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Factors that play a role in building resilience, autonomy, and sustainability of smallholder coconut farming in Aceh Province

Faktor-faktor yang berperan dalam membangun resiliensi, kemandirian, dan keberlanjutan usaha kelapa rakyat di Provinsi Aceh

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Abstract

Smallholder coconut plantation in Aceh Province faces increasing sustainability risks due to low farmer incomes driven by declining plantation areas, ageing trees, limited access to technology and extension services, and weak farmer institutions. Nevertheless, smallholder coconut plantations remain strategically important as a source of food, farmer income, industrial raw materials, employment opportunities, and environmental conservation. Therefore, strengthening farmers' capacity and resilience is crucial to effectively managing coconut-based farming. This study examines the interrelationships among farmer group functions, farmer group leadership, social capital, farmer resilience, farmer autonomy, and the sustainability of smallholder coconut farming. The study was conducted in 2014 in the Regencies of Aceh Besar, Simeulue, and Bireuen, using a survey of 277 coconut farmers. Data were analyzed using descriptive statistics and *Structural Equation Modeling* (SEM). The study results show that the functions of farmer groups and the roles of their leaders had a positive and significant influence on autonomy, and social capital had a positive and significant influence on farmer resilience. Furthermore, farmer resilience was positively associated with farmer autonomy and coconut farming sustainability, and farmer group leadership also directly influenced farmer autonomy. To support the sustainability of smallholder coconut farming in Aceh, based on these findings, it is recommended that the government and regional governments strengthen social and institutional capacities through farmer groups, primarily through strengthening social networks and trust, enhancing the role of farmer group leaders as motivators and facilitators, and strengthening farmer groups as platforms for collective learning and cooperation.

Keywords: coconut business sustainability, farmer autonomy, farmer groups, farmer resilience, social capital

Abstrak

Perkebunan kelapa rakyat di Provinsi Aceh menghadapi peningkatan risiko keberlanjutan usaha akibat rendahnya pendapatan petani dari usaha ini yang disebabkan oleh penurunan luas areal tanam, penuaan tanaman, keterbatasan akses terhadap teknologi dan penyuluhan, serta lemahnya kelembagaan petani. Meskipun demikian, perkebunan kelapa rakyat tetap memiliki posisi strategis sebagai sumber pangan, pendapatan petani, bahan baku industri, lapangan kerja, dan konservasi lingkungan. Oleh karena itu, penguatan kapasitas dan resiliensi petani menjadi faktor krusial untuk mampu secara optimal mengelola usaha berbasis kelapa. Penelitian ini mengkaji hubungan antara fungsi kelompok tani, peran kepemimpinan kelompok tani, modal sosial, resiliensi petani, kemandirian petani, dan keberlanjutan usaha kelapa rakyat. Penelitian dilakukan tahun 2024 di Kabupaten Aceh Besar, Simeulue, dan Bireuen melalui survei terhadap 277 petani kelapa. Analisis data menggunakan statistik deskriptif dan *Structural Equation Modeling* (SEM). Hasil penelitian menunjukkan bahwa fungsi kelompok tani dan peran ketuanya memiliki pengarup positif dan signoifikan trerhadap kemandirin, serta modal sosial berpengaruh positif dan signifikan terhadap resiliensi petani. Selanjutnya, resiliensi petani berhubungan positif dengan kemandirian petani dan keberlanjutan usaha kelapa, sementara kepemimpinan kelompok tani juga berpengaruh langsung terhadap kemandirian petani. Untuk mendukung keberlanjutan usaha kelapa rakyat di Aceh direkomendasikan kepada pemerintah dan pemerintah daerah untuk melakukan penguatan kapasitas sosial dan kelembagaan melalui kelompok tani, terutama melalui penguatan jejaring sosial dan kepercayaan, peningkatan peran ketua kelompok tani sebagai motivator dan fasilitator, serta penguatan kelompok tani sebagai wahana pembelajaran kolektif dan kerja sama.

Kata kunci: keberlanjutan usaha kelapa, kelompok tani, kemandirian petani, modal sosial, resiliensi petani

1. Introduction

Coconut farming plays an important role in supporting rural livelihoods and regional economies in Indonesia, particularly in coastal and peripheral areas. As a smallholder-based plantation commodity, coconut contributes to household income, employment, food security, and environmental functions (Directorate General of Estate Crops 2019). In Aceh Province, coconut farming also holds strategic importance for rural development and poverty reduction, given the dominance of small-scale farming systems and the province's socio-economic vulnerability (Baihaqi and Hamid 2015).

Despite its strategic role, the sustainability of coconut farming in Aceh has increasingly come under pressure. Land-use conversion for infrastructure development and shifts toward other commodities have contributed to a gradual decline in coconut plantation areas. Data from the Aceh Provincial Office of Agriculture and Plantations (2024) indicate that the coconut plantation area decreased from 104,776 hectares in 2014 to 102,601 hectares in 2023, accompanied by a slight decrease in production, from 63,098 tons to 63,071 tons. Production constraints are further exacerbated by ageing trees and pest attacks, particularly from wild boars and monkeys, which significantly reduce yields and increase production risks (Uristiati et al. 2020). Coconut productivity in Aceh, at 839 kilograms per hectare, remains far below its potential level of 3,300 kilograms per hectare, reflecting limited technological adoption and weak access to effective extension services (Alouw and Wulandari 2020).

Low productivity and unstable returns have reduced the attractiveness of coconut farming for rural households. This is reflected in the declining number of coconut farmers in Aceh over the past decade, from 151,269 in 2014 to 145,316 in 2023 (Aceh Provincial Office of Agriculture and Plantations 2024). Previous studies have shown that when plantation commodities fail to generate sufficient income, farmers tend to reduce maintenance efforts, diversify into other activities, or abandon farming altogether, thereby threatening the sustainability of the sector (Mawardati et al. 2022; Daulay and Meilin 2020). These challenges are compounded by declining cultivated areas, ageing coconut trees, limited access to technology, weak farmer institutional capacity, insufficient extension services, and price fluctuations (Uristiati et al. 2020; Mawardati et al. 2022; Aceh Provincial Office of Agriculture and Plantations 2024).

At the farm level, coconut farming in Aceh is dominated by small-scale operations with limited value addition and weak integration into downstream markets. Farmers face constraints on access to capital, information, technology, and institutional support, which increase their vulnerability to economic and environmental shocks (Dumasari 2020; Touch et al. 2024). These vulnerabilities are particularly pronounced in regions with a history of natural disasters and socio-economic disruption, such as Aceh (Syamsidik et al. 2019; Sina et al. 2019).

In this context, farmer resilience has become an increasingly important concept in agricultural and rural development. Resilience refers to the capacity of individuals and communities to absorb disturbances, adapt to change, and sustain livelihoods under conditions of uncertainty (Hegney et al. 2007; Bahadur et al. 2016). Empirical evidence shows that resilience is critical for maintaining farming activities and livelihood continuity in vulnerable rural areas (Maliati and Chalid 2021; Rozaki et al. 2023). Resilient individuals and groups tend to achieve higher levels of well-being across economic, social, and environmental dimensions than those with lower adaptive capacity (Joosen et al., 2022). Thus, building resilience constitutes a fundamental foundation for autonomy and long-term resource sustainability.

Resilience, however, does not emerge automatically. It is shaped by interactions between enabling and constraining factors originating from internal and external sources (Hegney et al. 2007). Internal enabling factors include education, asset ownership, social values, and social networks. At the same time, external support, particularly extension services and price stability, plays a crucial role in strengthening resilience capacity, as demonstrated in studies of plantation farmers (Idawati et al. 2018). When constraining factors dominate, farmers are more likely to experience maladaptation and livelihood vulnerability.

Problems in coconut business management are also evident in Aceh Province. Coconut farmers face multidimensional challenges arising from socio-ecological changes that hinder effective production and marketing (Sina et al. 2019). Coconut businesses are generally managed independently, with limited business partnerships and exposure to price fluctuations. Although partnerships have emerged in some areas to supply coconuts that meet factory-quality standards, market access remains uneven. In recent years, coconut prices have tended to increase during religious holidays due to declining market supply, further intensifying production and marketing uncertainties.

Resilience alone does not automatically translate into sustainable farming outcomes. Farmers must also possess autonomy in managing production, accessing resources, and engaging with markets. Farmer autonomy, closely associated with empowerment and self-reliance, enables farmers to make strategic decisions and reduce dependency on external actors (Sumardjo 1999; Sumardjo 2017). Autonomy is reflected in farmers' ability to make independent management decisions, supported by learning processes, access to information, and institutional support (Anantanyu et al. 2009; Sriati et al. 2020). Indicators such as problem-solving capacity and adaptive ability are closely related to farmer autonomy (Sina et al. 2019). Resilient farmers are better able to recognize problems, identify opportunities, and act independently to improve their livelihoods (Nashori and Saputro 2021). They are capable of adapting and transforming in response to changing conditions. Resilience enables individuals or groups to sustain their resources (Tohidimoghadam et al. 2023).

