievement by 2030, emphasizing the importance of building systems that are adaptive, sustainable, and capable of withstanding shocks (Ministry of National Development Planning, 2020).

Based on this background, the development of coconut farmers' resilience, as coconut represents one of the important agricultural commodities, becomes increasingly essential. However, a review of the existing literature indicates that the issue of coconut farmers' resilience has not yet been adequately explored in previous empirical studies, particularly in relation to farmers' autonomy and business sustainability. To address this research gap, this study aims to analyse the levels of farmer resilience and farmer autonomy, as well as the sustainability of coconut businesses; identify the key factors influencing these dimensions; and examine the effects and interrelationships among these three critical aspects.

This research offers several novel contributions, including a focus on the capacity development of farmers, the use of more comprehensive indicators of resilience, the inclusion of farmer autonomy variables in assessing the effect of resilience and business sustainability, the selection of a coastal, post-disaster, and disaster-prone region as the research location, and the focus on coconut as an essential commodity. The research findings are expected to contribute to the development of resilience and autonomous theory, supporting research-based policy-making to enhance the sustainability of the coconut business.

B. Method

This study was designed using a quantitative approach through a survey. The research location was selected purposively according to the following criteria: a coconut commodity centre, historically exposed to disasters, vulnerable to natural disasters, and with actively cultivating coconut farmers. According to these criteria, Aceh Besar Regency was selected as the research location.
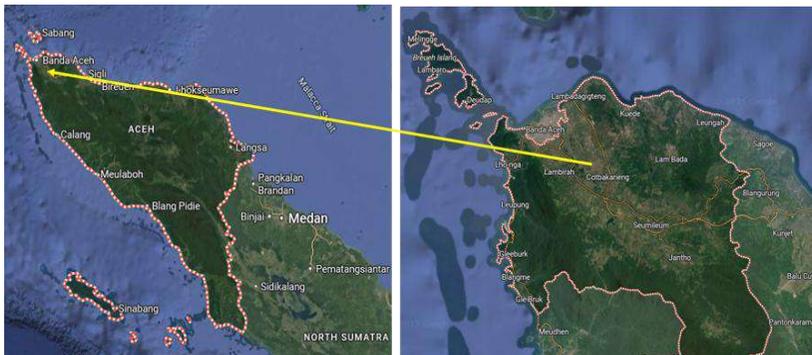
Figure 1. Aceh Besar District in Aceh Province

The population in this research involves 351 coconut farmers who are members of farmer groups and received government assistance between 2020 and 2023. The sample size was determined using statistical power guidelines for structural model estimation, accounting for six independent variables, a minimum R² value of 0.10, and a 10% significance level. Accordingly, 106 farmers were selected as the sample (*Appendix 1*). The sample was drawn from two sub-districts, Cot Glie and Peukan Bada, with 53 respondents from each.

Data in this research were collected using questionnaires with Likert scales used for perceptual items. A pilot test involving 30 coconut farmers in the Lhoknga sub-district was conducted to evaluate the construct validity and content reliability of the questionnaire items using SPSS. 156 questions were valid and reliable. Four trained enumerators assisted in data collection, selected based on independence from enumerators, local language proficiency, and a minimum of undergraduate education. Data collection in each sub-district was carried out by enumerators who conducted face-to-face interviews, averaging 45–60 minutes per respondent.

Data analysis using descriptive and partial least squares structural equation modelling, with the advantages include a multivariate statistical analysis technique used to test complex relationships between variables in a model, facilitating the testing and development of new theories, being able to analyze intermediate variables effectively, able to work on small sample sizes that are not normally distributed (Chin & Newsted, 1998; Hair, Jr. et al., 2022; Puryanto, 2022).

Each item was measured using a four-point Likert Scale based on respondents' perceptions, with the following response levels: Strongly Agree (Score 4), Agree (Score 3), Slightly Agree (Score 2), and Disagree (Score 1). Item scores were indexed and

categorized into four levels: very low (≤25), low (26–50), moderate (51–75), and high (>75) (Sumardjo, 1999). The hypotheses of this research include:

1. Individual characteristics, the implementation of extension, the role of extension workers, the functions of farmer groups, social capital, and the role of farmer group leaders have a direct effect on the levels of farmer resilience

2. Individual characteristics, the implementation of extension, the role of extension workers, the functions of farmer groups, social capital, and the role of farmer group leaders have a direct effect on the levels of farmer autonomy

3. The levels of farmer resilience and farmer autonomy have a direct effect on business sustainability.

C. Results and Discussion

The levels of farmers' resilience, autonomy, and business sustainability are dependent variables influenced by several independent variables, reflected in various indicators. The discussion will present the identification of indicators that reflect the dependent variables.

