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Sustainable Livelihood Assets Assessment and Strategic Prioritization of Papuan Nutmeg Farming Households

Dewi Saraswati[1*], Sri Mulatsih[2], Hermanto Siregar[2], Rully Novie Wurarah[3]

[1] Rural and Regional Development Planning Study Program, Faculty of Economics and Management, IPB University, IPB Dramaga Campus, Bogor 16680, Indonesia
[2] Department of Economics, Faculty of Economics and Management, IPB University, IPB Dramaga Campus, Bogor 16680, Indonesia
[3] Faculty of Economics and Business, State University of Papua, Manokwari 98314, Indonesia

Corresponding Author Email: dewisara@udel.edu

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ABSTRACT

This study explores rural agricultural development, emphasizing that it often relies heavily on capital and technology rather than evidence-based approaches reflecting farmers' real conditions. Using the Sustainable Livelihood Approach (SLA), the research examines Papuan nutmeg farming households in Fakfak Regency, West Papua, where empirical studies remain scarce. The objectives are to measure livelihood assets and design strategies for sustainable improvement. The Rank of Centroid (RoC) method was applied to build a weighted Livelihood Assets Index (LAI), while the Mann-Whitney test compared coastal and mountainous farmers. SWOT analysis identified internal and external factors, and the Analytical Hierarchy Process (AHP) determined strategic priorities. Results show LAI values between 1.78 and 3.13, averaging 2.29, indicating moderate livelihood levels, with coastal farmers generally better off. SWOT findings reveal a moderately favorable external environment and strong internal resources, though risks from climate variability, market instability, and geographic isolation persist. AHP highlights resilience-oriented strategies that leverage strengths to counter external threats as top priorities. The study underscores the importance of financial inclusion, infrastructure, institutional support, and adaptive capacity. It also demonstrates the effectiveness of integrating LAI with SWOT–AHP as a comprehensive framework for guiding sustainable rural livelihood development.

1. INTRODUCTION

In the context of rural development and sustainability, identifying an effective model to improve the livelihoods of smallholder farmers in ways that are economically viable, socially inclusive, and environmentally sustainable remains a major challenge. Rural areas that depend heavily on the agricultural sector face multiple constraints, including limited access to efficient production inputs, low levels of agricultural investment, challenges related to land governance and policy frameworks, as well as environmental degradation and climate change pressures. At the same time, the adoption of modern agricultural technologies and sustainable farming practices capable of generating socio-economic and environmental benefits remains limited [1]. The dual demands of promoting regional economic growth while improving farmers' living standards underscore the need for a more holistic and participatory model of rural agricultural development. Such an approach should integrate economic, social, institutional, and environmental dimensions to support sustainable rural transformation.

Rural development across Indonesia, particularly in eastern regions such as Papua, faces distinctive challenges that are often intensified by geographical isolation, limited infrastructure, and restricted access to markets. In Papua, the rugged terrain and underdeveloped road networks create significant barriers for farmers in accessing agricultural inputs, technologies, and local markets. These constraints, in turn, limit opportunities for sustainable rural development and economic advancement. As a result, there is a strong need for context-specific policies that directly address these structural and spatial challenges faced by farming communities.

Nutmeg has been one of Indonesia's treasures for centuries and is part of the daily life of the Indonesian people, especially in eastern Indonesia. In various literature and documents, it is recorded that Indonesia was the center of the spice trade. The glory of Eastern Indonesian monarchies in the past is part of world history, with Banda Island as the largest and most important nutmeg plantation area [2, 3]. The existence and importance of nutmeg plantations in eastern Indonesia are reflected in the significant contribution of nutmeg plantations to national nutmeg production. The contribution of nutmeg production in North Sulawesi, Maluku, North Maluku, and West Papua is 28%, 13%, 14%, and 14%, respectively, to

national production, which reached 41,000 tons in 2021 [4].

Papuan nutmeg (*Myristica argentea*, Warb) plays a crucial role in the economies of most indigenous people in Fakfak Regency and neighboring regions in West Papua Province. For generations, nutmeg farming has been the primary source of income for local people, contributing significantly to their livelihoods. In Fakfak, it is estimated that up to 70% of household income is derived from nutmeg farming, with the crop serving as a critical economic driver for rural communities. Smallholder farmers cultivate approximately 6,071 hectares of nutmeg, producing about 1,884 tons annually. Farmers in Central Fakfak, for example, average 9.8 hectares per farm, yielding around 30,000 fruits per hectare, which translates to an annual net profit of IDR 11.93 million per hectare [5].

Despite the strategic role of Papuan nutmeg as a livelihood backbone for rural communities in Fakfak, the sector faces challenges such as low productivity, disease outbreaks, and limited access to quality markets. Farmers continue to face difficulties related to access to efficient inputs and modern farming techniques, which limit the development of their livelihoods and economic well-being.

Development interventions have largely focused on production aspects, such as increasing output or improving cultivation techniques, rather than on a comprehensive understanding of farmers' livelihood systems. Programs have often lacked consideration of structural constraints, such as limited financial inclusion, weak institutional support, and disparities in access to resources between coastal and mountainous communities.

This situation creates a mismatch between development initiatives and the actual needs of farming households, leading to persistent vulnerability and uneven livelihood outcomes. Therefore, a more integrated analytical approach is needed to better capture the complexity of livelihood systems and to support evidence-based strategic planning [6, 7].

The research on Papuan nutmeg farming is limited, particularly in the context of rural economic development in West Papua, highlighting a significant gap in empirical studies. While much of the existing literature focuses on livelihood assessments in other agricultural sectors, there is a lack of comprehensive studies on the livelihoods of Papuan nutmeg farmers. Previous studies have examined similar agricultural contexts in other regions of Indonesia [8-10], but the application of the Sustainable Livelihood Approach (SLA) to Papuan nutmeg farming remains unexplored. For nutmeg farmers, this approach is highly relevant as it links their well-being to the efficient and sustainable management of resources. For instance, managing natural resources such as land and water, as well as enhancing technical skills in nutmeg cultivation, are key aspects of maintaining and improving their human and natural assets.

This study aims to fill this gap by providing a novel perspective on the livelihoods of nutmeg farmers in Fakfak, utilizing a multi-dimensional index approach to evaluate livelihood assets. The approach not only introduces a new methodology for assessing livelihood sustainability in this specific context but also contributes to the theoretical understanding of SLA by integrating cultural, social, and economic dimensions unique to the region. In the case of nutmeg farmers in Fakfak, these assets significantly influence their sustainability, especially since nutmeg farming serves as the primary source of income.

However, measuring livelihood assets alone is not sufficient to support effective rural development planning. Quantitative assessment needs to be complemented by a structured strategic framework capable of translating empirical findings into actionable priorities. Integrating strategic tools such as SWOT analysis with multi-criteria decision methods provides an opportunity to bridge the gap between diagnosis and policy formulation, allowing stakeholders to identify priority interventions based on both internal capacities and external challenges. Such an approach is particularly relevant in geographically complex regions like Papua, where development strategies must be context-specific and sensitive to local socio-cultural dynamics [11, 12].

By incorporating a strategic prioritization perspective, this study extends beyond conventional livelihood assessment to provide a decision-support framework for rural development planning [6]. The integration of multidimensional livelihood asset evaluation with strategic analysis enables a more comprehensive understanding of both the strengths that can be leveraged and the constraints that must be addressed to achieve sustainable development outcomes. This combined approach offers practical insights for policymakers, development agencies, and local stakeholders in designing targeted interventions that enhance resilience, reduce regional disparities, and support inclusive growth in nutmeg-based rural economies [13, 14].

The importance of a conceptual and evidence-based understanding of the condition of nutmeg farmer households is one of the steps in Papua's nutmeg-based rural socio-economic development strategy. This thinking is the foundation for conducting research related to sustainable livelihood, especially related to livelihood assets. Furthermore, this research was conducted to actively contribute to efforts in formulating the model and approach for people-based rural economy development in the area. The objectives of this study are to measure the sustainable livelihood index of Papuan nutmeg farmers and to ascertain whether there are differences in livelihood assets among nutmeg farmers in coastal and mountainous districts.

This study presents a novel contribution to the discourse on rural development through a commodity-based approach, focusing specifically on Papuan nutmeg farmers in Fakfak Regency. Unlike previous research that has largely concentrated on technical cultivation or general trade aspects of nutmeg, this study uniquely applies the SLA to comprehensively assess the sustainability of farmers' livelihoods in a region characterized by distinct geographical, cultural, and socio-economic conditions.