Social capital plays a critical role in strengthening both resilience and autonomy. Social capital, manifested in shared norms, trust, and networks, enables cooperation and collective action among farmers. In Aceh, strong social values and networks have enabled communities to cope with stressors arising from conflict and disasters (Nirzalin et al. 2023) and have a significant influence on farmers' resilience (Slijper et al. 2022). Social capital connects farmers through bonding, bridging, and linking relationships, which are often facilitated by farmer groups and their leaders.

Farmer groups, therefore, play a central role in strengthening both resilience and autonomy. As local institutions, farmer groups function as platforms for collective learning, coordination, and access to extension services and government programs (Ministry of Agriculture 2016; Hasan et al. 2020). Effective leadership within farmer groups enhances participation, motivates members, and improves group performance in addressing shared challenges (Falo 2016; Sarjito et al. 2019). In addition, social capital, which is manifested through trust, networks, and shared norms, facilitates cooperation among farmers and supports collective action. Strong social capital has been shown to enhance livelihood resilience, institutional effectiveness, and community adaptation in rural and post-disaster contexts, including in Aceh (Sumardjo et al. 2020; Nirzalin et al. 2023). Social capital also reduces transaction costs and strengthens farmers' capacity to respond collectively to production and market risks (Slijper et al. 2022).

Although previous studies have examined farmer groups, leadership, social capital, and resilience in agricultural development, these dimensions are often analyzed separately or limited to partial outcomes. Empirical evidence remains scarce on how farmer group leadership and social capital jointly shape farmer resilience and autonomy and how these capacities interact to influence the sustainability of coconut-based enterprises. In particular, farmer resilience is rarely treated as an intermediary mechanism, and farmer autonomy is seldom explicitly incorporated into analyses of smallholder plantation sustainability, especially in coconut farming systems in disaster-prone regions such as Aceh.

Accordingly, this study aims to examine he interrelationships among farmer group functions, farmer group leadership, social capital, farmer resilience, farmer autonomy, and the sustainability of coconut-based enterprises in Aceh Province. Specifically, it analyses how farmer group functions, leadership, and social capital are associated with farmers' resilience and autonomy, and how these capacities jointly contribute to the sustainability of the coconut business. By positioning farmer resilience and autonomy as interconnected mechanisms within a single analytical framework, this study seeks to clarify the pathways through which social and institutional factors shape the sustainability of smallholder coconut farming systems. The novelty of this study lies in its integrated analytical framework, which positions farmer resilience and autonomy as interconnected mechanisms linking social and institutional factors to the sustainability of the coconut business. By simultaneously incorporating leadership, social capital, resilience, and autonomy within a single SEM-based model, this study provides new empirical evidence to inform policies aimed at strengthening sustainable coconut-based livelihoods in Aceh.

2. Methodology

This study employed a quantitative research design using a survey approach. Surveys are a widely used quantitative method that relies on samples to draw inferences about a defined population (Munandar 2022). The research adopted a quantitative descriptive correlational approach, which aims to explain relationships, influences, and potential causal associations among the research variables (Rukajat 2018). This approach is appropriate for examining the structural relationships among institutional, social, and individual factors influencing farmer resilience, autonomy, and coconut business sustainability

2.1. Conceptual framework

Coconut farmers in Aceh face multiple external challenges, including declining cultivated area, aging coconut trees, limited access to technology, weak farmer institutions, insufficient extension services, and exposure to disaster-prone environments. These conditions make farmers more vulnerable to low and unstable income, potentially pushing them into cycles of poverty and other social issues, such as limited educational opportunities, while also creating ecological risks, including the gradual depletion of coconut resources. Strengthening resilience among poor and vulnerable communities is therefore essential to reducing exposure and vulnerability to economic, social, environmental, and climate-related shocks (Walsh et al. 2022).

Low and unstable incomes constrain household financial capacity, leading to expenditure patterns that prioritize basic needs while limiting investment in farm maintenance and postharvest processing (Daulay and Meilin 2020). As a consequence, crop damage tends to increase (Daulay and Meilin 2020), and value addition in coconut farming remains low (Directorate General of Estate Crops 2019), particularly due to the lack of technological intervention (Baihaqi and Hamid 2015). If these conditions persist, in the long term, coconut farmers are likely to switch to more profitable crops, leading to the depletion of coconut resources.

This study is grounded in sustainable livelihoods theory as proposed by Ellis (1999), which explains how rural households in developing countries seek to sustain and enhance their livelihoods despite structural constraints. Within this framework, livelihood sustainability is shaped by the interaction of five key elements: (1) the nature of threats and vulnerabilities; (2) ownership of resources, encompassing human, natural, physical, social, and economic capital; (3) process of resources mobilization through organizations, policies, and social interactions; (4) the selection of livelihood strategies; and (5) the impacts resulting from the strategies chosen.

In this process, farmers rely on different forms of capital: (1) human capital, including knowledge, skills, and health; (2) physical capital, such as cultivation and postharvest/processing equipment; (3) natural capital, including land and water; (4) social capital, and (5) economic capital, such as savings. Farmers utilize these forms of capital to withstand the pressures they face through organized communication and interactions. The result of mobilizing these resources is the creation of livelihood activities, some of which directly involve natural resources, while others do not. However, Ellis (1999) emphasizes that farmers' resilience is not limited to the capacity to withstand external pressures but also involves adaptation and transformation to develop new strategies for sustainable livelihoods. In this process of adaptation and transformation, farmers must enhance both their personal and social capacities through reflective thinking and proactive actions, enabling them to achieve autonomy.

In the context of a farmer, Sumardjo (2019) state farmers' autonomy encompasses three main dimensions: cognitive, behavioral, and skill. They can think critically and reflectively in decision-making, manage their own resources and take initiative, act efficiently and effectively, and assess, control, and continuously improve their actions. Farmers' autonomy is reflected in efforts to seek and manage information relevant to farm management needs (filtering capacity), application of this information in farm management to operate efficiently and produce high-quality products, and establishing mutually beneficial partnerships (interdependence) to ensure the long-term continuity of business activities (sustainable). The long-term sustainability of the coconut business requires the balanced consideration of three key interests, namely economic interests (income/profit), social interests (farm diversification/access to technology), and environmental interests (conservation of coconut as a primary livelihood resource) (Elkington 1994).

This study conceptualizes farmer group functions, farmer group leadership, and social capital as exogenous factors that enhance farmer resilience. Farmer resilience is positioned as a central mediating mechanism that strengthens farmer autonomy and directly contributes to the sustainability of the coconut business. In addition, farmer group leadership is hypothesized to influence farmer autonomy directly, reflecting its role in shaping farmers' decision-making capacity and self-reliance. These relationships form an integrated conceptual framework that is empirically tested using Structural Equation Modeling (SEM), as depicted in Figure 1.