1. Results

a. Identification of key indicators of farmers' resilience and autonomy, coconut business sustainability and affecting variables

Fundamentally, individual resilience refers to the capacity of individuals to recover and bounce back from circumstances that generate shocks or disturbances. This capacity reflects not only the ability to withstand immediate stress but also to respond constructively to changing conditions. The process of developing resilience comprises four stages—succumbing, recovering, adapting, and transforming or thriving—through which individuals move toward a stronger and more improved state over time (Carver, 1998). In this research, the conceptualization of farmers' resilience is derived from individual resilience theory and economic resilience, emphasizing both personal adaptive capacities and livelihood stability. This conceptual approach draws upon the sustainable livelihood framework proposed by Ellis (1998) and further elaborated by Dharmawan (2007), which views resilience as a dynamic interaction between assets, strategies, and external contexts shaping farmers' ability to sustain and improve their livelihoods.

The definition of farmers' resilience in this research is coconut farmers' capacity to cope with adversity, adapt, and transform to maintain their lives by mobilizing internal and external resources while preserving their original structures and social values (Ellis, 1998; Dharmawan, 2007). The key indicators and parameters are presented in Table 1.

Table 1. The key indicators and parameters of farmer resilience

No	Indicators	Parameters
1.	Capacity to apply a livelihood strategy	Strategies employed to maintain household income sustainability include employment diversification, reducing expenditures, utilizing savings, accessing credit, receiving support from others, selling assets, renting out assets, and expanding cultivation strategies
2.	Capacity for social integration	Having strong social ties with the community, harmony and the absence of conflict
3.	Capacity on coconut plant conservation	Carrying out coconut tree conservation by maintaining existing plants, replacing damaged ones, and replanting trees that have been cut down

The conceptualization of farmer autonomy in this research is derived from farmer autonomy theory by Sumardjo (1999), which conceptualizes autonomy as not dependent on others, characterized by the action to make appropriate decisions based on broad insights, acting effectively and efficiently to remain competitive and comparative. In this research, farmers' autonomy is defined as the ability of coconut farmers to make appropriate decisions in managing their businesses, based on broad insights, to operate their businesses efficiently to produce quality products, and to establish mutually beneficial partnerships. Farmers' autonomy is measured using the indicators of filtering capability, competitiveness, and comparativeness.

Table 2. The indicators and parameters of farmer autonomy

No	Indicators	Parameters
1.	Filtering capability	Actively seeking information from various credible sources, applied it to improve the management of their coconut business
2.	Competitive ness	Efficient in coconut business management to produce high-quality products
3.	Comparative ness	Build equitable and interdependent partnerships

The conceptualization of business sustainability in this research is derived from the sustainable development concept by Elkington (1998), which conceptualizes sustainability as integrating economic, social, and ecological interests in a balanced way to safeguard the sustainable resources for the future. Coconut business sustainability in this research refers to the preservation of coconut businesses in the long term (10 years), measured by increased profits or income, partnerships, the number of products, and the area of well-managed coconut plantations.

Table 3. Indicators and parameters of business sustainability

No.	Indicators	Parameters
1.	Income	The increase in income generated from the coconut business after reducing costs
2.	Business partnership	Collaborative ventures undertaken with others in the development of the coconut business
3.	Product diversification	The processed products are produced
4.	Well-managed coconut plantations area	Coconut plantation areas are managed in accordance with good agricultural practices

b. Factors affecting resilience

Based on the survey, more than 90% of respondents have cultivated other plants, raised livestock, and become fishermen before managing the coconut business. This shows that they have experience in agricultural business management. The majority of farmers cultivate tall coconuts, and 1.89% of farmers cultivate hybrid coconuts. These results indicate a homogeneity in the types of coconut cultivated by farmers. As many as 50% of farmers diversify crops and raise livestock in their coconut cultivation.

This research hypothesizes that resilience is affected by variables, including: individual characteristics, the implementation of extension, the role of extension workers, the function of the farmer group, social capital and the role of the farmer group leader. The descriptions of the variables and indicators for individual characteristics are presented in Table 4.

Table 4. The description of the individual characteristics of coconut farmers

No.	Indicators	Categories	(n)	(%)	Description
1.	Age (years)	a) 18 - 36	26	24.53	Average: 44.66
		b) 37 - 54	59	55.66	years old
		c) 55 – 72	18	16.98	
		d) 73 - 90	3	2.83	