The novelty lies in the use of a multi-dimensional index to evaluate livelihood assets and in the comparative analysis between coastal and mountainous communities, an approach that has not been explored before in the context of Papuan nutmeg. Furthermore, the focus on Papuan nutmeg, a locally significant yet under-researched commodity, enhances the originality of this study by contributing empirical insights to the theoretical framework of SLA and supporting the formulation of people-centered rural economic development strategies in eastern Indonesia.

2. LITERATURE REVIEW

As stated by Scoones [15], the concept of livelihood refers to how individuals or families secure their basic needs through access to the assets they possess, such as natural, human,

social, physical, and financial assets. Recently, in rural studies and poverty reduction research, 5 basic capitals have been developed by incorporating psychological capital [16-18] and cultural assets [19-21]. Psychological capital includes self-efficacy, hope, optimism, willingness to develop, and resilience [22], and cultural assets cover ceremony and custom, local wisdom and practices, craft and tools [23]. Sustainable livelihood is depicted as the state that withstands any disturbance and strains, recovers from them, and retains or improves its assets and capacities, advancing without threatening the base of natural resources [15]. The SLA has been broadly applied in a wide range of studies, including communities in aerial, mountainous, and coastal regions of communities with numerous community sources of economy. It is crucial to ascertain household livelihood circumstances, local access to capital for livelihood, and factors affecting livelihood [24]. Li et al. [25] asserted that rural revitalization as a part of rural development, poses sustainable livelihood as one of the main objectives of rural revitalization. In the context of rural development, to support livelihood, the approach emphasizes the competence and prospective resources among individuals and communities and provides essential considerations on institutions, social interactions, and governmental procedures [26]. For fostering sustainable living and growth, the government and its counterparts are encouraged to integrate and apply the SLA in their development policies [27].

Livelihood has become an essential viewpoint in rural development for decades due to the importance of recognizing what individuals do for a living in various socioeconomic and environmental conditions [28]. Livelihood is also defined as the set of resources, skills, and revenue-producing endeavors that individuals or families preserve and develop and that may be utilized to support themselves and enhance their long-term living conditions [29]. A livelihood consists of activities that provide an instrument of life, assets, social and material resources [15]. The SLA emphasizes the importance of sustainability in utilizing these assets without depleting the natural resource base, while also providing resilience to social and economic pressures [30].

3. RESEARCH METHOD

3.1 Study area and sampling

The survey was conducted from February to March 2024 in 6 districts purposively selected to achieve this study goal. To determine the minimum sample for a survey, the Slovin formula [31] was employed with the following formula:

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

n represents the number of samples, *N* the number of nutmeg farmers, and *e* the error limitation, which is set at 10%. From a population of approximately 6,300 nutmeg farmers, an initial sample size of 98 respondents was determined. However, in line with the principle that a larger sample enhances representativeness and strengthens analytical robustness, the sample size was subsequently increased to 170 farmers. After excluding incomplete or unqualified responses, the final sample comprised 151 nutmeg-farming households drawn from 34 villages across both coastal and mountainous districts of Fakfak Regency, as presented in Table 1 and Figure 1.

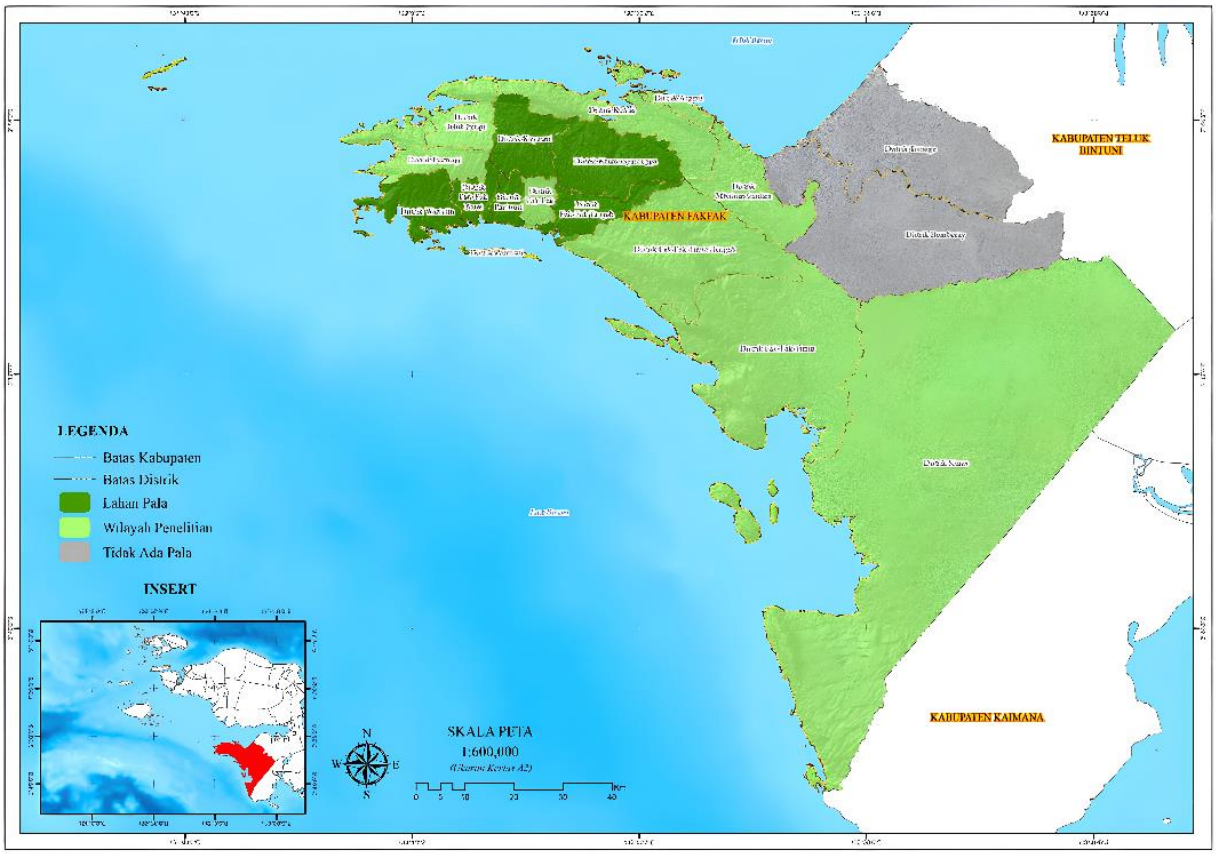

Figure 1. The map of the research location in Fakfak Regency

Table 1. Study area and number of samples

Districts	Type of Region	Distance from the Capital City (km)	Number of Villages Surveyed	Samples
1. Wartutin (War)	Coastal	22.20–46.00	6	18
2. Fakfak Barat (FB)	Coastal	8.30–17.20	9	26
3. Fakfak Tengah (FT)	Coastal	9.50–19.70	8	23
4. Fakfak Timur Tengah (FTT)	Coastal	26.80–45.40	10	29
5. Kramongmongga (Kr)	Mount	31.80–51.80	10	29
6. Kayauni (Ky)	Mount	22.10–40.60	9	26

The selection of districts represents the main nutmeg production areas and reflects geographical diversity, allowing comparison between coastal and upland livelihood conditions. For the strategic analysis using SWOT–AHP, additional respondents were involved to capture both community and institutional perspectives. A total of 20 key informants were selected using purposive sampling, consisting of representative nutmeg farmers and officials from the local agricultural office. These respondents were chosen based on their experience, knowledge of nutmeg farming systems, and involvement in agricultural development programs to ensure the validity of strategic factor identification and prioritization.

3.2 Selection of attributes of assets

To measure the livelihood asset, a system of variables and attributes was developed based on 7 types of livelihood assets [16, 17, 25, 32-38]. Several attributes not addressed in previous studies were incorporated in this research, including grafting skills, pest control skills, sasi, and nutmeg seed storage, based on brainstorming with field experts. Sasi refers to a form of local wisdom and customary regulation that prohibits harvesting nutmeg before it reaches proper maturity. These additional attributes were included to better capture context-specific aspects of farmers' livelihood assets. Attributes for each asset in the questionnaire were measured using an ordinal scale ranging from 1 to 4 [33, 39] as shown in Table 2.