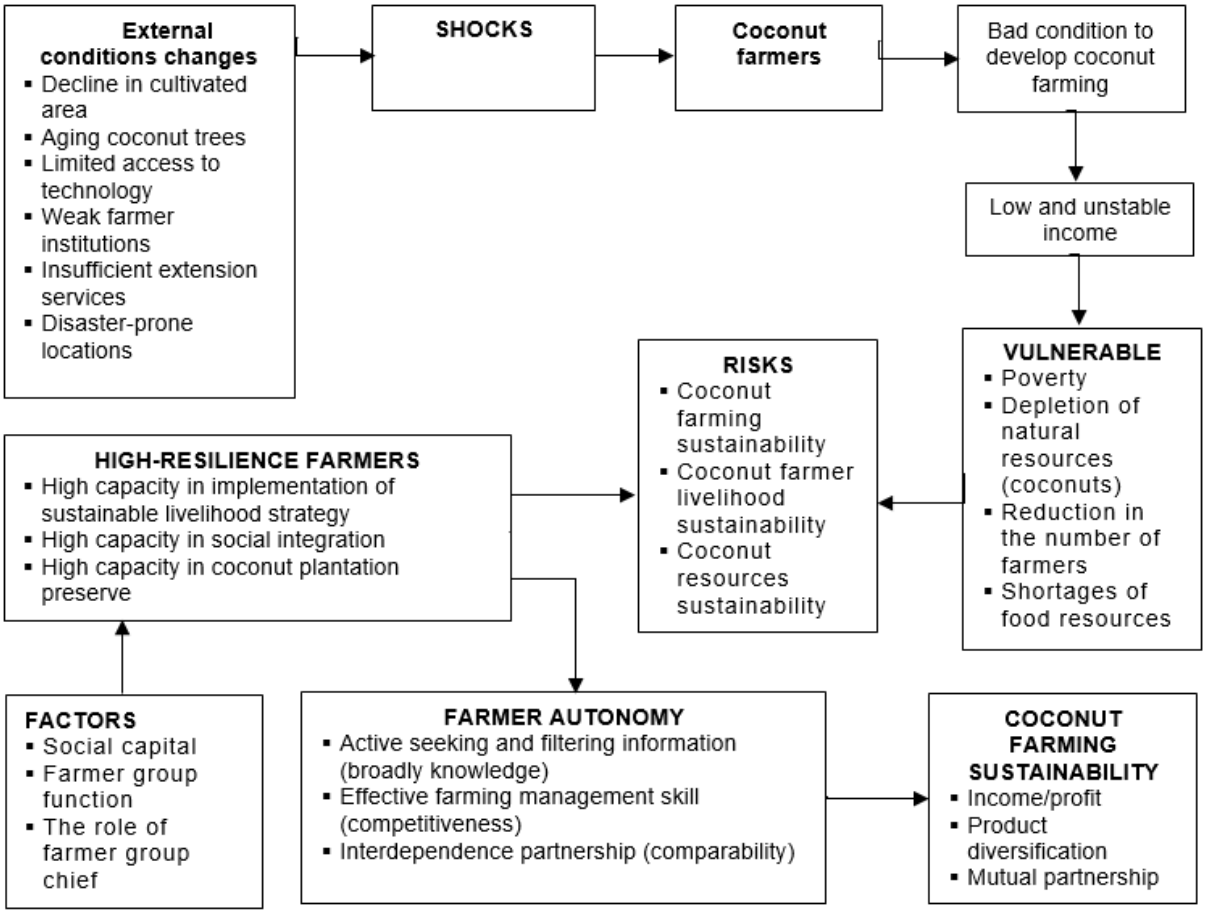

Figure 1. Conceptual framework

2.2. Scope of the study

This study examines the social and institutional determinants of the sustainability of coconut businesses among smallholder coconut farmers in Aceh Province. The scope is limited to analyzing the roles of farmer group functions, farmer group leadership, and social capital in shaping farmer resilience and farmer autonomy, and how these capacities contribute to the sustainability of coconut-based enterprises.

Empirically, the study is confined to coconut farmers who are members of farmer groups in three major coconut-producing regencies in Aceh: Aceh Besar, Simeulue, and Bireuen. These locations were selected to represent variations in agroecological conditions, market access, and socio-institutional contexts within the province. The unit of analysis is individual farmers, and all variables are measured based on farmers' perceptions and self-reported experiences obtained through a structured survey.

Analytically, the study employs a quantitative approach using Structural Equation Modeling (SEM) to test the hypothesized relationships among the selected constructs. The analysis emphasizes relational and mediating effects, particularly the roles of farmer resilience and farmer autonomy as mechanisms linking social and institutional factors to coconut business sustainability. The study does not assess technical production efficiency, biophysical performance, price transmission, or macro-level policy impacts, nor does it evaluate downstream processing or value chain competitiveness.

Conceptually, the scope is grounded in the sustainable livelihoods and resilience frameworks, with sustainability defined in terms of economic, social, and environmental dimensions at the farm and household level. The findings are therefore intended to inform policy and program design related to farmer group strengthening, leadership development, and social capital enhancement in the coconut sector, rather than to provide generalized conclusions for all plantation commodities or regions beyond Aceh Province.

2.3. Study area

The study locations were selected using purposive sampling, whereby research sites are determined based on predefined criteria relevant to the study objectives (Rukajat 2018). The selection criteria included: (1) regencies recognized as major centers of coconut production; (2) representation of Aceh Province's geographic zones: southwestern, central, and eastern regions; and (3) the presence of coconut farmers who remain actively engaged in farm management. Based on these criteria, three regencies were selected: Simeulue Regency representing the southwestern region, Aceh Besar Regency representing the central region, and Bireuen Regency representing the eastern region of Aceh Province. The geographical distribution of the study areas is presented in Figure 2.

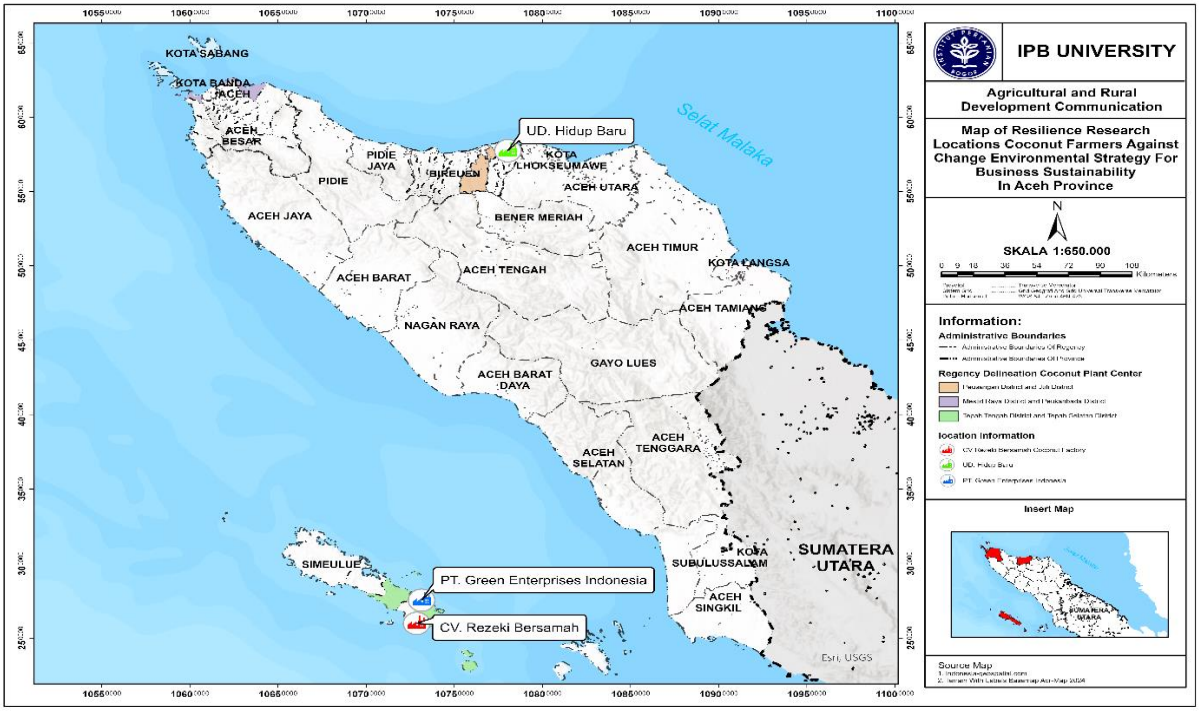

Figure 2. Aceh Province, including Simeulue, Aceh Besar, and Bireuen Regencies

Within each selected regency, subdistricts were purposively selected to capture areas with high concentrations of coconut farming. Two subdistricts were selected from each regency based on their prominence as centers of coconut farm management. According to data from BPS-Statistics Indonesia Aceh Province (2023), the selected subdistricts were Teupah Tengah and Teupah Selatan in Simeulue Regency, Peukan Bada and Seulimum in Aceh Besar Regency, and Juli and Jeumpa in Bireuen Regency.

2.4. Population dan sample

The population of this study consisted of coconut farmers meeting the following criteria: (1) owning a coconut business or processing business; (2) being members of a farmer group, and (3) having received government assistance between 2018 and 2023. According to data from the Aceh Provincial Office of Agriculture and Plantations (2024), a total of 897 farmers fulfilled these criteria and were organized into 40 active farmer groups across the study area.

The sample size was determined using the Yamane formula (as cited in Ahmed 2024), expressed as follows:

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

where:

n = sample size
N = population
e = margin of error

Using a 5% margin of error (0.05), the calculated sample size was 276.6, which was rounded up to 277 coconut farmers.

$$n = \frac{897}{(897\ x\ (0{,}05)^2) + 1} = 276{,}63$$

The adequacy of this sample size was further confirmed based on SEM requirements. According to Hair et al. (2017), SEM analysis requires a minimum sample size of at least ten times the number of observed variables. This study included six latent variables (three exogenous and three endogenous), implying a minimum sample size of 60 respondents. The final sample size of 277, therefore, exceeded the minimum threshold and was considered sufficient for robust SEM analysis. A 5% margin of error is also commonly applied in social research (Hair et al. 2017).

This approach is consistent with the recommendation of Neuman (2014), who argues that multistage cluster sampling is an appropriate strategy for studies involving large and geographically dispersed populations. A similar method was also applied by Touch et al. (2024) in agricultural and rural research employing smallholder farmers as respondents. Stratification at the regency level was implemented to ensure that geographical, ecological, social, and institutional variations across regions were adequately represented in the overall sample. Accordingly, this sampling approach enabled the study to obtain a representative sample.

At the first stage, the three selected regencies (Simeulue, Aceh Besar, and Bireuen) were treated as strata. At the second stage, farmer groups that had received government assistance during the period 2020–2023 were identified as sampling clusters. Based on data from the Aceh Provincial Office of Agriculture and Plantations (2024), a total of 40 farmer groups received assistance, comprising 10 in Simeulue Regency, 15 in Aceh Besar Regency, and 15 in Bireuen Regency. All identified farmer groups were included in the study, resulting in a cluster census at the group level. At the third stage, respondents were selected from within each farmer group, comprising both group leaders (officials) and member farmers. The distribution of the sample across regencies is presented in Table 1, while the allocation of respondents across farmer groups and their composition is detailed in Appendix 1.