No.	Indicators	Categories	(n)	(%)	Description
2.	Formal education level	a) Elementary School	11	10.38	Dominant Senior High School
		b) Junior High School	23	21.70	
		c) Senior High School	63	59.43	
		d) University	9	8.49	
3.	Farming experience (years)	a) 1 - 17	67	63.21	Average=14.74 years
		b) 18 - 34	34	32.08	
		c) 35 - 51	4	3.77	
		d) 52 - 69	1	0.94	
4.	Income (IDR)	a) 500,000 - 1,875,000	38	35.85	Average = IDR 2,246,698
		b) 1,875,001 - 3.250,000	57	53.77	
		c) 3,250,001 - 4,625,000	5	4.72	
		d) 4,625,001 - 6,000,000	6	5.66	
5.	Household dependents (persons)	a) 0 - 3	42	39.62	Average = 4 persons
		b) 4 - 7	62	58.49	
		c) 8 - 11	2	1.89	
		d) 12 – 15	0	0.00	
6.	Coconut plantation area (Hectares)	a) 0.10 – 9.58	105	99.06	Average = 1.17 Hectares
		b) 9.59 – 19.06	0	0.00	
		c) 19.07 – 28.54	1	0.94	
		d) 28.55 – 38.00	0	0.00	
7.	Coconut tree ownership (trees)	a) 10 - 806	105	99.06	Average = 65 trees
		b) 807 - 1604	1	0.94	
		c) 1605 - 2402	0	0.00	
		d) 2403 - 3200	0	0.00	
8.	Frequency of extension over the past three years (times)	a) Never	31	29.25	Average= 2 times
		b) 1 - 18 times	75	70.75	
		c) 19 - 36 times	0	0.00	
		d) > 36 times	0	0.00	
9.	Number of non-coconut business jobs	a) None	5	4.72	Dominant = 1-3 jobs
		b) 1 - 3 jobs	101	95.28	
		c) 4 - 6 jobs	0	0.00	
		d) >6 jobs	0	0.00	
10.	Motivation	a) Very low	8	7.55	Dominant= Low
		b) Low	64	60.38	
		c) Moderate	7	6.60	
		d) Hingh	27	25.47	

On average, farmers are in the productive age range, have completed higher education, have more than 10 years of farming experience, and have 65 coconut trees. Most farmers are involved in 1 to 3 other jobs in addition to the coconut business. Most farmers (60.38%) demonstrate low motivation in managing the coconut business—the description of coconut extension implementation received by farmers is presented in Table 5.

Table 5. The description of the material, method and media of extension received by farmers

No.	Indicators	Categories	n	%	Description
1.	Material	Not Needed (0–25)	5	4.72	Dominant
		Slightly Needed (26–50)	19	17.92	needed
		Needed (51–75)	49	46.23	
		Highly Needed (76–100)	33	31.13	
2.	Method	Very Difficult (0–25)	5	4.72	Dominant easy
		Difficult (26–50)	36	33.96	
		Easy (51–75)	53	50.00	
		Very Easy (76–100)	12	11.32	
3.	Media	Not understanding (0-25)	19	17.92	Dominant
		Limited understanding	46	43.40	limited
		Easy	40	37.74	understanding
		Very easy	1	0.94	

Coconut extension materials are clearly needed by farmers to support improvements in their knowledge and farming practices. In practice, extension materials delivered through individual and group-based approaches are generally well understood by farmers, as these methods allow for direct interaction and contextual explanations. In contrast, the use of extension media such as written materials and books tends to result in limited understanding, indicating that such media are less effective when not accompanied by direct guidance. Table 6 presents data on the role of extension workers as motivators, facilitators, and educators, revealing that the performance of these three roles remains very low. This finding suggests that extension workers rarely provide motivation, offer limited facilitation in accessing resources, and play a minimal role in educating farmers. Furthermore, Table 7 describes the functions of farmer groups, particularly as learning classes and as vehicles for farmer cooperation, highlighting how these groups have not yet functioned optimally in strengthening collective learning and collaborative activities among coconut farmers.

Table 6. The description of the motivator, facilitator and educator roles of extension workers

No.	Indicator	Categories	n	%	Description
1.	Motivator	Very low (0-25)	80	75.47	Average = 16.64, Very
		Low (26-50)	24	22.64	low
		Moderate (51-75)	2	1.89	
		High (76-100)	0	0.00	
2.	Facilitator	Very low (0-25)	97	91.51	Average = 11.46, very
		Low (26-50)	8	7.55	low
		Moderate (51-75)	1	0.94	

No.	Indicator	Categories	n	%	Description
3.	Educator	High (76-100)	0	0.00	
		Very low (0-25)	92	86.79	Average= 11.95
		Low (26-50)	13	12.26	Very low
		Moderate (51-75)	1	0.94	
		High (76-100)	0	0.00	

Table 7. The Description of farmer groups functions as a learning class and a cooperation vehicle

No.	Indicator	Categories	n	%	Description
1.	Learning class	Very low (0-25)	63	59.43	Average = 25.44,
		Low (26-50)	30	28.30	Low
		Moderate (51-75)	13	12.26	
		High (76-100)	0	0.00	
2.	Cooperation vehicles	Very low (0-25)	60	56.60	Average = 23.14,
		Low (26-50)	37	34.91	Very Low
		Moderate (51-75)	9	8.49	
		High (76-100)	0	0.00	

The function of farmer groups as a learning class and a vehicle for cooperation falls into the low and very low categories. This indicates that the farmer groups have not been functioning effectively and that their existence has not provided benefits to their members. Social capital plays a vital role in determining the success of development (Fukuyama, 2000). Descriptions of the social capital of coconut farmers are presented in Table 8.