Table 2. Attributes of assets for measuring livelihood assets

Type of Asset	Attributes	Scale
Human (A_1)	Number of family members contributed to family income (A_{11})	1 (none)–4 (more than 2)
	Participation in training and courses in the last 3 years (A_{12})	1 (never)–4 (more than 2)
	Level of formal education (A_{13})	1 (elementary school)–4 (bachelor)
	Number of productive laborers for nutmeg farming (A_{14})	1 (none)–4 (more than 2)
	Availability of trainers (A_{15})	1 (none)–4 (exist and functional)
	Grafting skill (A_{16})	1 (unknowledgeable)–4 (skilled)
	Pest control skill (A_{17})	1 (unknowledgeable)–4 (skilled)
Social (A_2)	Membership in cooperative or village-owned enterprises (A_{21})	1 (not member)–4 (member and active)
	Being a part of management in cooperatives or village-owned enterprises (A_{22})	1 (no)–4 (management and active)
	Existence of farmer group (A_{23})	1 (no)–4 (exist and routine)
	Membership in farmer group (A_{24})	1 (not member)–4 (member and active)
	Cooperation in nutmeg farming (A_{25})	1 (no)–4 (exist and often)
Natural (A_3)	Frequency of cutting trees for firewood (A_{31})	1 (always)–4 (never)
	Number of kinds of economic trees (A_{32})	Number (classified into 4 categories)
	Land ownership status (A_{33})	1 (lease land)–4 (personal property)
Physics (A_4)	Size of the floor area of the house (A_{41})	Size of floor area (M^2); classified to 4 categories
	Ownership of vehicles for transportation (A_{42})	1 (no vehicle)–4 (4 wheel vehicle)
	TV or radio ownership (A_{43})	1 (no TV and no radio)–4 (TV and Radio)
	Cellular phone ownership (A44)	1 (no cellphone)–4 (cellphone for business)
Financial (A_5)	Machete ownership (A_{45})	number of machetes
	Hoe ownership (A_{46})	number of hoe
	Drying nutmeg infrastructure (A_{47})	1 (no)–4 (more than 2)
	Bank savings (A_{51})	1 (no)–4 (more than 10 million rupiahs)
	Financial grant (A_{52})	1 (unavailable)–4 (available and had a grant)
	Access to loans from friends or family members (A_{53})	1 (unavailable)–4 (available and anytime)
	Bank loan (A_{54})	1 (never tried)–4 tried and had a loan)
Cultural (A_6)	Compliance with Sasi (A_{61})	1 (not obedient)–4 (very obedient)
	Storage of nutmeg seeds as stock (A_{62})	1 (not at all)–4 (always)
Psychological (A_7)	Self-efficacy (A_{71})	1 (not satisfied)–4 (very satisfied)
	Self-confidence (A_{72})	1 (not confident–4 (very confident)
	Willingness to develop (A_{73})	1 (not eager)–4 (very eager)
	Hope (A_{74})	1 (not sure)–4 (very sure)
	Optimism (A_{75})	1 (not optimistic)–4 (very optimistic)

3.3 Data analysis of livelihood assets measurement

Farmers' livelihood assets were measured using the Livelihood Asset Index (LAI) approach proposed by Singh and Hiremath [40], as follows:

$$LAI_j = \sum_{i=1}^{n} (LA_i)/a_i \quad (2)$$

where, LAI_j is the value of livelihood assets of farmer number-j, LA_i denotes the value of asset number-i, a_i is the number of attributes of asset number-i, n denotes the n_{th} asset (n = 1, 2, 3, 4, 5, 6, 7).

To calculate the index, interview data were first converted from ordinal responses into interval-scale data using the Method of Successive Intervals (MSI), applied through an Excel add-in function. This step is commonly used in social research based on questionnaires, as it allows ordinal data to be transformed into a scale that is more suitable for statistical analysis.

Indices were classified into three qualitative categories—low, medium (Med.), and high—based on the range between the minimum and maximum index values of each asset.

Considering stakeholders' perceptions of the relative importance of each asset and attribute, a weighted index based on RoC weights was applied following Krishna et al. [41] using principal component, Li et al. [42] using entropy, Hao et al. [43] using AHP with scoring, and Hua et al. [44] using the normalization method. This research employed RoC to weight the index as used by Sureeyatanapas et al. [45]. RoC provides a simple and effective approach for weighting ranking data based on order and priority level perceived by stakeholders at local, provincial, and national levels. The RoC is mainly employed for studies that measure the composite index. The basic formula of RoC is depicted as follows:

Criteria 1 ≥ Criteria 2 ≥ Criteria 3…Criteria n, k is the number of criteria, W is the weight of C.

The weight of Criteria 1 (W1) is larger than the weight of Criteria 2 (W2), and so forth.

$$W1 = \frac{1 + \frac{1}{2} + \frac{1}{3} + \cdots + \frac{1}{k}}{k} \quad (3)$$

$$W2 = \frac{0 + \frac{1}{2} + \frac{1}{3} + \cdots + \frac{1}{k}}{k} \quad (4)$$

$$k = \frac{0 + 0 + 0 + \cdots + \frac{1}{k}}{k} \quad (5)$$

Assets or attributes are weighted using the formula as follows:

$$Wk = \frac{1}{k}\sum_{i=1}^{k}\left(\frac{1}{Ri}\right) \quad (6)$$

Wk represents the weight of the k-th sub-objective, i = 1, 2, 3...k, *Ri* denotes its rank.

The RoC method was implemented by distributing questionnaires via Google Forms to nine experts and stakeholders, consisting of one academic, two non-governmental organizations (NGOs) representatives, one representative from the local planning board, one from the local plantation office, one from the provincial plantation office, one from the Directorate General of Plantations, one representative from the nutmeg association, and one legislator. Respondents were asked to rank the livelihood assets from 1 to 7, as well as to rank the attributes associated with each asset.

3.4 Mann–Whitney test

The Mann–Whitney test was employed to determine whether there are differences in livelihood assets between nutmeg farmers in coastal and mountainous regions.

A coastal district is defined as a rural area located adjacent to the sea or along a coastline, whereas a mountainous region is defined as an inland area situated away from the coast and without direct access to the coastline.

The Mann–Whitney test was also applied by Epanda et al. [46] to assess changes in assets before and after the implementation of a community-based co-management project. The calculations were performed using IBM SPSS software.

A hypothesis has been developed as follows:

H0: There is no significant difference in livelihood asset values between farmers in coastal and mountainous districts.

H1: There are differences in livelihood asset values between farmers in coastal and mountainous districts.

3.5 SWOT analysis

A SWOT analysis was conducted to identify strategic factors influencing the sustainability of nutmeg farming livelihoods. Internal factors, comprising strengths and weaknesses, were derived from the empirical results of livelihood asset measurements. Meanwhile, external factors, including opportunities and threats, were identified through semi-structured interviews with nutmeg farmers and representatives from the agricultural office [47, 48]. Each factor was evaluated using a rating scale that reflects both its level of importance and its current condition. The factors were subsequently organized into the Internal Factor Evaluation (IFE) and External Factor Evaluation (EFE) matrices. Weighted scores were then calculated by multiplying the assigned weights by their respective ratings, allowing for the assessment of each factor's relative influence within the strategic framework [49].

3.6 Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) was applied to determine priority weights of SWOT factors using pairwise comparison matrices. The AHP was selected due to its suitability for multi-criteria analysis involving expert judgement. It enables structured pairwise comparisons with consistency validation. Compared to the SWOT, this combination offers greater transparency and is well-suited for a participatory and decision-oriented rural research context. Respondents compared factors using the Saaty scale, ranging from 1 to 9, to indicate relative importance. The comparison matrices were normalized to obtain priority weights. Consistency of judgments was tested using the Consistency Ratio (CR), with values below 0.10 considered acceptable. The resulting weights were used to rank strategic factors and identify priority strategies for improving the sustainability of nutmeg farming livelihoods [50, 51].

4. RESULTS AND DISCUSSION

4.1 General characteristics of nutmeg farmers

The characteristics of nutmeg farmers in Fakfak Regency show significant variability in terms of age, number of household dependents, distance from home to farm, and harvest yields, as shown in Table 3.

Table 3. Characteristics of the nutmeg farmers surveyed

District	The Distance of Nutmeg Farm from the House (m)	Age (Years)	Number of Dependents	Number of Nutmeg Seeds Harvested (x 1.000)
War	3–5,000	31–64	1–11	7.5–54
FB	100–3,000	24–75	3–10	3.6–122.25
FT	150–7,000	25–65	1–9	9.75–45
FTT	20–11,000	27–63	2–7	4.5–60
Kr	100–4,000	31–65	1–8	6–60
Ky	20–12,000	22–69	2–7	6–75

Note: War = Wartutin; FB = Fakfak Barat; FT = Fakfak Tengah; FTT = Fakfak Timur Tengah; Kr = Kramongmongga; Ky = Kayauni.

4.2 Weight value of assets and attributes

The results of the weight with the RoC pattern are obtained as shown in Table 4.