Table 1. Distribution of sample size across regencies

No.	Regency	Total sample
1.	Simeulue	64
2.	Aceh Besar	106
3.	Bireun	107
	Total	277

2.5. Data collection

This study utilized both primary and secondary data. Primary data were collected through structured interviews using a pre-designed questionnaire administered directly to coconut farmers. Interviews were conducted by trained enumerators who guided respondents through the questionnaire. Respondents were asked to indicate their level of agreement using a four-point Likert scale: Strongly Agree (4), Agree (3), Disagree (2), and Strongly Disagree (1). In addition to interviews, direct field observations were conducted to assess coconut farming activities, farmers' livelihood conditions, and the availability of facilities and infrastructure. These observations validated and complemented the interview data.

Secondary data were obtained from official documents and reports published by government institutions, including the Central Bureau of Statistics and relevant agricultural agencies. Scientific literature, including books, peer-reviewed journal articles, and previous research findings, was also reviewed to support the analysis and interpretation of the primary data. Field data collection was carried out from May to August 2024.

2.6. Data analysis

This study employed descriptive and inferential analyses. Descriptive analysis was used to portray the empirical condition of each variable by transforming mean indicator scores into index values ranging from 0 to 100, which were classified into four categories: Very Low ($\leqslant$ 25), Low (26–50), Moderate (51–75), and High (>75) (Sumardjo 1999).

Inferential analysis was conducted using Partial Least Squares–Structural Equation Modeling (PLS-SEM) with SmartPLS version 3.0 to test the hypothesized relationships specified in the conceptual framework (Figure 1). PLS-SEM was selected due to several advantages, including (1) it enables the analysis of complex relationships among variables, both direct and indirect, simultaneously; (2) it can be effectively applied to relatively small sample sizes with non-normal data distributions and (3) it facilitates the testing and development of new theoretical models, including the analysis of mediating (intervening) variables effectively (Hair et al. 2017).

The SEM analysis consists of two stages: model evaluation and structural model evaluation. The model evaluation stage is conducted to test the significance of the indicators in representing their respective variables through analyses of validity and reliability. The validity of the indicators is determined based on the following criteria: a loading factor (LF) value ≥ 0.6 and an Average Variance Extracted (AVE) value > 0.5 (Hair et al. 2017). The reliability criteria were assessed using Cronbach's Alpha and Composite Reliability (CR) values. A Cronbach's Alpha coefficient ≥ 0.6 was considered acceptable, as this study is exploratory in nature, while a CR value ≥ 0.7 was used to indicate adequate internal consistency reliability (Henseler et al. 2015). The second step is the evaluation of the structural model, which aims to analyze the direction and significance of the relationships among variables.

The structural model evaluation focused on testing the direction and significance of the hypothesized paths. Path coefficients were considered statistically significant when the t-statistics exceeded 1.96, and the p-value was $\leqslant$ 0.05 (Hair et al. 2017). The SEM analysis tested the following direct and indirect relationships: (1) the effects of farmer group functions (X1), the role of farmer group leaders (X2), and social capital (X3) on farmer resilience (Y1); (2) the effect of farmer resilience (Y1) on farmer autonomy (Y2); (3) the effects of farmer resilience (Y1) and farmer autonomy (Y2) on coconut business sustainability (Y3); and (4) the mediating role of farmer autonomy (Y2) in the relationship between farmer resilience (Y1) and coconut business sustainability (Y3). These paths correspond directly to the hypotheses and SEM structure presented in Figure 1.

Farmer resilience (Y1) was defined as farmers' capacity to sustain and adapt their livelihoods in response to economic, social, and environmental pressures and was measured using indicators of livelihood strategy implementation, social integration, and resource conservation (Serino et al. 2021). Farmer autonomy (Y2) referred to farmers' ability to make independent and strategic management decisions and was measured using indicators of information-filtering capacity, managerial capability, and partnership capacity (Sumardjo et al. 2019). Coconut business sustainability (Y3) represented long-term farm performance across economic, social, and ecological dimensions and was measured using indicators related to income improvement, product diversification, long-term partnerships, and the application of good agricultural practices (Elkington 1994; Yanti et al. 2018).

3. Results and discussion

This section presents and discusses the results of the PLS-SEM analysis in relation to the proposed hypotheses and conceptual framework. It examines how farmer group functions, farmer group leadership, and social capital influence farmer resilience, autonomy, and the sustainability of coconut businesses in aceh, including the mediating role of farmer autonomy. The discussion interprets these findings within the sustainable livelihoods perspective to explain the institutional and social mechanisms underpinning resilient and sustainable coconut-based livelihoods.

3.1. Descriptive analysis of farmer resilience, autonomy, and coconut business sustainability

The conditions of resilience, autonomy, and coconut business sustainability, along with their influencing factors, are essential to analyze to obtain an overview of farmers' resilience capacity, farmer autonomy, and coconut business sustainability. The analysis used descriptive statistics. Based on the survey of 277 respondents, the levels of resilience, farmer autonomy, and coconut business sustainability were identified. The results of the analysis are presented in Table 2.

The table shows that the overall resilience level of coconut farmers in Aceh falls within the low category. This low level of resilience is primarily attributed to the farmers' limited capacity to implement livelihood strategies and conserve coconut trees. On the other hand, the social integration of coconut farmers is classified as moderate. This condition indicates that the capacity of coconut farmers to endure, adapt, and make various improvements to sustain their livelihoods is primarily influenced by their strong social integration capacity.

Table 2. Coconut farmers' capacity in livelihood strategies, social integration, and coconut plant conservation

No.	Indicator	Category	n	%	Average	Description
1.	Capacity in livelihood strategies	Very low (0−25)	174	62.82	29.92	Low
		Low (26−50)	59	21.30		
		Moderate (51−75)	39	14.08		
		High (76−100)	5	1.81		
2.	Capacity in social integration	Very low (0−25)	106	38.27	51.76	Moderate
		Low (26−50)	57	20.58		
		Moderate (51−75)	30	10.83		
		High (76−100)	84	30.32		
3.	Capacity in coconut plant conservation	Very low (0−25)	164	59.21	36.37	Low
		Low (26−50)	53	19.13		
		Moderate (51−75)	25	9.03		
		High (76−100)	35	12.64		
	Average				39.35	Low

Based on the survey, 79.42% of farmers had no occupation other than coconut cultivation; 16.25% managed coconut farms while engaging in trading; 3.97% combined coconut business with civil service, military, or police work; and 0.36% were retired while still managing coconut farms. These findings indicate that the majority of coconut farmers rely solely on the coconut business as their primary source of income, while only 20.58% have additional income sources outside coconut-related activities.

The survey results also show that the average monthly household income of coconut farmers is IDR 2,124,188, which is below the Aceh Minimum Wage (UMK) of IDR 3,460,672, as stipulated in Aceh Governor Regulation No. 560/1666/2023. Regarding crop diversification, 40.43% of the farmers cultivated only coconut; 7.94% grew chili; 8.30% planted vegetables; 17.69% cultivated corn; 18.05% raised cattle or goats; and the remaining 7.69% intercropped rice, livestock, corn, and vegetables among the coconut trees. These data suggest that nearly 80% of farmers rely exclusively on coconut farming and that many have not yet utilized the interspaces between coconut trees for other crops.

Farmers have made diversification efforts to maintain income sustainability; however, these efforts have resulted in minimal maintenance of coconut trees, which remain the primary source of household income. Coconut is often regarded as a subsidiary crop, less profitable, and requiring little intensive care. Fertilization is generally performed only once at planting, with no subsequent fertilization or watering. Furthermore, pest control, particularly against wild boars and monkeys, is poorly managed, causing severe damage or death to young coconut plants.

According to an interview with a community leader and coconut farmer (Mr. ZA, 65 years old, January 17, 2024, in Aceh Besar), pest control, especially against wild boars, requires expensive fencing costs, which most farmers cannot afford. As a result, newly planted coconut trees are often damaged by wild animals, leading to an increasing number of unproductive trees. Continuous plant damage has consequently led to declining production and productivity in coconut plantations over time.

According to the data of the Directorate General of Estate Crops (2019), the potential coconut yield using certified seedlings is 3,300 kilograms per hectare, while the actual productivity in 2023 reached only 1,112 kilograms per hectare. The average coconut productivity in Aceh in 2023 was 839 kilograms per hectare, equivalent to 27% of its potential productivity. This condition indicates a declining trend in the development of coconut as the farmers' primary livelihood source.

However, the mechanism for sustaining livelihoods, as stated by emphasizes the efforts of business households to maintain a stable long-term income without degrading their natural resource base. Income sustainability strategies are implemented to mitigate risks such as crop failure, fluctuating market prices, and natural disasters. The ultimate goals of these livelihood strategies are to increase income, enhance food security, reduce vulnerability and risk, improve overall well-being, and preserve natural resources.

In reality, maintaining the original source of livelihood has not been achieved among coconut farmers in Aceh. Their livelihood strategies tend to focus on diversifying occupations rather than conserving the primary natural resource base, the coconut trees themselves. As a result, both production and

productivity remain low, and the cultivated area of coconut plantations continues to decline. This condition is inconsistent with the principles of sustainable livelihoods, as the core objectives of livelihood strategies for income enhancement, risk reduction, and long-term resource conservation have not been realized.