Table 8. The description of social value, network and trust

No.	Indicator	Categories	n	%	Description
1.	Social value	Very low (0-25)	0	0.00	Average = 80.67,
		Low (26-50)	0	0.00	High
		Moderate (51-75)	36	33.96	
		High (76-100)	70	66.04	
2.	Social Network	Very low (0-25)	21	19,81	Average = 23.14,
		Low (26-50)	54	50,94	Very Low
		Moderate (51-75)	28	26,42	
		High (76-100)	3	2,83	
3.	Trust	Very low (0-25)	3	2,83	Average = 61.39,
		Low (26-50)	16	15,09	Moderate
		Moderate (51-75)	74	69,81	
		High (76-100)	13	12,26	

Social values are relatively high, social networks are relatively low, and social trust is relatively moderate. Coconut farmers exhibit strong social values, as reflected

in their attitudes and behaviors, such as honesty, paying debts, cooperation, sharing fortune, helping each other, and not stealing. The social network is reflected in the breadth of the communication network built and in the ease of accessing information related to coconut business development through it. Table 9 illustrates the role of the farmer group leader as a leader and motivator for group members in developing coconut businesses.

Table 9. Description of the role of the farmer group leader as a leader and motivator

No.	Indicator	Categories	n	%	Description
1.	As a leader	Very low (0-25)	13	12,26	Average = 50.36,
		Low (26-50)	39	36.79	Moderate
		Moderate (51-75)	44	41.51	
		High (76-100)	10	9.43	
2.	As a motivator	Very low (0-25)	18	16.98	Average = 47.84,
		Low (26-50)	33	31.13	Low
		Moderate (51-75)	43	40.57	
		High (76-100)	12	11.32	

c. The levels of farmer resilience, farmer autonomy, and business sustainability

The levels of farmer resilience, farmer autonomy, and business sustainability are shown in Table 10. It shows that the overall levels of farmer resilience, farmer autonomy, and coconut business sustainability are categorized as low. This can be attributed to extremely low competitiveness, the capacity to apply a livelihood strategy, and moderate social integration.

Table 10. The level of farmer resilience, autonomy, and coconut business sustainability

No.	Indicators	Result	Description
	Farmer resilience		
	Average	34.55	Low
1.	Capacity to apply a livelihood strategy	24.76	Very low
2.	Social integration	51.65	Moderate
	Farmer Autonomy		
	Average	28.34	Low
1.	Filter capability	29.62	Low
2.	Competitiveness	23.84	Very low
3.	Comparativeness	31.57	Low
	Coconut business sustainability		
	Average	37.34	Low
1.	Increased income	40,57	Low
2.	Increase in business partners	37.42	Low

No.	Indicators	Result	Description
3.	Increase in well-managed coconut planting area	37.42	Low
4.	Increase in the number of coconut plants	33.96	Low

d. Structural model analyzing affects among variables

An analysis of the effects of various factors on the levels of farmer resilience, farmer autonomy, and the sustainability of coconut businesses was carried out in 2 stages: model evaluation and model structure evaluation. Model evaluation is conducted by testing the validity and reliability of indicators across all variables simultaneously and by generating an outer model. Validity criteria for indicators represent variables include: the loading factor (LF) ≥ 0.6 and the Average Variable Extracted (AVE) value≥ 0.5. Reliability criteria for indicators are met when the composite reliability (CR) is ≥ 0.6. (Chin & Newsted, 1998).

The second stage was undertaken to assess the effect of variables, as hypothesized. A variable has a significant impact if the p-value ≤ 0.05. According to Hair et al., (2017), in exploratory research, a p-value ≤ 0.06 is still acceptable. The structural evaluation results in the development of the inner model. The results of the analysis are presented in Figure 2.
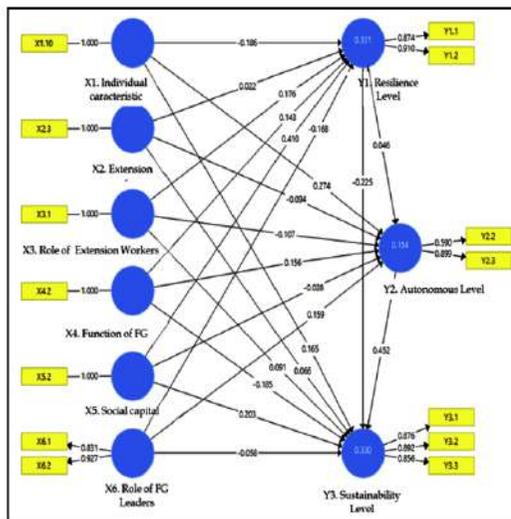
Figure 2a. Outer model   Figure 2b. Inner model
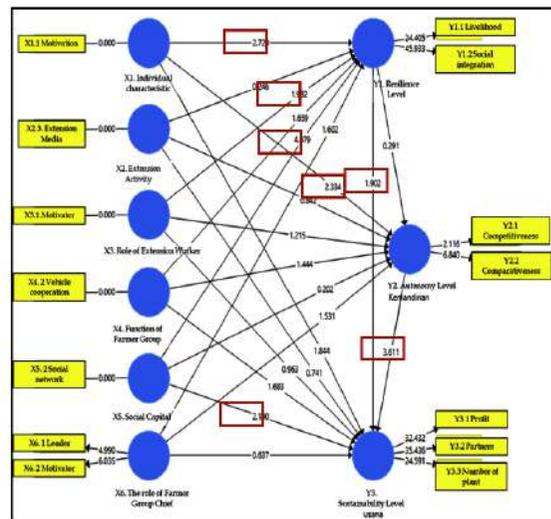
Figure 2a illustrates the outer model, showing valid and reliable indicators of the independent and dependent variables. The individual characteristics variable is

represented by the motivation. The extension media represent the extension implementation variable; their role represents the role of the extension workers as a motivator, the farmer group function is represented by its role as a vehicle of cooperation, the social network represents the social capital variable, and their role represents the role of the farmer group leader as a leader and a motivator.