Table 4. Weight of assets and attributes using the Rank of Centroid (RoC) method

Weight of Assets	Weight of Attributes
Human (0.30)	A_{11} = 0.16, A_{12} = 0.15, A_{13} = 0.16, A_{14} = 0.16, A_{15} = 0.19, A_{16} = 0.05, A_{17} = 0.13
Social (0.11)	A_{21} = 0.16, A_{22} = 0.08, A_{23} = 0.26, A_{24} = 0.17, A_{25} = 0.33
Natural (0.18)	A_{31}= 0.28, A_{32} = 0.26, A_{33}=0.46
Physics (0.14)	A_{41} = 0.08, A_{42} = 0.14, A_{43} = 0.05, A_{44} = 0.14, A_{45} = 0.22, A_{46} = 0.14, A_{47} = 0.24
Financial (0.17)	A_{51} = 0.41, A_{52} = 0.32, A_{53} = 0.11, A_{54} = 0.16
Cultural (0.06)	A_{61} = 0.65, A_{62} = 0.35
Psychological (0.04)	A_{71} = 0.11, A_{72} = 0.18, A_{73} = 0.31, A_{74} = 0.27, A_{75} = 0.13

4.3 Farmers' Livelihood Assets Index

The Livelihood Assets Index (LAI) of nutmeg farmers in Fakfak ranges from 1.78 to 3.13, with an average score of 2.29, as presented in Table 5. Three districts—Fakfak Timur Tengah, Kramongmongga, and Kayauni—fall within the low index category, while the other three districts are classified as having a medium index. Among them, Fakfak Barat and Wartutin record the highest average index values, indicating relatively better access to livelihood resources, including human, financial, and other forms of capital. In contrast, Kayauni and Kramongmongga show the lowest index values, reflecting greater constraints in resource availability.

A spatial pattern also emerges, with coastal districts generally exhibiting higher asset values than mountainous areas. This difference is likely associated with better infrastructure, market access, and support services in coastal regions. Conversely, farmers in mountainous areas face greater challenges, including limited market access and higher transportation costs, which can constrain livelihood development. Figure 2 presents the spatial distribution and differences in livelihood assets across districts.

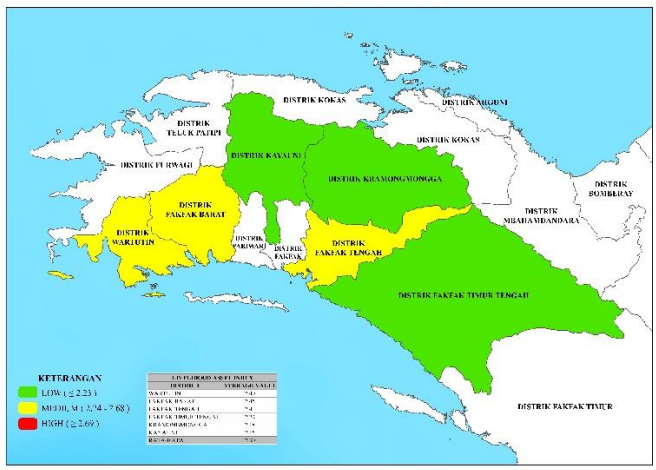

Figure 2. The spatial variation in livelihood assets across districts

Table 6 presents the LAI of nutmeg farmers across districts in Fakfak Regency, showing that all districts fall within the low to medium LAI category. Wartutin and Fakfak Barat exhibit a more balanced asset distribution, particularly with relatively higher values in natural and cultural assets. In contrast, Fakfak Timur Tengah, Kramongmongga, and Kayauni demonstrate lower asset levels, especially in human, financial, and psychological capital.

Table 5. The assets index in each district

District	Average Value of Assets							
	Human	Social	Natural	Physical	Financial	Cultural	Psychological	Livelihood
War	2.00	2.18	3.14	2.20	1.63	4.54	3.44	2.40
FB	2.24	2.03	2.90	2.48	1.66	4.01	4.03	2.45
FT	2.48	2.39	2.55	2.32	1.72	3.27	3.28	2.41
FTT	1.97	2.51	2.37	2.15	1.75	2.93	3.78	2.22
Kr	1.90	2.75	2.19	2.24	1.72	2.91	3.43	2.18
Ky	1.80	2.54	2.26	2.16	1.77	2.91	3.56	2.15
Average	2.06	2.42	2.53	2.26	1.71	3.35	3.60	2.29
Min	1.33	1.23	1.70	1.41	1.00	1.00	2.82	1.78
Max	3.36	3.50	4.07	3.33	3.03	4.57	4.61	3.13

4.4 Differences in livelihood assets among nutmeg farmers in coastal and mountainous districts

Table 7 presents the differences in livelihood assets among nutmeg farmers in coastal and mountainous districts. The results indicate statistically significant differences, as reflected by an Asymp. Sig. value of less than 0.001. Specifically, natural, human, social, and cultural assets differ significantly between farmers in the coastal and mountainous areas. In contrast, no significant differences were found in physical, financial, and psychological assets, as indicated by relatively higher Asymp. Sig. values of 0.062, 0.517, and 0.123, respectively. A Z value of -5.395 corresponds to an effect size of 0.44. The Z value of -5.395 corresponds to an effect size of 0.44, suggesting a moderate to relatively strong difference in overall livelihood assets between the two districts.

Table 6. Assets index category in each district

District	Average Value	District	Average Value	District	Average Value	District	Average Value	District
	Human	Social	Human	Physical	Human	Cultural	Human	LAI
War	Low	Med.	Med.	Med.	Low	High	Med.	Med.
FB	Med.	Med.	Med.	Med.	Low	High	High	Med.
FT	Med.	Med.	Med.	Med.	Med	Med.	Low	Med.
FTT	Low	Med.	Low	Med.	Med.	Med.	Med.	Low
Kr	Low	Med.	Low	Med.	Med.	Med.	Med.	Low
Ky	Low	Med.	Low	Med.	Med.	Med.	Med.	Low

Table 7. Results of the Mann-Whitney test for assets between coastal and mountain farmers

Asset	Average		Mann-Whitney	Asymp.Sig (2-Tailed)	Z Value
	Coastal Districts (n = 96)	Mountainous Districts (n = 55)			
Physic	2.29	2.20	2157	0.062	
Financial	1.70	1.75	2484.5	0.517	
Natural	2.70	2.22	1134	< 0.001	
Human	2.17	1.85	1455.5	< 0.001	
Social	2.29	2.65	1538.5	< 0.001	
Psychological	3.66	3.49	2255	0.123	
Cultural	3.61	2.91	1375	< 0.001	
Livelihood Assets Index (LAI)	2.36	2.17	1244.5	< 0.001	-5.397

Table 8. IFE Matrix–internal strategic factors of nutmeg farming livelihoods

IFE	Component	No.	Statement	AV	W	R	TS
Strength	Natural Capital	1	Availability of productive land supports sustainable nutmeg farming	4.10	0.05	4	0.174
		2	Diversity of economic trees strengthens ecological resilience	3.95	0.05	4	0.200
		3	Long experience in traditional nutmeg cultivation	3.95	0.05	3	0.149
	Cultural Capital	4	Strong adherence to local wisdom (sasi) supports resource sustainability	4.20	0.05	4	0.218
		5	Strong cultural identity supporting community cohesion	3.70	0.04	3	0.148
	Social Capital	6	Strong community cooperation in farming activities	3.85	0.05	3	0.154
		7	Existence of informal farmer cooperation networks	3.75	0.04	3	0.141
	Human Capital	8	Availability of productive labor in households	3.80	0.04	3	0.148
	Psychological Capital	9	High optimism and willingness to develop farming activities	3.90	0.05	3	0.156
	Livelihood Stability	10	The moderate livelihood asset index indicates baseline stability	3.60	0.04	4	0.157
			Total Strengths		**0.46**		**1.64**
Weakness	Financial Capital	1	Limited access to formal credit and banking services	4.25	0.05	3	0.155
		2	Low savings ownership among farmers	4.10	0.05	2	0.116
	Physical Capital	3	Limited farming infrastructure and equipment	4.00	0.05	2	0.113
		4	Limited transportation accessibility	3.80	0.04	2	0.107
	Human Capital	5	Limited access to agricultural training and extension services	3.95	0.05	2	0.112
	Market Access	6	Limited market access, especially in mountainous districts	3.90	0.05	3	0.119
		7	Limited access to market and price information	3.60	0.04	2	0.098
	Institutional Capacity	8	Weak institutional coordination and support	3.85	0.05	3	0.127
	Technology Adoption	9	Low adoption of modern agricultural technology	3.75	0.04	2	0.088
	Value Chain	10	Limited post-harvest processing facilities	3.70	0.04	3	0.122
	Economic Risk	11	High dependency on a single commodity	3.65	0.04	2	0.103
	Investment Capacity	12	Limited capital for farm improvement	3.55	0.04	3	0.109
			Total Weaknesses		**0.54**		**1.36**
			TOTAL IFE		**1.00**		**3.01**

4.5 Internal Factor Evaluation for sustainable livelihood development

The IFE matrix (Table 8) is employed to identify and assess internal factors influencing the sustainability of nutmeg farming livelihoods in Fakfak Regency. This analysis focuses on evaluating the strengths and weaknesses emerging from empirical measurements of livelihood assets, including human, social, natural, physical, financial, cultural, and psychological capital. Through a quantitative assessment, the IFE matrix examines how these internal factors either support or constrain livelihood sustainability, thereby providing a foundation for strategic formulation. The identified strengths and weaknesses are evaluated based on their contribution to livelihood capacity, resource availability, institutional support, and adaptive resilience. Collectively, this analysis offers a systematic basis for understanding internal conditions that shape the sustainability of nutmeg-based livelihoods.