Based on the survey, the ability of coconut farmers to sustain their livelihoods is largely supported by their social integration capacity, which is categorized as moderate but approaching low. Social integration in this context refers to farmers' ability to build and maintain cohesiveness with their surrounding social environment. This social cohesion is reflected in farmers' participation in community and religious activities. Religious values serve as guiding principles for farmers, as evidenced by their engagement in various social and religious activities, such as attending religious gatherings, participating in community events, helping others, avoiding conflicts, resolving issues through deliberation, visiting relatives or neighbors affected by misfortune, forgiving others, engaging in mutual cooperation (*gotong royong*), and sharing with others. This relatively strong social integration among coconut farmers plays an essential role in supporting and sustaining their livelihoods.

This condition is in line with the findings of previous research by Maliati and Chalid (2021), which revealed that strong family ties and mutual support networks have enabled rural communities in Aceh to avoid food insecurity risks in the aftermath of the tsunami. The survey results support this condition; the level of farmer autonomy among coconut farmers falls into the low category, as presented in Table 3. The table indicates that, overall, the farmers' autonomy of coconut is low, as all three of its indicators consist of filtering capability, competitiveness, and collaboration. Filtering capability refers to farmers' actions to seek, collect, sort, and use information as a basis for decision-making in coconut business management. The low level of filtering capability suggests that coconut farmers have not yet made optimal efforts to obtain and utilize information from relevant and credible sources to support effective farm management.

The lack of such actions has resulted in inefficient management of the coconut business. Efficient farm management reflects the competitive capacity of coconut farmers. Efficiency, in this context, refers to the management of business activities that utilize minimal inputs to achieve maximum outputs (Soekartawi 2001). Based on field observations, efficiency in coconut farm management has not yet been achieved, suggesting low competitiveness among coconut farmers. Coconut production has not reached its optimal level, even though production costs are minimal, primarily because farmers do not allocate expenses for crop maintenance.

However, based on field observations, the coconuts sold by farmers are consistently absorbed by the market. This condition does not reflect the efficiency of the coconut business; instead, it results from the fact that coconuts are an essential food commodity with increasing demand and limited production. This finding is supported by the results of previous research by Sambodo et al (2024) which found that Indonesia is currently experiencing a shortage of coconuts, particularly as a raw material for the food and industrial sectors, due to declining supply over the past few years.

Inefficient farm management leads to low-efficiency production, contributing to the low competitiveness of coconut farmers. They have not yet established mutually beneficial business partnerships with various stakeholders. One indicator of this low competitiveness is the price determination process, which is primarily controlled by intermediary traders (collectors). The selling price of coconuts is typically set by subjective estimates from traders, reflecting weak partnership networks between coconut farmers and other actors involved in business development.

Despite facing numerous constraints, farmers have made limited efforts to address these challenges through cooperative partnerships. This condition is consistent with the findings of previous research by Sjaf et al. (2022), which emphasized that partnerships serve as an effective means to overcome various constraints in the agricultural sector.

Sumardjo et al. (2020) was stated that positive social activities represent creative social energy, serving as social capital for community empowerment aimed at achieving welfare and resolving social conflicts. The low capacity to conserve natural resources poses a significant threat to the future sustainability of the coconut business in Aceh. Based on the survey results, the long-term sustainability level of the coconut business in Aceh falls into the low category, as presented in Table 3.

Table 3. Level of farmers' autonomy based on filtering, competitiveness, and collaboration capabilities

No.	Indicators	Category	n	%	Average	Description
1.	Capability in filtering information	Very low (0−25)	70	25.3	37.5	Low
		Low (26−50)	123	44.4		
		Moderate (51−75)	84	30.3		
		High (76−100)	0	0.0		
2.	Competitiveness	Very low (0−25)	68	24.6	35.3	Low
		Low (26−50)	149	53.8		
		Moderate (51−75)	55	19.9		
		High (76−100)	5	1.8		
3.	Collaboration	Very low (0−25)	89	32.1	38.0	Low
		Low (26−50)	85	30.7		
		Moderate (51−75)	88	31.8		
		High (76−100)	15	5.4		
Average					34.9	Low

Table 4 shows that all indicators are classified as low, including the overall level of business sustainability. This finding indicates that, in the long term (within the next 10 years), the sustainability of the coconut business in Aceh is facing serious challenges. Conversely, it is projected that domestic and international demand for coconuts and their derivative products will continue to increase over the long term (Ministry of Agriculture 2022). This trend is partly driven by the growing public awareness of health and healthy lifestyles (Alouw and Wulandari 2020). This condition presents a significant opportunity for coconut farmers to expand and develop their business.

Table 4. Increase in profit, number of partnerships, number of processed products, and plantation area managed according to Good Agricultural Practices (GAP)

No.	Indicators	Category	n	%	Average	Description
1.	Profit	Very low (0−25)	59	21.30	44.65	Low
		Low (26−50)	88	31.77		
		Moderate (51−75)	107	38.63		
		High (76−100)	23	8.30		
2.	Interdependence partnership	Very low (0−25)	44	5.88	39.35	Low
		Low (26−50)	149	3.79		
		Moderate (51−75)	74	6.71		
		High (76−100)	10	3.61		
3.	Processing product	Very low (0−25)	34	12.27	40.31	Low
		Low (26−50)	157	56.68		
		Moderate (51−75)	80	28.88		
		High (76−100)	6	2.17		
4.	Plantation area managed in accordance with good agricultural practices (GAP)	Very low (0−25)	77	27.80	34.30	Low
		Low (26−50)	125	45.13		
		Moderate (51−75)	65	23.47		
		High (76−100)	10	3.61		
Total					41.67	Low

The lowest average score was found for the indicator measuring the number of business partnerships to be established in the long term. In fact, partnerships play a crucial role in maintaining the sustainability of income and resources. The livelihood sustainability mechanism proposed by Ellis (1998) emphasizes that one of the key efforts to access and utilize resources effectively is through partnerships established within organizational frameworks. Mutually respectful and beneficial partnerships serve as an important strategy to overcome business constraints and enhance agricultural enterprise performance (Sjaf et al. 2022). The ability to establish partnerships is one of the key indicators used to measure the level of autonomy among coconut farmers. The autonomous variable serves as a moderating variable, assumed to have both direct and indirect effects on the sustainability of coconut business enterprises.

3.2. The function of farmer groups, the role of farmer group leaders, and social capital

In this research, the function of farmer groups is categorized into two leading roles: as learning classes and as cooperation platforms for their members. The function of farmer groups as learning classes refers to their role in enhancing members' knowledge and skills to improve production, profits, and plantation management in accordance with good agricultural practices (GAP), post-harvest handling, processing, training, access to capital, and marketing. Meanwhile, the function of farmer groups as cooperation platforms concerns their capacity to facilitate members' access to various resources for the development of coconut business, such as seeds, fertilizers, collective marketing, cultivation and post-harvest technologies, harvesting, pest control, and other aspects of coconut farm management. Based on the survey results, the function of farmer groups as both learning classes and cooperation platforms was found to be at a low level. This finding indicates that farmer groups have not yet functioned effectively in either role. Most groups lack a secretariat and do not display organizational identity boards, even though they have formal management structures. Their activities are generally limited to occasions when programs are initiated by the government or other external parties, and agricultural extension services are conducted mainly through group meetings. The internal organizational mechanisms of the groups are not functioning properly. Meetings are held only every three to four months, annual member assemblies are not conducted, and group membership size varies considerably.

These findings suggest that the functions of farmer groups need to be revitalized. At present, farmer groups tend to serve merely as symbolic entities rather than as functional organizations. Many are established primarily for administrative purposes, such as qualifying for government assistance, rather than from farmers' genuine needs to collaborate. The formation of farmer groups should be based on members' shared interests and similar socio-economic conditions. This aligns with the original purpose of establishing farmer groups, which is to serve as a medium for improving farmers' welfare through various functions, including their roles as learning classes and cooperation platforms among members (Ministry of Agriculture 2016).

The nonfunctional and primarily administrative (symbolic) existence of farmer groups is further corroborated by survey findings on social capital and the role of farmer group leaders. The results indicate that social values are categorized as high, whereas social networks and social trust are at a moderate level. This suggests that although members are socially close and familiar with one another, they do not effectively perform institutional functions such as holding regular deliberations, planning collective business activities, or managing group affairs. Social values such as honesty, timely debt repayment, mutual assistance, respect for others' rights, adherence to religious obligations, and active participation in religious and social activities should ideally serve as driving forces in the formation and strengthening of social networks among coconut farmers. These networks are essential for maintaining group existence and facilitating the development of coconut-based enterprises.

The social networks of farmers encompass the extent to which coconut farmers can access and utilize information and resources to enhance farm management. These resources include financial capital, agricultural inputs, technology, education and training, government assistance, pest and disease management, and business partnerships. Well-established social networks foster social trust, reflected in cooperative practices such as borrowing and lending agricultural tools or capital, as well as joint marketing activities among coconut farmers. Mutual trust is a crucial foundation for developing sustainable business partnerships. The role of farmer group leaders as leaders and motivators was found to be moderate. As leaders, they assist members in resolving problems, accessing resources, adopting technologies, and developing members' knowledge and skills in coconut farm management. As motivators, they encourage and engage members in actively participating in group development and managing their coconut enterprises. A more detailed overview of the factors influencing the level of farmer resilience is presented in Table 5.