Thus, farmer resilience is represented by the capacity of a livelihood strategy and social integration; farmer autonomy, represented by competitiveness and comparativeness; variable coconut business sustainability, represented by profit or income; the number of products to be diversified; and the number of business partners to be established in the long term.

Figure 2b illustrates the effects among variables. Based on Figure 2b, seven models of significant positive affects among variables are identified, namely: individual characteristics to the resilience level, individual characteristics to the autonomy level, extension worker role to the resilience level, social capital to the resilience level, social capital to the coconur business sustainability level, resilience level to the business sustainability level, and farmers autonomy level to the business sustainability level.

The model was then subjected to a goodness-of-fit test to assess how well the proposed structural model fits the observed data. Several fit indices were used, including SRMR, Chi-square, and NFI (J. et al., Hair, 2010). The fit test criteria and the results are described in Table 11.

Table 11. Model fit testing

Criteria	Results	Desvription
SRMR, <0,08	0,079	Fit
Chi-Square, >0,05	176,040	Fit
NFI, Closer to 0	0,585	Fit

Table 11 shows that the SRMR, Chi-Square, and NFI values meet the goodness-of-fit criteria, indicating that the model representing the effects among variables is statistically reliable and acceptable.

2. Discussion

The demand for coconuts continues to increase in Aceh Besar Regency, both young and mature coconuts. All coconuts produced are consistently absorbed by the market despite rising prices. Generally, coconut farmers sell their harvest to

intermediaries who come directly to the plantation to pick the coconuts. The price received by farmers excludes the costs of harvesting and transportation. On average, the selling price (early 2024) is IDR 3,000-3,500 per young coconut and IDR 2,000-2,500 per mature coconut. The harvesting cost is IDR 20,000 per tree.

Based on observations, coconut farmers prefer to receive prices that exclude harvesting costs, as laborers for coconut harvesting have become increasingly scarce. The scarcity of coconut harvesters is attributed to the increasing height of coconut trees, which significantly increases the risk of falling-related accidents.

Despite the ongoing increase in coconut prices, coconut farmers' income remains below the district minimum wage in 2024. The average monthly income of coconut farmers (IDR 2,246,698) remains below the minimum wage in Aceh Besar District (IDR 3,460,672). It is caused by the limited coconut tree resources. On average, farmers own 65 coconut trees per hectare. This number is lower than the recommended number stated in the Guidelines for Good Agricultural Practices in Coconut Cultivation (2013), which suggests an average cultivation of 90–120 coconut trees per hectare.

According to Ellis (2000), the ownership of natural resources, such as crops, constitutes a form of capital in developing livelihood sustainability. The greater the resources owned, the higher the level of resilience. The limited number of coconut trees owned potentially increases farmers' vulnerability to low income, as the quantity of coconut production remains limited.

Income is a function of sales volume multiplied by price (Soekartawi, 2007). When the sales volume is limited, farmers' income remains low despite the increase in prices. The coconut harvest cycle is every four months. The average yield is around 15-20 coconuts per tree. Assumption that farmers own 65 coconut trees, and the selling price (early 2024) is IDR 3,000-3,500 per young coconut and IDR 2,000-2,500 per mature coconut, per harvest. A farmer collects 10 young coconuts and 5 mature coconuts per tree. The income calculation is: Young coconuts: 10 fruits × 65 trees × IDR 3,500 = IDR 2,275,000. Mature coconuts: 5 fruits × 65 trees × IDR 2,500 = IDR 812,500. The total income per harvest is IDR 3,087,500. Total income per harvest spread over four months, resulting in a monthly income of less than IDR 772,000. This amount is equivalent to 34 percent of farmers' average total monthly income.

In addition to the small production volume, the scattered location of coconut plantations caused farmers to sell their harvests to intermediaries who come directly to the fields. Due to the lack of well-organized farmer groups, coconut farmers have

weak bargaining power. As a result, the price of coconuts is predominantly dictated by these middlemen. In fact, the existence of farmer organizations is essential as a vehicle for cooperation and mutual learning among farmers in the development of farming business. Whereas social networks and organizations serve as instruments for accessing and mobilizing resources. The more effectively farmer organizations function, the greater the opportunities to access various resources for the development of the coconut business (Ellis, 1998).