The IFE indicates that nutmeg farming livelihoods in Fakfak Regency are supported by strong natural and cultural capital, reflected in productive land availability, biodiversity, and strong adherence to local wisdom practices such as *sasi*. Social cohesion and psychological resilience further strengthen the adaptive capacity of farming households, while the availability of productive labor supports farming continuity. Despite these strengths, several structural weaknesses remain significant. Limited access to formal financial services, low savings ownership, and inadequate infrastructure constrain farmers' capacity to expand production and adopt improved technologies. In addition, limited extension services and weak institutional coordination restrict knowledge transfer and the adoption of innovation. Disparities in market access, particularly in mountainous districts, further reduce economic opportunities and contribute to uneven livelihood outcomes. The total IFE score of 3.01 indicates moderately strong internal conditions, suggesting that farmers possess important livelihood assets to sustain their livelihoods. However, targeted interventions are still needed to address structural weaknesses, improve institutional and financial support, and enhance overall livelihood sustainability.

4.6 External Factor Evaluation for sustainable livelihood enhancement

The EFE matrix presented in Table 9 identifies opportunities and threats influencing nutmeg farming livelihoods. External factors are assessed based on economic opportunities, policy support, environmental risks, and market dynamics.

The EFE results indicate that nutmeg farming livelihoods in Fakfak Regency are situated within a moderately supportive external environment, characterized by a balance between emerging opportunities and persistent structural risks. The relatively higher total opportunity score (1.259) compared to threats (0.734) reflects favorable external conditions, particularly driven by increasing global demand for nutmeg products, the availability of government agricultural and rural development programs, and the growing potential for sustainable agriculture practices such as agroforestry systems. These opportunities suggest that external institutional and market environments provide significant momentum for improving farmers' livelihoods, especially through enhanced access to financial services, cooperative strengthening, and the integration of nutmeg farming with eco-tourism initiatives that can diversify income sources. Despite these positive prospects, the external environment remains vulnerable to several critical threats, including climate variability that directly affects productivity stability, fluctuating commodity prices that create income uncertainty, and geographic isolation that limits market access and increases transaction costs, particularly for farmers in mountainous areas. Additional pressures, such as pest and disease outbreaks and land degradation, further exacerbate production risks and threaten long-term sustainability. The overall EFE score of 1.99 suggests that while external conditions are generally favorable, strategic interventions are required to strengthen farmers' adaptive capacity, improve market resilience, and enhance institutional support systems in order to fully capitalize on available opportunities while mitigating external risks to sustainable livelihood development.

Table 9. EFE matrix–external strategic factors of nutmeg farming livelihoods

EFE	Component	No.	Statement	AV	W	R	TS
Opportunities	Market Development	1	Increasing demand for nutmeg products	4.2	0.10	3	0.315
	Government Support	2	Availability of rural development and agricultural programs	4.0	0.10	3	0.258
	Sustainable Agriculture	3	Opportunities for agroforestry and sustainable farming practices	3.8	0.09	2	0.206
	Financial Inclusion	4	Expansion of microfinance and cooperative systems	3.7	0.09	2	0.191
	Eco-tourism Integration	5	Potential integration of nutmeg farming with eco-tourism	4.3	0.11	3	0.289
	Total Opportunities				0.51		1.259
Threats	Climate Risk	1	Climate variability affecting crop productivity	4.1	0.10	2	0.159
	Market Volatility	2	Fluctuating commodity prices	4.0	0.10	1	0.145
	Geographic Isolation	3	Limited accessibility in mountainous regions	3.9	0.10	2	0.161
	Pest and Disease	4	Increasing risk of plant disease	3.0	0.07	2	0.116
	Land Degradation	5	Environmental degradation affecting productivity	3.7	0.09	2	0.153
	Total Threats				0.48		0.734
	TOTAL EFE				1.00		1.99

4.7 Internal–External matrix analysis of livelihood development strategy

The Internal–External (IE) matrix analysis was conducted to determine the strategic position of nutmeg farming livelihood development in Fakfak Regency based on the results of the IFE and EFE. The IE matrix integrates internal strengths and weaknesses with external opportunities and threats to identify appropriate strategic directions for sustainable livelihood enhancement. This analysis provides a strategic mapping that indicates whether livelihood development should focus on growth, stability, or defensive strategies.

Calculation of Coordinates

Based on the results of the IFE and EFE matrices, the coordinates of the IE matrix are calculated as follows:

Total Strength Score = 1.645

Total Weakness Score = 1.369

X-coordinate (IFE) = 1.645 + 1.369 = 3.01

Total Opportunity Score = 1.259

Total Threat Score = 0.734

Y-coordinate (EFE) = 1.259 + 0.734 = 1.99

Based on the calculated coordinates (3.01; 1.99), the strategic position of nutmeg farming livelihoods lies in Quadrant IV (Grow and Build) of the IE matrix. This position indicates that nutmeg farming livelihoods possess strong internal capacity supported by natural, cultural, and social capital, while facing moderate external opportunities and environmental constraints. The strong internal condition suggests that farmers have sufficient internal resources to support development, but external challenges such as market volatility, climate risks, and geographic isolation still need to be addressed.

The position in Quadrant IV implies that livelihood development strategies should emphasize expansion and capacity strengthening to leverage existing strengths while improving adaptive capacity to external risks. Strategic priorities should focus on enhancing productivity, strengthening market integration, and improving institutional support systems. The recommended strategic focus includes:

a. Strengthening human capital through training and extension services
b. Improving financial inclusion and access to credit facilities
c. Enhancing value chain development and market access
d. Promoting sustainable farming practices and resource management
e. Improving rural infrastructure and transportation accessibility
f. Strengthening farmer institutions and cooperative development
g. Supporting diversification of income sources to reduce economic vulnerability
h. Strengthening climate adaptation strategies

The IE matrix analysis indicates that nutmeg farming livelihoods in Fakfak Regency are relatively well-positioned internally, with strong natural resources, cultural cohesion, and social capital contributing positively to livelihood sustainability. However, moderate external conditions suggest that farmers still face structural constraints such as limited market access, climate risks, and financial limitations. Therefore, strategic interventions should aim to capitalize on strong internal capacities while enhancing resilience to external challenges. The Grow and Build strategy reflects the need to strengthen productive capacity, improve institutional support, and enhance economic opportunities to achieve sustainable livelihood development.

4.8 SWOT matrix of livelihood strategies

The SWOT matrix presented in Table 10 integrates internal strengths and weaknesses with external opportunities and threats to formulate strategic alternatives for enhancing the sustainability of nutmeg farming livelihoods in Fakfak Regency. The matrix is developed based on empirical findings from livelihood asset assessments, regional disparities, and stakeholder perspectives.

Table 10. SWOT matrix

	Strengths (S)	**Weaknesses (W)**
	SO Strategies	WO Strategies
Opportunity	1. Develop sustainable nutmeg production systems leveraging strong natural and cultural capital	1. Improve farmer capacity through training and extension programs
	2. Promote integration of nutmeg farming with agroforestry and eco-tourism initiatives	2. Expand access to financial services and microcredit schemes
	3. Strengthen community-based resource management using local wisdom practices	3. Improve rural infrastructure to enhance accessibility
	4. Promote value-added processing and diversification of nutmeg products	4. Strengthen institutional support and farmer organizations
	5. Develop cooperative-based marketing systems to improve market access	5. Improve post-harvest facilities and technology adoption
Threats	**ST Strategies**	**WT Strategies**
	1. Implement climate-resilient farming practices to maintain productivity	1. Develop risk mitigation programs for vulnerable farming households
	2. Strengthen land management and conservation practices to prevent degradation	2. Improve disaster preparedness and response systems
	3. Strengthen farmer institutions to improve bargaining power in volatile markets	3. Strengthen policy coordination and governance mechanisms
	4. Promote diversification of income sources to reduce dependency on nutmeg	4. Improve access to agricultural insurance and financial safety nets
	5. Enhance monitoring and evaluation of resource use to maintain sustainability	5. Strengthen infrastructure development in remote districts

This analysis aims to identify strategic actions that leverage internal strengths, address internal weaknesses, capitalize on external opportunities, and mitigate potential threats affecting livelihood sustainability.