Table 5. Functions of farmer groups, social capital, and the role of farmer group leaders, 2024

No.	Variables	Category	n	%	Average	Description
The function of the farmer group						
1.	Learning class	Very low (0−25)	130	46.93	32.58	Low
		Low (26−50)	87	31.41		
		Moderate (51−75)	50	18.05		
		High (76−100)	10	3.61		
2.	Cooperation platform	Very low (0−25)	138	49.82	30.75	Low
		Low (26−50)	80	28.88		
		Moderate (51−75)	44	15.88		
		High (76−100)	15	5.42		
Social capital						
1.	Social value	Very low (0−25)	0	0.00	77.04	High
		Low (26−50)	6	2.17		
		Moderate (51−75)	115	41.52		
		High (76−100)	156	56.32		
2.	Social networking	Very low (0−25)	34	12.27	52.35	Moderate
		Low (26−50)	95	34.30		
		Moderate (51−75)	114	41.16		
		High (76−100)	34	12.27		
3.	Social trust	Very low (0−25)	6	2.17	63.67	Moderate
		Low (26−50)	47	16.97		
		Moderate (51−75)	172	62.09		
		High (76−100)	52	18.77		
The role of farmer group leader						
1.	Leader	Very low (0−25)	34	12.27	55.18	Moderate
		Low (26−50)	73	26.35		
		Moderate (51−75)	106	38.27		
		High (76−100)	64	23.10		
2.	Motivator	Very low (0−25)	38	13.72	55.29	Moderate
		Low (26−50)	69	24.91		
		Moderate (51−75)	100	36.10		
		High (76−100)	70	25.27		

3.3. Validity and reliability testing of indicators using Structural Equation Modeling (SEM)

Structural equation modeling (SEM) is a statistical technique used to analyze the simultaneous relationships among variables (Hair et al. 2017). The first step in SEM analysis is to examine the validity and reliability of indicators and variables presumed to influence the model through validity and reliability testing. The validity test assesses the extent to which an indicator accurately represents a variable, whereas the reliability test evaluates the consistency of the indicators as measurement instruments. Validity and reliability testing of indicators in SEM yields the outer model, as shown in Figure 3. Indicators are considered valid and reliable representations of a variable if they meet the testing criteria outlined in Table 6. Indicators that do not meet the required thresholds are excluded from the model, and the validity and reliability tests are then repeated. The results of this reevaluation are presented in Table 7 and Figure 4.

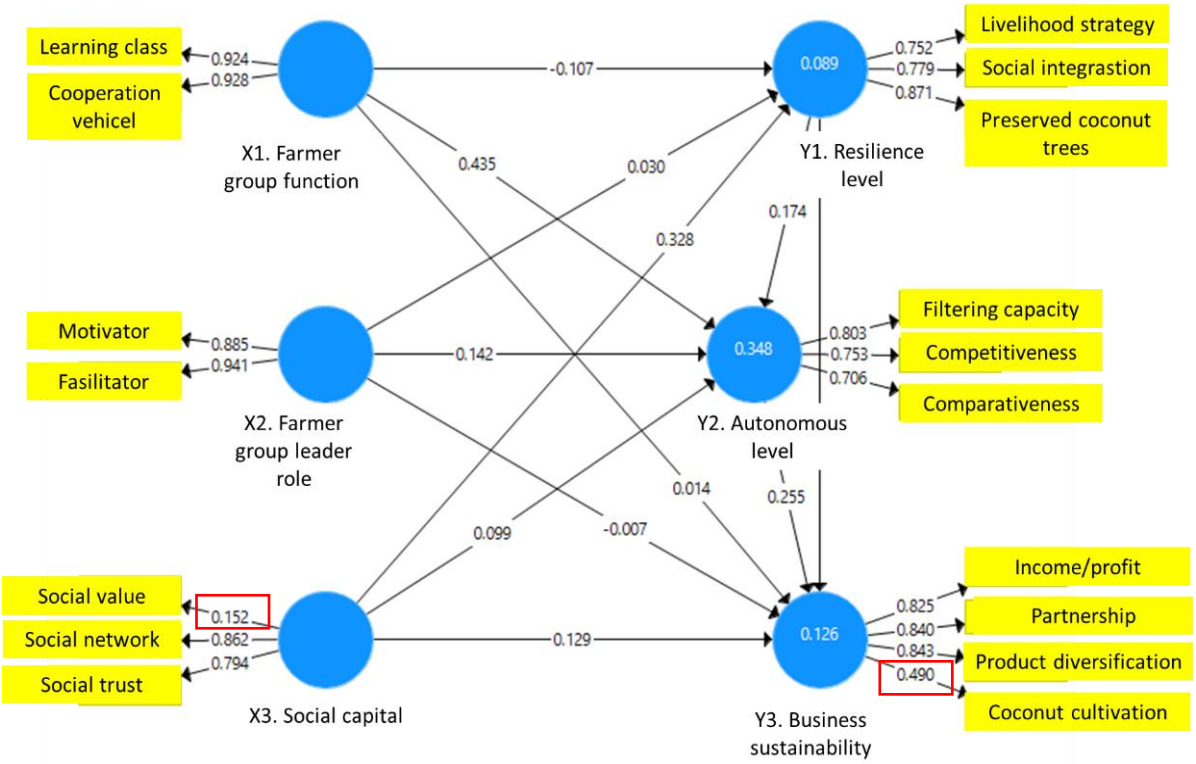

Figure 3. Initial outer model of coconut farmers' resilience in responding to strategic environmental changes in Aceh Province

The initial outer model indicates that two indicators did not meet the validity criteria, namely social value and coconut cultivation according to good agricultural practices, as highlighted in the red boxes in Figure 3. Detailed results of the validity and reliability tests for farmer resilience, farmer autonomy, and business sustainability are presented in Table 6.

Table 6. Results of validity and reliability tests for farmers' resilience, autonomy, and business sustainability indicators

Variables and indicators	Measurement criteria					
	LF	AVE	Note	CR	Cronbach's Alfa	Description
Farmer resilience (Y1)						
Convergent validity		0.643*	Valid	0.843*	0.742*	Reliable
▪ Livelihood strategy	0.752*		Valid			
▪ Social integration	0.779*		Valid			
▪ Conserve resources	0.871*		Valid			
Farmer autonomy (Y2)						
Convergent validity		0.570*	Valid	0.799*	0.625*	Reliable
▪ Filterability	0.803*		Valid			
▪ Competitiveness	0.753*		Valid			
▪ Mutual partnership	0.706*		Valid			
Business sustainability (Y3)						Reliable
Convergent validity		0.584*	Valid	0.844*	0.746*	
▪ Income	0.825*		Valid			
▪ Product diversification	0.840*		Valid			
▪ Business partners	0.843*		Valid			
▪ Good cultivation	0.490		*Not Valid*			

Note: LF=Loading factor, AVE= Average varian extracted, CR=Composite reliability

Based on Table 6, among the three dependent variables represented by ten tested indicators, nine indicators were found to be valid and reliable, while one indicator, the area of coconut plantations managed in accordance with good coconut cultivation practices, was identified as invalid. This indicator did not meet the validity criteria due to the low variation in respondents' answers. Most respondents indicated that, in the long term, the management of the coconut business in accordance with good agricultural practices remained low. Furthermore, in accordance with the validity and reliability testing criteria proposed by Hair et al. (2017), indicators that did not meet the validity and reliability criteria were excluded from the model, followed by a bootstrapping procedure. The results are shown in Table 7.

Table 7. Bootstrapping results for resilience, autonomy, and business sustainability indicators

Variables and indicators	Measurement criteria					
	LF	AVE	Note	CR	Cronbach's Alfa	Description
Farmer resilience (Y1)						
Convergent validity		0.645*	Valid	0.845*	0.742*	Reliable
▪ Livelihood strategy	0.761*		Valid			
▪ Social integration	0.781*		Valid			
▪ Conserve resources	0.864*		Valid			
Farmer autonomy (Y2)						
Convergent validity		0.570*	Valid	0.799*	0.625*	Reliable
▪ Filter capacity	0.804*					
▪ Competitiveness	0.755*		Valid			
▪ Comparativeness	0.703*		Valid			
Business sustainability (Y3)						
Convergent validity		0.734*	Valid	0.892*	0.819*	Reliable
▪ Income	0.869*					
▪ Product diversification	0.858*					
▪ Mutual partnership	0.844*					

Subsequent testing was conducted on the indicators of farmer group functions, social capital, and the role of farmer group leaders. The results presented in Table 8 indicate that the social values were invalid. A bootstrapping analysis was then performed after removing the invalid and unreliable indicators; the results are shown in Table 9. Six indicators were valid and reliable, as demonstrated by factor loadings that met the threshold values, and the constructs showed adequate levels of Composite Reliability and Average Variance Extracted.