Under conditions of limited resources, coconut farmers adopt survival strategies to sustain their livelihoods, as they have not yet developed the capacity to accumulate resources. Persistently low income limits farmers' ability to accumulate assets. Almost all respondents did not have savings; only 8 respondents (7.5%) reported having any savings.

To address the lower income, coconut farmers adopt survival strategies to sustain their livelihoods by mobilizing their human capital, such as farming, livestock, and other occupational skills, along with their savings and assets, in order to improve their livelihoods. They implement livelihood diversification in the form of: (1) cultivating crops other than coconuts, such as rice, maize, vegetables, cloves, coffee, cassava, and pepper, as well as raising livestock; (2) engaging in non-agricultural activities, such as working as fishermen, construction laborers, traders, and employees in the private sector, (3) sell their assets, (4) seek assistance from others, and reduce expenses when their income is insufficient to meet basic living needs.

This condition reflects that, in implementing survival strategies, coconut farmers rely on their skills and social capital. As stated by Ellis (2000), rural households, when faced with low income, sustain their livelihoods by mobilizing available resources, including their skills and social capital. The social capital of coconut farmers in Aceh Besar is embodied in close kinship ties and reciprocal support, as an expression of the religious values they uphold.

In general, coconut farmers have one to three additional occupations in addition to managing their farms. According to the sustainable livelihoods theory (Ellis, 2000), increasing occupational diversity enhances the resilience of individuals and groups. However, farmers who engage in other occupations tend to neglect their coconut plantations. Coconut cultivation is treated as a side activity and receives minimal care. Fertilization is typically conducted only during the initial planting stage; irrigation depends entirely on rainfall; and pest control, particularly against

wild boars, is not intensive. This has resulted in low production and productivity of their coconut crops. The adaptability of coconut trees to various geographical conditions is the main reason farmers cultivate them. Although coconut is a relatively easy crop to cultivate, it still requires good maintenance to achieve high levels of production (Lata & Osborne-Naikatini, 2025; Sholihah et al., 2024).

The lack of serious motivation among farmers to manage the coconut business is evident in their low competitiveness and comparativeness, both of which jointly affect sustainability. It is a threat to the long-term sustainability of coconut resources. Farmer resilience must be sustained through both livelihood continuity and the preservation of inherent social values. One of the key factors in sustaining farm household livelihoods is maintaining their primary source of income, namely, coconut cultivation. If this primary source of livelihood is lost, the sustainability of farmers' household livelihoods cannot be achieved (Dharmawan, 2007; Muamar et al., 2024).

Based on the inner model, the level of farmer resilience and autonomy is relatively low, and both have a direct and significant effect on the sustainability of the coconut business. Resilience is positively affected by farmers' motivation, the role of extension workers in motivating farmers, and social networks. These findings are in line with the view that strengthening farmers' social capital can enhance their adaptability in agrarian-based livelihoods (Sufyan et al., 2022). Furthermore, farmers' motivation also significantly affects farmer autonomy. This indicates that the sustainability of coconut farming depends on farmers' resilience and autonomy. However, in the long term, the sustainability of the coconut business will likely stagnate, as indicated by stagnant income, weak partnerships, and limited product diversification (Supriyadi et al., 2023; Yahya et al., 2023).

The limited resilience of coconut farmers is partly caused by the low level of involvement of agricultural extension workers as motivators. Interviews with one farmer revealed that extension workers play an important role in providing advice and solutions to farmers' problems. However, their role as motivators remains minimal. Extension activities are conducted only once every six months, usually through dialogue or group meetings. Interviews with extension workers indicate that the low level of extension support for the coconut business is due to the absence of specific programs for coconut development. Most extension programs focus on food crop cultivation, resulting in minimal attention to the coconut commodity (Sukma & Zulheldi, 2021; Nugroho et al., 2022; Zulkifli et al., 2025).

Weak social networks significantly affect both farmer resilience and the sustainability of the coconut business. These networks encompass the breadth and strength of farmers' communication in accessing resources essential for coconut development. While farmers have strong peer-to-peer networks that enable them to exchange information easily, their connections with agricultural extension officers, plantation-related government agencies, universities, and seed suppliers are notably weak. This gap is critical, as such networks play a vital role in supporting the development of the coconut sector (Putnam et al., 1993; Bakar et al., 2024; Humaidi et al., 2024). Stronger institutional collaboration is essential to close this gap (Hidayah, 2023; Osorio, 2023; Fitria et al., 2024).

Based on the analysis, several variables, such as the implementation of extension, the function of farmer groups, and the roles of farmer group leaders, do not have statistically significant effects on farmers' resilience and autonomy. This indicates that the current extension strategies have not succeeded in raising farmers' awareness, attitudes, and capacities to sustain and develop their coconut businesses. Farmer groups, which are supposed to function as platforms for peer learning and collaboration, have not been fully implemented. Observations revealed that these groups often serve only administrative purposes, primarily to meet the requirements of government assistance programs. Most farmer groups lack formal secretariats despite having organizational structures. Meetings are typically held only during government aid distribution or extension visits (Sugirman et al., 2024; Kusumaningtyas et al., 2022).