The SWOT matrix indicates that sustainable livelihood development of nutmeg farmers should prioritize strategies that leverage strong natural, cultural, and social capital while addressing structural weaknesses related to financial access, infrastructure, and institutional capacity. SO strategies emphasize maximizing existing strengths to capture opportunities through sustainable production, diversification, and community-based resource management. WO strategies focus on addressing structural constraints through capacity building, infrastructure improvement, and strengthening institutional support systems. ST strategies highlight the importance of resilience-based approaches, including climate adaptation, conservation practices, and strengthening farmer institutions to respond to external risks. Meanwhile, WT strategies focus on reducing vulnerability through improved governance, disaster preparedness, and strengthening economic resilience. Overall, these strategic alternatives provide a comprehensive framework for enhancing the sustainability and resilience of nutmeg farming livelihoods while reducing regional disparities between coastal and mountainous districts.

4.9 Analytical Hierarchy Process analysis for strategy prioritization of sustainable livelihood development

The Analytical Hierarchy Process (AHP) was employed to determine the priority strategies for enhancing sustainable livelihood development of nutmeg farmers in Fakfak Regency. This method enables structured decision-making by comparing multiple strategic alternatives through a pairwise comparison matrix.

In this study, 20 strategies derived from the SWOT matrix (SO, WO, ST, WT) were analyzed to determine which strategies have the most significant influence on improving livelihood sustainability, reducing regional disparities, and strengthening the adaptive capacity of nutmeg farmers. The analysis involved calculating eigenvalues, priority weights, and ranking of each strategy, enabling prioritization based on their relative importance and feasibility. This structured hierarchy ensures that strategic planning decisions are evidence-based, participatory, and aligned with sustainable livelihood principles. In the AHP stage, pairwise comparison judgments from 20 informants were aggregated using the *geometric mean* method to preserve the ratio properties of the Saaty scale and produce a representative collective comparison matrix. The aggregated matrix was then normalized to derive priority weights using the eigenvector method, and consistency was evaluated through the CR, with a threshold of $CR < 0.10$ indicating acceptable consistency.

The consistency test results show $\lambda max = 22.51$, Consistency Index (CI) = 0.13, and CR = 0.08, which is below the acceptable threshold of 0.10. This indicates that the pairwise comparison judgments are consistent and reliable for further analysis.

The AHP results presented in Table 11 indicate a clear prioritization pattern among the proposed livelihood development strategies. The highest priority is the Strengths–Threats strategy S-T-1 (S11) with a weight of 0.087, highlighting the importance of leveraging internal strengths to mitigate external risks affecting nutmeg farming livelihoods. This is followed by S-O-1 (S1) and W-O-4 (S9), which emphasize the role of utilizing strengths to capture opportunities and addressing key structural weaknesses to maximize external support. Several other high-ranking strategies, including S-T-2 (S12), W-T-4 (S19), and W-T-5 (S20), further underscore the need to strengthen resilience and reduce vulnerabilities in response to environmental and market uncertainties. Overall, the distribution of weights suggests that adaptive and risk-responsive strategies are more critical than purely opportunity-driven approaches, reflecting the external pressures and structural challenges faced by nutmeg farmers in sustaining their livelihoods.

Table 11. Integrated comparison matrix and weight priorities

Strategy Category	Code	Strategy Code	Geometric Mean	Eigen Value	Weight Priority	Rank
Strengths-Opportunities (S-O) Strategies	S-O-1	S1	0.0822	1.8742	0.083	2
	S-O-2	S2	0.0318	0.7134	0.032	17
	S-O-3	S3	0.0412	0.9258	0.041	14
	S-O-4	S4	0.0449	1.0192	0.045	11
	S-O-5	S5	0.0306	0.6864	0.030	18
Weaknesses-Opportunities (W-O) Strategies	W-O-1	S6	0.0268	0.6033	0.027	20
	W-O-2	S7	0.0303	0.6771	0.030	19
	W-O-3	S8	0.0334	0.7452	0.033	16
	W-O-4	S9	0.0819	1.8433	0.082	3
	W-O-5	S10	0.0354	0.7894	0.035	15
Strengths-Threats (S-T) Strategies	S-T-1	S11	0.0866	1.9551	0.087	1
	S-T-2	S12	0.0615	1.3914	0.062	4
	S-T-3	S13	0.0434	0.9671	0.043	13
	S-T-4	S14	0.0493	1.1032	0.049	9
	S-T-5	S15	0.0566	1.2698	0.056	7
Weaknesses-Threats (W-T) Strategies	W-T-1	S16	0.0446	1.0017	0.044	12
	W-T-2	S17	0.0480	1.0725	0.048	10
	W-T-3	S18	0.0501	1.1473	0.051	8
	W-T-4	S19	0.0610	1.3816	0.061	5
	W-T-5	S20	0.0602	1.3727	0.061	6
Total			1	22.5400		

The results of the AHP analysis presented in Table 12 reveal a clear strategic orientation toward strengthening resilience, improving institutional capacity, and leveraging internal strengths to address external risks affecting nutmeg farming livelihoods in Fakfak Regency. The highest-ranked strategy, ST-1 (strengthen internal capacity to address external risks), with a priority weight of 0.087, reflects the urgent need to enhance farmers' adaptive capacity in responding to environmental challenges, market uncertainty, and geographic constraints. This finding indicates that strengthening internal resources such as human capital, social cohesion, and natural resource management is critical to improving livelihood sustainability.

The second-ranked strategy, SO-1 (utilizing internal strengths to capture opportunities), highlights the importance of leveraging strong natural and cultural capital to benefit from increasing market demand, government support programs, and sustainable agriculture initiatives. This strategy emphasizes the role of internal strengths as a foundation for livelihood expansion and diversification. The third priority strategy, WO-4 (improving infrastructure and financial access), underscores the importance of addressing structural weaknesses identified in the livelihood asset analysis, particularly low financial inclusion and limited infrastructure in mountainous districts. Improving these aspects is essential to enable farmers to take advantage of available opportunities.

Strategies ranked fourth and fifth, ST-2 and WT-4, emphasize resilience-based approaches and governance strengthening, indicating that addressing environmental risks and reducing livelihood vulnerability are key priorities. These strategies suggest the importance of strengthening institutional coordination, improving resource management, and enhancing adaptive capacity to maintain livelihood stability.

To enhance methodological transparency, an AHP hierarchical structure diagram is provided, organized into three levels: (1) the overall goal, namely strategic prioritization of sustainable livelihood development; (2) the criteria level, consisting of four SWOT-based strategy categories (S-O, W-O, S-T, and W-T); and (3) the alternative level, comprising 20 sub-strategies that are further synthesized into 10 strategic focus areas. The diagram also illustrates the propagation of weights across levels using local weights (w_{ij}) at the sub-criteria level and global weights at the strategy level, enabling a clear and traceable understanding of the decision-making structure and weighting process (Figure 3).

Table 12. Summary of top priority strategies

Rank	Code	Strategy	Weight Priority
1	ST-1 (S11)	Strengthen internal capacity to address external risks and environmental challenges	0.087
2	SO-1 (S1)	Utilize internal strengths to capture market and development opportunities	0.083
3	WO-4 (S9)	Improve infrastructure and financial access to maximize opportunities	0.082
4	ST-2 (S12)	Strengthen resilience strategies to address climate variability	0.062
5	WT-4 (S19)	Reduce livelihood vulnerability through improved governance	0.061
6	WT-5 (S20)	Strengthen institutional coordination and adaptive capacity	0.061
7	ST-5 (S15)	Strengthen monitoring and sustainable resource management	0.056
8	WT-3 (S18)	Strengthen risk mitigation and resilience programs	0.051
9	ST-4 (S14)	Improve land and resource management practices	0.049
10	WT-2 (S17)	Strengthen policy and institutional coordination	0.048