Table 8. Results of validity and reliability tests for farmer group functions, farmer group leader role, and social capital indicators

Variables and indicators	Measurement criteria					
	LF	AVE	Note	CR	Cronbach's Alfa	Note
Function of farmer group (X1)		0.858*	Valid	0.923*	0.834*	Reliable
▪ Cooperation platform	0.924*		Valid			
▪ Learning class	0.928*		Valid			
The role of farmer group leaders (X2)		0.834*	Valid	0.910*	0.806*	Reliable
▪ Motivator	0.885*		Valid			
▪ Facilitator	0.941*		Valid			
Social capital (X3)		0.466		0.671*	0.374	Not Reliable
▪ Social value	0.152		*Not Valid*			
▪ Social networking	0.862*		Valid			
▪ Social trust	0.794*		Valid			

The final results indicate that all remaining indicators met the required threshold values for factor loadings, Composite Reliability, and Average Variance Extracted. Six indicators were confirmed as valid and reliable representations of their respective constructs. The refined outer model, free from invalid indicators, is presented in Figure 4.

Table 9. Bootstrapping results for farmer group functions, farmer group leader role, and social capital variables

Measurement criteria	LF	AVE	Note	CR	Cronbach's Alfa	Note
Function of farmer group (X1)		0.858*	Valid	0.923*	0.834*	Reliable
▪ Cooperation platform	0.925*		Valid			
▪ Learning class	0.927*		Valid			
The role of farmer group leaders (X2)		0.834*	Valid	0.910*	0.806*	Reliable
▪ Motivator	0.885*		Valid			
▪ Facilitator	0.941*		Valid			
Social capital (X3)		0.693*	Valid	0.818*	0.560	Reliable
▪ Social networking	0.868*		Valid			
▪ Social trust	0.796*		Valid			

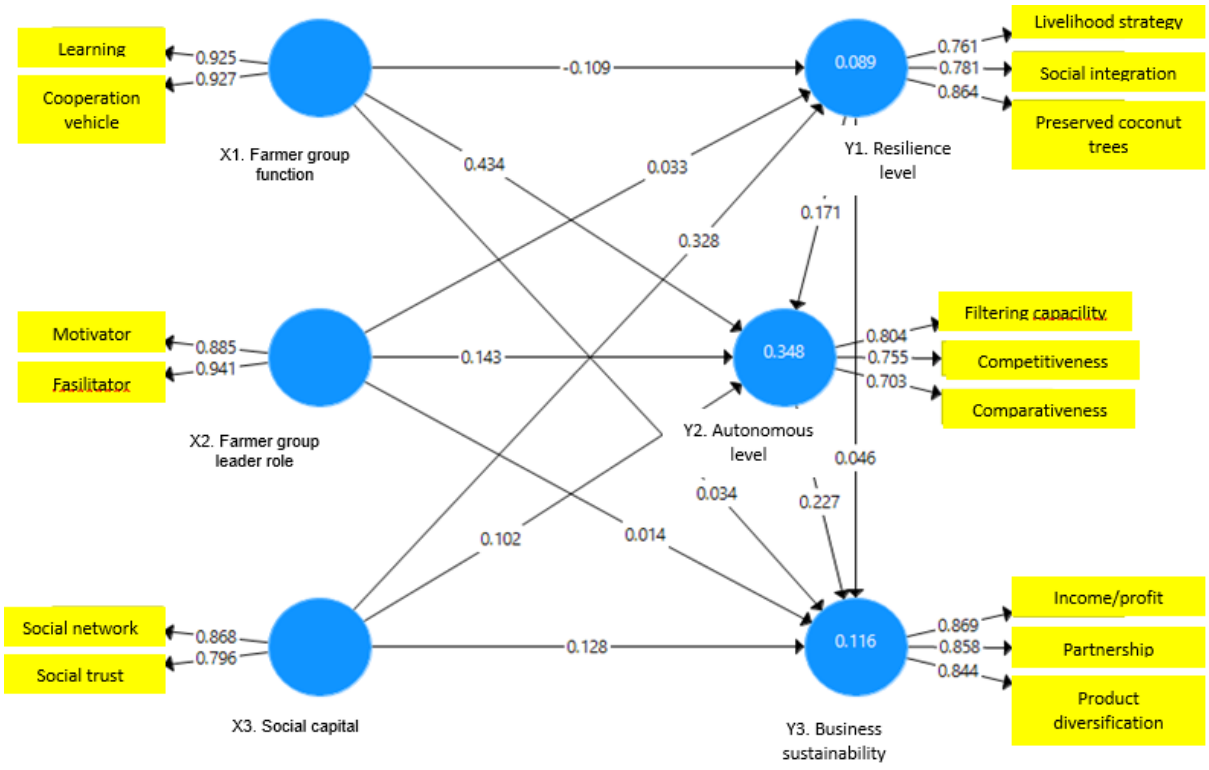

Figure 4. Second outer model of coconut farmers' resilience in responding to strategic environmental changes in Aceh Province

3.4. Relationships among variables

The relationships between dependent and independent variables were examined by evaluating the structural model. The evaluation criteria for the structural model were as follows: a t-statistic greater than 1.96 indicates the existence of a relationship between variables, and a p-value ⩽ 0.05 indicates that the relationship is statistically significant. Direct relationships between variables are illustrated in the inner model, shown in Figure 5. Figure 5 shows positive and significant relationships (t-statistic > 1.96) are highlighted in red boxes. The model identifies the following direct positive relationships: (1) farmer group functions → farmer autonomy, (2) the role of farmer group leaders → farmer autonomy, (3) social capital → farmer resilience, (4) farmer resilience → farmer autonomy, and (5) farmer autonomy → coconut business sustainability.

The positive relationship between farmer group functions and farmer autonomy indicates that the effectiveness of farmer groups as learning classes and cooperation platforms is positively associated with members' knowledge (filtering ability), efficiency in daily life and coconut farm management, and the development of partnerships. More active and dynamic farmer groups create greater opportunities for members to enhance their knowledge and skills, thereby supporting livelihood sustainability. When farmers are able to strengthen their livelihoods, improvements in farm management practices are more likely to follow.

Farmer group dynamics are closely linked to the role of group leaders. The leader's function as a motivator influences members' willingness to improve knowledge and skills, while the role as a facilitator determines members' access to available resources, including development programs and coconut business initiatives. Active leadership encourages farmers to take advantage of existing opportunities to improve their livelihoods. This finding is consistent with previous research showing that group dynamics and leadership roles significantly affect members' capabilities (Sriati et al. 2020).

As shown in Figure 5, social capital has a positive and significant relationship with coconut farmers' resilience. This indicates that stronger social networks and higher levels of trust enhance farmers' capacity to respond to problems and unfavorable strategic environmental changes. Extensive and well-established networks provide a foundation for trust, enabling farmers to communicate effectively with various stakeholders and access resources. Such conditions strengthen farmers' ability to survive, adapt, and respond to external pressures.

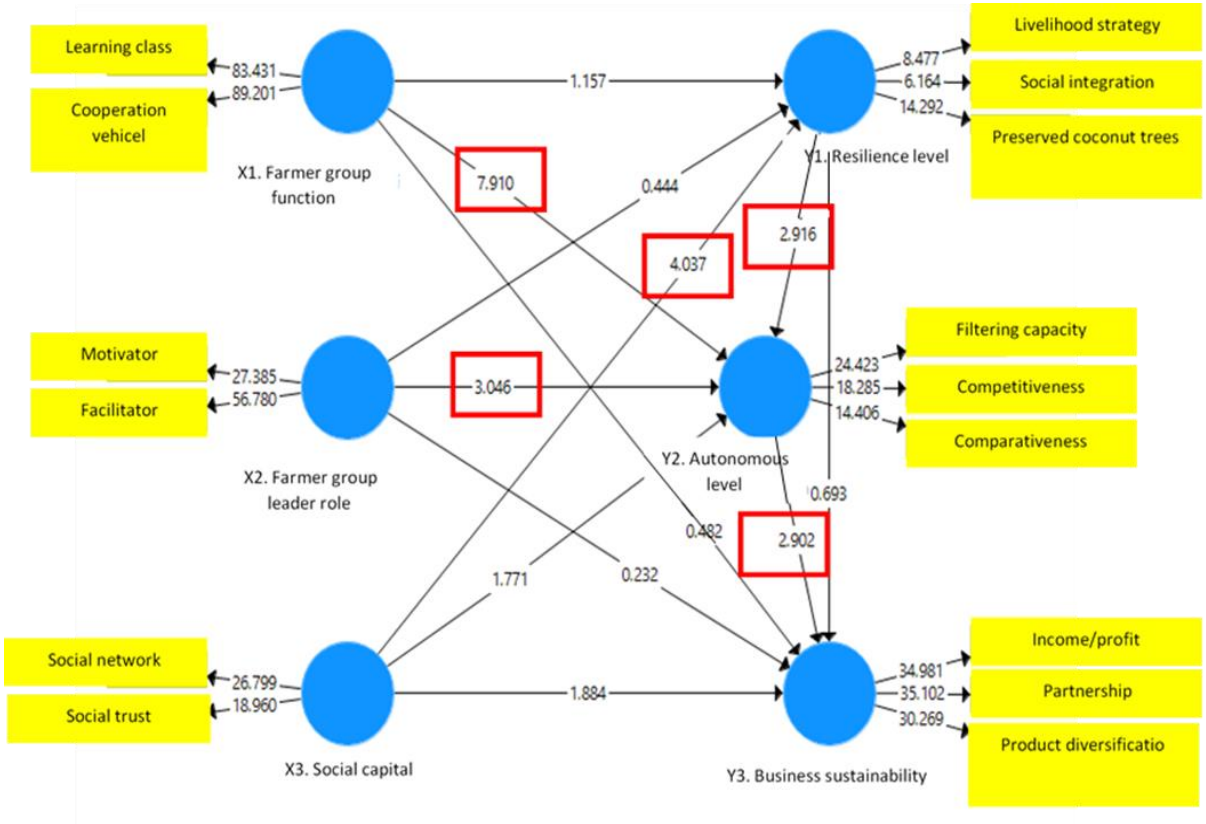

Figure 5. Inner model of coconut farmers' resilience, autonomy, and coconut business sustainability in Aceh Province