The formation of farmer groups without considering farmers' actual needs can lead to long-term unsustainability. Purnaningsih & Lestari (2021) emphasize that the sustainability of a group or program depends heavily on the level of member participation. Similarly, Fukuyama (2000) argues that community groups represent a vital form of social capital in the implementation of development. This aligns with Ellis (2000), who states that mobilizing resources for sustainable livelihoods is conducted through collective organizations. Group leaders also play a crucial role. However, their leadership roles remain mostly administrative and symbolic, rather than motivational or empowering. Studies have highlighted the strategic role of farmer group leaders in promoting autonomy and empowerment (Rahayu & Malia, 2018; Sarjito et al., 2019; Azzaki et al., 2023).

Serious efforts are needed to revitalize extension programs to improve the functioning of farmer groups. The leadership capacity of extension workers also needs enhancement. According to Fatchiya et al., (2019), well-conducted extension services

not only strengthen farmers' capacities but also empower their families and groups. Limited extension services have directly contributed to weak leadership roles within farmer groups. Effective empowerment models should therefore aim to improve both institutional quality and human resource capacity at the grassroots level (Alam et al., 2025; Sholihah et al., 2024; Sugitanata et al., 2023).

Based on the analysis, strengthening farmers' resilience and autonomy serves as a fundamental basis for enhancing the sustainability of the coconut business in Aceh Besar. Sambodo et al., (2024) state that several coconut-producing countries, such as the Philippines, India, and Sri Lanka, serve as key references in the development of coconut farmers. The Philippine government provides farmers and their families with access to reliable health insurance through training programs. These initiatives involve institutions such as the Technical Education and Skills Development Authority and the Agriculture Training Institute, which adopt the Seek-Find-Train-Assess-Certify-Employ framework. The Philippines also emphasizes modernization, large-scale replanting, and increasing the value-added of coconut production (Supriyadi et al., 2023).

India focuses on enhancing farmers' income through value addition, expanding productive areas, and supporting research-based innovations. They established the Coconut Development Board (CDB) under the Ministry of Agriculture, which plays a central role in upstream and downstream development, research, training, and export promotion. Similarly, Sri Lanka has developed innovative research on coconut and strengthened farmers' institutional capacity. The country has built a structured and comprehensive institutional ecosystem for coconut development covering the entire value chain. Coconut training programs in Sri Lanka use educational videos, digital applications, and capacity-building initiatives, reflecting the importance of integrating technology with farmer empowerment (Alam et al., 2025; Humaidi et al., 2024).

Drawing lessons from these countries, efforts to enhance the capacities of coconut farmers in Aceh Besar should be pursued through strengthened research, the development of replanting programs, and the reinforcement of farmers' institutions. These efforts need to be implemented collaboratively through pentahelix synergy—bringing together the government, private sector, academia, communities, and mass media—to address sectoral limitations and create cross-institutional innovations (Kusumaningtyas et al., 2022; Sufyan et al., 2022). Collaborative extension programs should be developed with systematic curricula that encompass aspects of cultivation,

processing, and marketing, while also incorporating entrepreneurship and digital access (Muamar et al., 2024; Saleh et al., 2025).

As Swanson et al., (1997) state, the government has comparative advantages in providing programs, policies, and funding; the private sector contributes technological and financial resources; while universities provide innovations through research. The findings of this research significantly contribute to the theoretical development of farmer resilience and autonomy, particularly in post-disaster coastal areas with high socio-economic vulnerability. So far, farmer resilience has often been treated normatively, whereas this study underscores the critical role of internal motivation, social networks, and extension agents as empowering catalysts—an insight also supported by Fatchiya et al., (2019) and further affirmed by the socio-epistemological dimension of participatory development (Hidayah, 2023; Husendro, 2024).

These implications extend Ellis's (1998) theory of livelihood resilience by emphasizing psychosocial and relational dimensions, rather than solely economic indicators. Autonomy is redefined through indicators such as filtering capability, comparativeness, and competitiveness—positioning farmer independence as a strategic capacity to assess, decide, and act in uncertain environments. Additionally, compared with cases in the Philippines, India, and Sri Lanka, it becomes clear that the sustainability of the coconut sector in Aceh Besar requires more than just physical interventions. It demands social protection, institutional reform, replanting programs, and the modernization of training, drawing from best practices globally and tailoring them to local conditions (Sholihah et al., 2024; Ardi et al., 2024).

Programs like the Seek, Find, Train, Assess, Certify, and Employ system in the Philippines, combined with audiovisual media and digital platforms, can serve as models for Aceh's future training curricula that go beyond technical instruction toward social and entrepreneurial development (Azzaki et al., 2023; Sugirman et al., 2024). However, current support for the coconut sector in Aceh remains limited, particularly in public extension agendas. Therefore, a collaborative pentahelix extension approach is urgently needed to bridge systemic gaps and foster sustainable partnerships

This study also reveals that variables such as farmer group function and leadership roles do not significantly influence resilience or autonomy. This highlights a critical institutional gap: formality does not equal functionality. Many farmer groups remain passive and primarily administrative—formed to meet bureaucratic requirements rather than mobilize grassroots empowerment (Bakar et al., 2024; Fukuyama, 2000). As

such, revitalizing these groups requires leadership capacity building and the internalization of collaborative values, anchored in both social capital and collective agency. Consistent with Purnaningsih & Lestari (2021), program sustainability depends heavily on the active participation of its members and leaders.