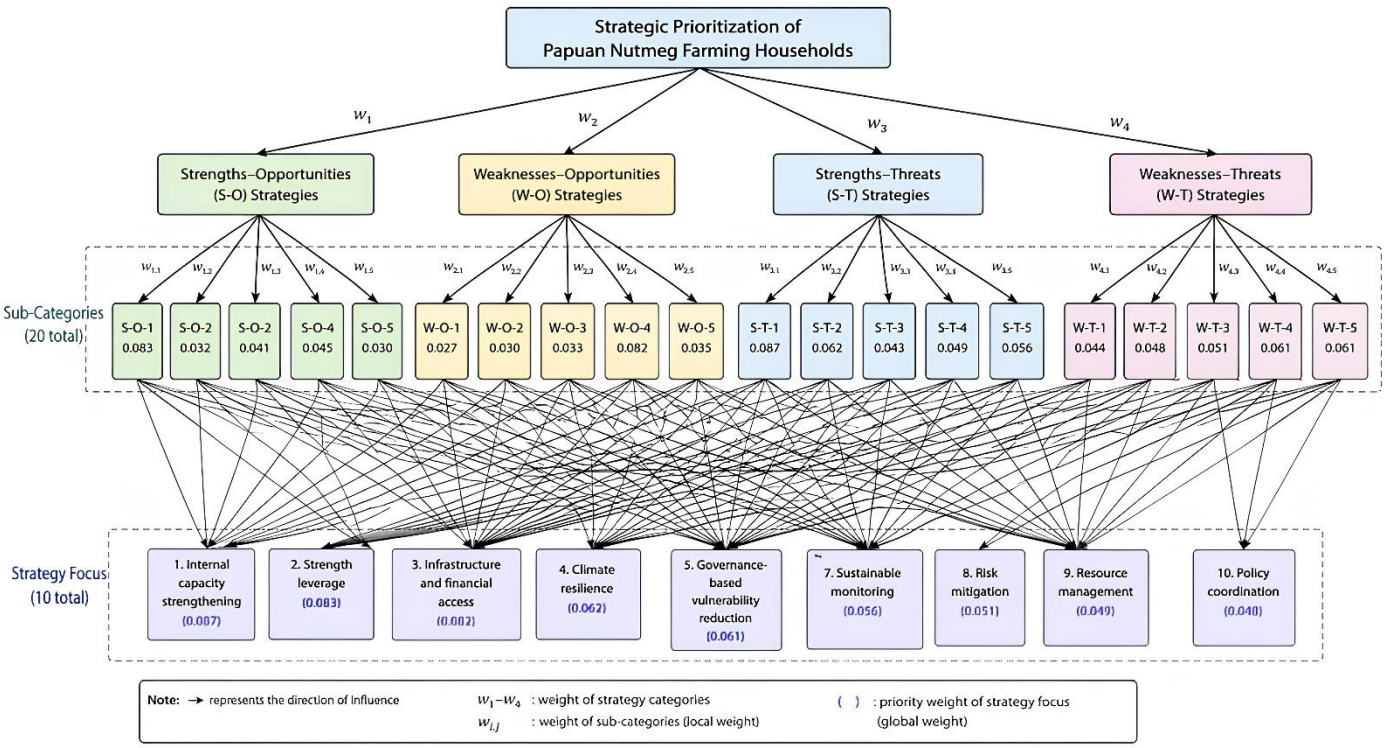

Figure 3. Integrated SWOT–AHP hierarchical structure for strategy prioritization

Overall, the AHP results demonstrate that strategies focusing on resilience strengthening, capacity building, and institutional improvement are the most critical priorities for sustainable livelihood development. The dominance of Strength–Threat strategies among the top rankings indicates that while farmers possess significant internal strengths, external risks such as climate variability, market volatility, and geographic isolation remain major challenges that must be addressed through adaptive and proactive strategies. The prioritization results suggest that sustainable livelihood development should focus on strengthening adaptive capacity, improving infrastructure and financial inclusion, enhancing institutional support, and promoting sustainable resource management. These strategic priorities are expected to improve livelihood resilience, reduce regional disparities between coastal and mountainous districts, and enhance long-term sustainability of nutmeg farming livelihoods.

4.10 Discussion

Within the Sustainable Livelihood Framework (SLF), the value of livelihood assets reflects the capacity of households to pursue sustainable livelihood strategies and cope with economic and environmental shocks. In the case of nutmeg farming communities in Fakfak, the overall asset values point to a livelihood system that remains vulnerable, with moderate to low endowments across most asset categories. As emphasized by Tsikata and Yaro [52], households with limited asset ownership tend to have lower livelihood resilience and weaker adaptive capacity, regardless of how important those assets may be perceived to be.

Human capital among nutmeg farmers is characterized by low to moderate levels and is primarily constrained by limited formal education, restricted access to training, and minimal exposure to agricultural innovation. Education plays a fundamental role in shaping livelihood opportunities and improving productivity. As noted by Thamaga-Chitja and Morojele [53], lower levels of education are often associated with unstable livelihood options and reduced productivity. This condition is evident among the farmers studied, where only 32% have completed high school and merely 6% have attained tertiary education. Access to agricultural extension services has been shown to significantly improve household income by strengthening farmers' technical capacity [54]. However, farmer empowerment efforts remain constrained by the limited availability of professional trainers and extension support. Although experiential knowledge contributes substantially to farming practices, the absence of structured capacity-building limits farmers' ability to enhance productivity and diversify income sources. This finding aligns with Thamaga-Chitja and Morojele [53], who emphasize that low educational attainment is closely linked to fragile livelihood strategies and persistent income instability. Harahap et al. [55] further underscored the importance of education in agricultural development, particularly for smallholder farmers, while Akbar et al. [56] highlighted the role of human capital in strengthening agribusiness institutions through leadership development. Within the SLF, weak human capital diminishes households' capacity to effectively mobilize and transform other livelihood assets into positive and sustainable livelihood outcomes.

Natural capital constitutes the core asset base for nutmeg farmers, primarily in the form of land access or ownership, as well as ownership of nutmeg and other productive trees. This asset is assessed at moderate to high levels, with land ownership emerging as a key determinant. Most farmers have full access to their farmland; however, land management practices remain limited, and production intensification is generally low. Access to and control over land are also shaped by customary tenure arrangements. Bhandari [57] emphasized that access to land is fundamental for sustaining rural livelihoods; however, land access alone does not guarantee sustainable livelihoods unless it is supported by secure tenure and effective resource management. This perspective is particularly relevant in Fakfak, where land tenure security is closely linked to the stability of farming systems. Similarly, Ekpodessi and Nakamura [58], as well as Nhamo et al. [59], underscore the central role of secure land access in sustaining agricultural production. In this context, natural capital in Fakfak functions more as a subsistence safety net than as a productive asset capable of generating optimal economic returns.

Financial capital remains at relatively low to medium levels, reflected in limited savings, weak access to credit, and high dependence on seasonal nutmeg income. This condition constrains farmers' capacity to invest in farm inputs, adopt improved technologies, enhance post-harvest handling, and manage economic fluctuations [17]. Aazami and Shanazi [24] demonstrated that low financial capital significantly constrains livelihood intensity and increases household vulnerability to shocks. Similarly, Acclassato et al. [60] highlighted that limited financial assets reduce farmers' ability to improve productivity and manage risks. Within the SLF, inadequate financial capital restricts farmers' capacity to transform natural and human capital into sustainable livelihood strategies.

Physical capital across all surveyed districts is categorized at a medium level, encompassing farming tools, infrastructure, and transportation facilities. Despite this moderate asset base, limited ownership of production equipment and inadequate market access constrain operational efficiency and contribute to post-harvest losses. Ownership and utilization of physical assets are also influenced by the adoption of farming practices, as noted by Islam et al. [61]. This suggests that the persistence of traditional farming practices in nutmeg cultivation may partly limit the effective utilization of physical capital. In support of this, Jezeer et al. [62] highlighted that higher levels of physical capital are strongly associated with improved input use and greater productivity. In Fakfak, relatively low levels of physical assets further reinforce the persistence of low-input, low-output farming systems.

Similar to physical capital, social capital among nutmeg farmers is categorized at a medium level across all districts, indicating that social relationships, networks, and institutional participation remain insufficiently developed. This suggests limitations in the strength of trust, farmer cohesion, collaboration, and collective deliberation, all of which are important for supporting productivity [63]. Measures of social capital reflect the extent to which trust and social cooperation contribute to livelihood performance. In this regard, Nguyen and Nguyen [64] highlighted the essential role of social capital in strengthening community resilience.

Psychological and cultural capital, although not core components of the original SLF pentagon, play complementary roles in shaping livelihood sustainability. Psychological assets, while not as directly associated with productivity as tangible resources such as land and financial capital, enhance motivation, coping capacity, and resilience

under conditions of uncertainty [65]. Likewise, cultural assets—including traditional practices such as *sasi*—contribute to regulating resource use, although they are not generally regarded as direct drivers of productivity, as noted by Daskon and McGregor [66]. However, the contribution of these assets to economic outcomes remains largely indirect and often depends on the availability of tangible assets. Without sufficient human, financial, and physical capital, psychological and cultural assets alone are unlikely to generate substantial productivity improvements. Nevertheless, their medium to high levels indicate considerable potential to strengthen resilience against economic shocks and reinforce farmers' confidence in the sustainability of their livelihoods. Although these assets represent important adaptive resources, targeted interventions are still needed to better leverage their potential contribution to productivity and long-term livelihood sustainability [17, 21].