Farmers' resilience contributes to business sustainability when it is accompanied by the capacity to act autonomously. Autonomy is reflected in farmers' ability to make independent decisions related to sustaining, adapting, and transforming coconut farm management in ways that suit their specific conditions and ensure long-term profitability. Decision-making capacity is supported by farmers' ability to seek, filter, and select relevant information. This information is then applied in farm management, resulting in more efficient resource use and the production of higher-quality coconuts and processed products. Product quality, in turn, strengthens farmers' bargaining position and increases their leverage in negotiations and collaborations.

The functions of farmer groups, the role of group leaders, and social capital are all positively associated with farmer autonomy. This indicates that farmers' capacity to access and use information, produce high-quality products, and strengthen their bargaining power depends on the effectiveness of farmer groups, the quality of leadership, and the availability of social capital. Farmer group progress is largely shaped by leadership performance. When leaders effectively fulfill both leadership and motivational roles, groups become more dynamic and better able to access resources for coconut enterprise development. Access to such resources is further facilitated by strong social networks and trust, which support informed and effective decision-making in farm management.

These findings, particularly those related to resilience, are consistent with resilience theory, which emphasizes that efforts to sustain livelihoods depend on the mobilization of human, physical, natural, and financial capital, supported by social capital in the form of networks and trust. Empirically, farmers' social networks enhance access to information related to seeds, fertilizers, government programs, and coconut development technologies. Broader and stronger networks improve farmers' knowledge and skills, forming the basis for informed decision-making.

Knowledge accumulation is critical for effective management of the coconut business under conditions of uncertainty. Farmers with broader knowledge are better able to balance inputs and outputs, manage resources efficiently, and achieve sustainable income. Efficient management supports the production of higher-quality products that meet market demand, thereby strengthening farmers' bargaining power. For example, farmers producing higher-quality coconuts are better positioned to negotiate prices based on quality and market conditions, and to select buyers who offer fair prices.

The analysis identified two indicators that did not meet validity or reliability criteria: (1) social values and (2) the area of coconut plantations managed according to good agricultural practices. These indicators were excluded due to low response variability. Empirical data indicate that social values, such as *gotong royong, peusijuek, khanduri blang*, and traditional cultivation practices, remain deeply embedded in Acehnese community life, resulting in homogeneous responses that limit their statistical explanatory power. Similarly, most respondents reported not implementing good agricultural practices, as coconut cultivation is predominantly carried out using traditional methods. These indicators are therefore recommended for further refinement in future research to better capture variation and improve measurement validity.

4. Conclusions and policy implications

4.1. Conclusions

The PLS-SEM results confirm that several institutional and social factors play a critical role in shaping farmer autonomy and the sustainability of coconut businesses in Aceh Province. Significant positive relationships were identified between farmer group functions and farmer autonomy, the role of farmer group leaders and farmer autonomy, social capital and farmer resilience, farmer resilience and farmer autonomy, and farmer autonomy and coconut business sustainability. These results indicate that improvements in institutional capacity and social resources are associated with higher levels of resilience, autonomy, and long-term business sustainability.

Among these relationships, the strongest effect was observed between farmer group functions and farmer autonomy, highlighting the importance of effective farmer groups as learning platforms and as mechanisms for cooperation. Stronger farmer group functions substantially enhance farmers' decision-making capacity, information filtering ability, competitiveness, and bargaining position. Farmer resilience also plays a pivotal role, as higher resilience—reflected in farmers' capacity to implement livelihood strategies, maintain social integration, and conserve coconut resources—significantly strengthens farmer autonomy. In turn, greater autonomy contributes directly to improved sustainability of coconut businesses.

The findings further indicate that current livelihood strategies, primarily based on job diversification, have not been effective in increasing farmers' incomes. Coconut farming, as the main livelihood source, has not been able to generate income at a level comparable to the provincial minimum wage. This condition is largely driven by low coconut production and productivity. Even when market prices increase, limited output constrains income growth, underscoring that price incentives alone are insufficient without productivity improvements.

Income improvement is, therefore, a prerequisite for adopting good coconut cultivation practices. Farmers with higher and more stable incomes are more likely to invest in farm maintenance, certified seedlings, fertilizers, and other productivity-enhancing inputs. The use of certified, high-yielding planting material emerges as a key determinant of increased coconut productivity and, ultimately, business sustainability.

4.2. Policy implications

Policy efforts to promote the sustainability of coconut businesses in Aceh should prioritize the adoption of good agricultural practices and the integration of coconut-based intercropping systems. These strategies can increase farm income while maintaining coconut as the primary enterprise. However, their effectiveness depends heavily on farmers' resilience and autonomy, which enable them to manage risks, adapt to change, and sustain improvements without excessive reliance on external assistance.

Strengthening farmer resilience requires deliberate investment in social and institutional capacity building. Expanding farmer networks is essential to improving access to markets, technologies, extension services, and processing opportunities. This can be achieved most effectively by revitalizing the functions of farmer groups and enhancing the role of group leaders as facilitators and motivators. Dynamic farmer groups serve as entry points for development programs, collective learning, and resource mobilization.

Ultimately, resilient farmers form the foundation of farmer autonomy. Farmers who are capable of enduring shocks, adapting to constraints, and transforming their livelihood strategies are better positioned to seek, evaluate, and apply relevant information. Such capacities are crucial for sustaining coconut-based livelihoods and ensuring the long-term viability of the coconut sector in Aceh.

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Appendix 1. Distribution of respondents by farmer group and membership status

No.	Farmer group	Sample	Composition
	Simeule Regency		
1.	Urep Samo	7	3 officials, 4 members
2.	Daita Samo	7	3 officials, 4 members
3.	Kuala Makmur	7	3 officials, 4 members
4.	Mangida Maju	4	3 officials, 1 member
5.	Usaha Basamo	7	3 officials, 4 members
6.	Siron Indah	4	3 officials, 1 member
7.	Karya Sejahtera	7	3 officials, 4 members
8.	Tanau Sefakat	7	3 officials, 4 members
9.	Fajar Makmur	7	3 officials, 4 members
10.	Karya Bakti	7	3 officials, 4 members
	Aceh Besar Regency		
1.	Ue Dalam	8	3 officials, 5 members
2.	Sepakat	7	3 officials, 4 members
3.	Maju Bersama	7	3 officials, 4 members
4.	Usaha Bersama	7	3 officials, 4 members
5.	Semangat Baru	7	3 officials, 4 members
6.	Mita Raesuki	7	3 officials, 4 members
7.	Badeuk Meeh	7	3 officials, 4 members
8.	Bina Sejahtera	7	3 officials, 4 members
9.	Beseupakat Reudeup	7	3 officials, 4 members
10.	Tani Jaya	7	3 officials, 4 members
11.	Tron Rahmat	7	3 officials, 4 members
12.	Kana Usaha	7	3 officials, 4 members
13.	Mandiri	7	3 officials, 4 members
14.	Rahmad Sejahtera	7	3 officials, 4 members
15	Makmur Tani	7	3 officials, 4 members
	Bireuen Regency		
1.	Gapoktan Udep Besaree	9	4 officials, 5 members
2.	Koptan Huda Hudu	7	3 officials, 4 members
3.	Gle Meng Meng	7	3 officials, 4 members
4.	Mudah Rizeki	7	3 officials, 4 members
5.	Barona	7	3 officials, 4 members
6.	Bagi beusaree	7	3 officials, 4 members
7.	Pante Sejahtera	7	3 officials, 4 members
8.	Lubuk Reunee	7	3 officials, 4 members
9.	Batee Raya Hijau	7	3 officials, 4 members
10.	Beule Lam Saba	7	3 officials, 4 members
11.	Mata Ie Meuh	7	3 officials, 4 members
12.	Tani Baru	7	3 officiasl, 4 members
13.	Sejahtera Raya	7	3 officials, 4 members
14.	Bina Karya Mulia	7	3 officials, 4 members