Finally, this research demonstrates that resilience, autonomy, and sustainability are mutually reinforcing. Strong social networks and effective extension services amplify adaptive capacity, while autonomy strengthens strategic decision-making. Thus, sustainability cannot rely solely on economic access but must be rooted in personal motivation and social solidarity. The complexity of these interrelations underscores the need for interdisciplinary policy solutions that draw on sociology, agribusiness, education, and development studies. In the long run, these findings serve as an empirical foundation for designing inclusive, context-sensitive, and scalable training models that can be replicated across other coastal, disaster-prone regions.

Although this study has presented significant findings on the factors influencing the resilience and sustainability of coconut farmers in Aceh Besar, several limitations should be noted. The study covered only a single administrative area and had a limited number of respondents, so generalizing the results to other regions should be done cautiously. In addition, the quantitative approach used did not delve deeply in the social and cultural dynamics that may affect farmers' resilience. These limitations open opportunities for further research using qualitative or mixed methods in a wider area. Despite these limitations, the findings of this study remain globally relevant, particularly for developing countries in Southeast Asia facing similar challenges in building farmers' resilience to economic pressures and climate change. In this context, the results of this research contribute to the international discourse on sustainable agricultural development and the empowerment of small-scale farmers in coastal areas.

D. Conclusion

This study concludes that the sustainability of the coconut business in Aceh Besar is not solely determined by farmer resilience, but is significantly supported by farmers' autonomy and social capital. While resilience reflects the capacity to manage livelihood strategies, its impact is greater when combined with the ability to act independently and to integrate into community networks. The findings also highlight that human capital, within the framework of household livelihood strategies, extends

beyond education and health, emphasizing the crucial role of farmers' motivation in sustaining their productivity.

Theoretically, this study enriches the concept of resilience by integrating social dimensions such as trust and cooperation as essential factors in measuring farmers' adaptive capacity. It contributes to the development of a more comprehensive model of farmer resilience that can be utilized in coastal and disaster-prone regions. Practically, the research suggests that increasing farmers' motivation and autonomy, rather than focusing solely on structural support, can significantly enhance the sustainability of the coconut business. The use of empirical variables and tested indicators provides a conceptual model that may inform policies for community empowerment and disaster mitigation in vulnerable agricultural sectors.

Given some limitations of this study, particularly the limited number of indicators representing several latent variables, future research is encouraged to broaden the scope of variables and include more diverse and comprehensive indicators. Further investigation using mixed-method approaches is also recommended to explore underlying social, cultural, and institutional dynamics that were not captured in this quantitative model. Moreover, comparative studies across coastal regions in Southeast Asia could provide valuable cross-cultural insights and validate the model's generalizability.

As a final point, this study offers a novel and contextually grounded framework for assessing and enhancing farmer resilience as a key to sustainable agricultural development. The findings not only strengthen the theoretical discourse on resilience but also offer practical strategies to improve farmer capacity in the face of economic and environmental uncertainty—issues that are increasingly relevant in the global south and coastal agricultural economies.

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Declaration of Competing Interest

The authors declare that they have no known competing financial or non-financial interests that could have appeared to influence the work reported in this paper.

Declaration of Generative AI

During the preparation of this manuscript, the authors used Grammarly for language editing and readability improvement. All outputs generated by the tool were carefully reviewed and edited by the authors, who take full responsibility for the content of this article.

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Appendix 1

Sample size recommendation in PLS-SEM for a statistical power of 80%
(J. F. Hair et al., 2017)

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Exhibit 1.7 Sample Size Recommendation in PLS-SEM for a Statistical Power of 80%

Maximum Number of Arrows Pointing at a Construct (Number of Independent Variables)	Significance Level											
	10%				5%				1%			
	Minimum R²				Minimum R²				Minimum R²			
	0.10	0.25	0.50	0.75	0.10	0.25	0.50	0.75	0.10	0.25	0.50	0.75
2	72	26	11	7	90	33	14	8	130	47	19	10
3	83	30	13	8	103	37	16	9	145	53	22	12
4	92	34	15	9	113	41	18	11	158	58	24	14
5	99	37	17	10	122	45	20	12	169	62	26	15
6	106	40	18	12	130	48	21	13	179	66	28	16
7	112	42	20	13	137	51	23	14	188	69	30	18
8	118	45	21	14	144	54	24	15	196	73	32	19
9	124	47	22	15	150	56	26	16	204	76	34	20
10	129	49	24	16	156	59	27	18	212	79	35	21

Source: Cohen (1992): A Power Primer. Psychological Bulletin 112: 155–159.