The LAI among nutmeg farmers in Fakfak indicates a livelihood structure that remains heavily reliant on natural capital, while constrained by relatively weak human, financial, and physical capital. From a SLF perspective, strengthening these asset bases through improvements in education, financial inclusion, infrastructure, and institutional support is essential for enhancing livelihood sustainability. While psychological and cultural assets provide an important foundation for long-term resilience, strengthening tangible asset endowments remains critical for improving productivity and achieving sustainable nutmeg-based livelihoods.

The results of the Mann–Whitney test reveal significant differences in several livelihood assets between nutmeg farmers in coastal and mountainous districts, particularly in natural, human, social, and cultural capital. Farmers in coastal districts generally exhibit higher asset values, which may be attributed to better access to fertile land, water resources, infrastructure, and support services. This finding is consistent with Bhandari [57], who emphasizes that access to productive natural resources is fundamental to sustaining rural livelihoods. Higher human capital values in coastal districts also align with the work of Scoones [28], who highlights the critical role of education, skills, and extension services in enhancing agricultural productivity and livelihood outcomes. Greater access to education and extension services in coastal areas likely contributes to these differences, supporting the view that capacity-building is essential for improving agricultural performance [67]. Similarly, higher social and cultural capital values in coastal districts suggest stronger social networks and locally embedded practices that support farming resilience, consistent with observations by Bennett and Dearden [32]. Overall, these differences indicate clear regional disparities in livelihood assets. Coastal districts, which are relatively closer to the district capital and benefit from more favorable spatial characteristics, provide farmers with better opportunities to accumulate and utilize livelihood assets. This pattern is also consistent with findings by Li et al. [35], who reported disparities in livelihood assets between higher- and lower-elevation areas, where households in highland regions tend to possess lower asset endowments. Similar conditions are evident in the mountainous districts of Fakfak.

However, physical, financial, and psychological capital did not show significant differences between coastal and mountainous districts. This may be explained by the generally low level of physical infrastructure—such as roads and transportation facilities—in both regions, which limits variation in physical asset conditions. Likewise, financial capital remains low across both areas, reflected in limited savings and restricted access to credit, indicating broader challenges of financial inclusion in rural settings. Limited access to conventional credit and financial services constrains farmers' ability to strengthen their productive capacity and manage risks. In this regard, improving financial inclusion through need-based agricultural credit and greater access to financing for micro-enterprises and smallholder farmers is critical for enhancing financial capacity [26]. This is particularly relevant given that many farmers have been unable to access conventional government credit schemes due to institutional and procedural constraints [68]. Similarly, the absence of significant differences in psychological capital may indicate that resilience and coping capacities are shaped less by geographic location and more by shared livelihood uncertainties experienced across districts. Strengthening psychological resilience, alongside financial inclusion, remains important for enabling farmers to respond to external pressures and sustain productivity [22].

The lack of statistically significant differences in psychological capital suggests that farmers face relatively similar mental and emotional challenges across both coastal and mountainous regions. Zeweld et al. [65] underscored the importance of psychological capital—particularly resilience and motivation—in enabling farmers to manage agricultural stress. These findings indicate that farmers in both settings experience comparable psychological pressures, especially those associated with climate variability, market fluctuations, and resource management constraints. Accordingly, psychological resilience appears to be shaped more by shared livelihood risks than by geographical differences.

The findings suggest that strengthening natural, human, and cultural assets in mountainous areas—where asset values are comparatively lower—could enhance the overall sustainability of farmers' livelihoods. Policies aimed at expanding access to productive land, agricultural support services, and education in mountainous districts may help reduce disparities between these areas and coastal districts. Meanwhile, the relative uniformity of financial and psychological assets across both regions underscores the need for broader, system-wide interventions to improve access to financial services, such as credit and savings programs, while simultaneously strengthening farmers' psychological resilience. Such measures would address constraints common to both districts rather than those arising solely from spatial differences. Overall, although coastal districts benefit from relatively greater resource accessibility, targeted resource allocation and support services for farmers in mountainous regions are essential to mitigating regional inequalities and fostering more balanced and sustainable agricultural development in Fakfak.

The SWOT analysis reveals that nutmeg farming livelihoods in Fakfak Regency are shaped by a complex interaction between strong internal resource endowments and persistent structural limitations. Internal strengths such as cultural practices, natural resource availability, and strong community cohesion provide a solid foundation for sustaining nutmeg farming systems, while weaknesses remain evident in financial capacity, infrastructure access, and limited technological adoption [14]. The external environment presents considerable opportunities, particularly through increasing global demand for nutmeg products, supportive government programs, and the potential integration of

sustainable agriculture and eco-tourism initiatives. At the same time, the sector continues to face substantial threats, including climate variability, pest and disease risks, geographic isolation, and market price volatility [69-71]. These findings suggest that livelihood sustainability is not solely determined by resource availability but also by the capacity of farmers and institutions to adapt to changing environmental and market conditions.

The combination of IFAS and EFE results indicates that nutmeg farmers operate in a moderately favorable strategic position, where opportunities slightly outweigh threats, yet internal constraints limit the ability to fully capitalize on these opportunities [48]. The dominance of human, natural, and cultural assets in the livelihood structure highlights the importance of strengthening institutional support systems, improving access to financial services, and enhancing technological extension programs [69, 72]. Spatial disparities between coastal and mountainous areas further reinforce the need for context-specific interventions, particularly in improving market access and infrastructure connectivity for remote farming communities. Strengthening cooperative systems, promoting sustainable land management, and improving extension services emerge as key strategic directions to enhance resilience and productivity while maintaining ecological sustainability [73].

The AHP results further refine these findings by identifying priority strategies that should be emphasized in policy and development planning. The dominance of Strength–Threat strategies among the highest-ranked priorities indicates that strengthening adaptive capacity and resilience is the most critical pathway for sustainable livelihood development [13, 74]. High-priority strategies emphasize leveraging internal strengths to mitigate environmental and market risks, followed by strategies that utilize opportunities for market expansion and institutional support while addressing structural weaknesses [14, 70]. This prioritization confirms that risk management and resilience strengthening should be the central focus of livelihood development interventions, supported by institutional coordination, financial inclusion, and capacity building [13]. Overall, the integration of SWOT and AHP provides a comprehensive strategic framework that supports evidence-based decision-making to improve the sustainability and resilience of nutmeg farming livelihoods in Fakfak Regency.

5. CONCLUSIONS

This study assessed the livelihood assets of Papuan nutmeg farming households in Fakfak Regency using a multidimensional index approach supported by the RoC weighting method. The findings revealed an overall LAI ranging from 1.78 to 3.13, with an average value of 2.29, indicating that farmers generally possess livelihood assets at a moderate level. The analysis further showed that coastal farmers tend to have higher natural, social, cultural, and human capital compared to farmers in mountainous areas, while financial and physical capital exhibited relatively limited variation across locations, suggesting shared constraints related to access to finance and infrastructure. Psychological capital levels were also relatively similar across both areas, reflecting the collective resilience of nutmeg farmers in responding to agricultural challenges.

These findings highlight the importance of more targeted development efforts, particularly in the mountainous areas, to improve farmers' access to productive resources, strengthen social support networks, enhance financial inclusion, and address gaps in infrastructure as part of broader sustainable rural development strategies. Because this study relied solely on quantitative methods, future research would benefit from incorporating qualitative and longitudinal approaches. This would help capture the deeper social and cultural dynamics that shape farmers' livelihoods and provide a more complete picture of how livelihood assets evolve over time.

The integration of SWOT and AHP analyses further strengthens these findings by identifying priority strategic directions for enhancing the sustainability of nutmeg-based livelihoods. The results indicate that resilience-oriented strategies that leverage internal strengths to mitigate external threats constitute the highest strategic priority. These are followed by strategies that capitalize on emerging opportunities while addressing structural weaknesses, particularly limited financial capacity and inadequate infrastructure. This prioritization highlights the importance of strengthening institutional support, improving market access, enhancing adaptive capacity to climate variability, and promoting sustainable farming practices. The combined SWOT–AHP framework provides a practical and evidence-based strategic roadmap to support policymakers and stakeholders in designing targeted interventions for improving the long-term sustainability and resilience of nutmeg farming households in Fakfak Regency.

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