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Development strategy to enhance local agroforestry based on nutmeg in Murano village Kaimana regency west Papua province

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Abstract

The biophysical and socio-economic potential of Murano Village and its agroforestry institutions has not been thoroughly studied, and local wisdom guides the expansion of agroforestry. This hybrid study included quantitative and qualitative methodologies. The structure and content of nutmeg (*Myristica argentea*) produced the highest IVI value, around 200. MPTS fruits, lawang wood, and masohi also contained IVI. The Shannon-Wiener diversity value (H') of 1.33 is moderate (1 < H' < 3). The mild category featured 16 species. Agroforestry samples have a medium aggregate evenness of species (E) of 0.48. Murano Village uses lineages and keret for social agroforestry. A more diverse nutmeg and fruit system earned US$ 5,529.41/ha/year. Cleaning supplies and fertilisers cost the community up to US$ 88,24. Nutmeg-based agroforestry is achievable because the B/C Ratio > 1. IFAS and EFAS scores were 2.74 and 2.92 after SWOT analysis. Combining 8 strengths and 8 opportunities in the SO quadrant takes 64 combinations. The government needs to develop priority plans and policies to enhance the agroforestry system in Murano Village, Kaimana Regency. Farmers receive financing from the Kaimana Regency Government to foster the development of agroforestry, diversify nutmeg-based agroforestry types, develop downstream products, educate farmers, and collaborate with local universities to maintain high-quality harvests. Legality, farmer institutions, funding, marketing, and extension are government services.

Keywords: Agroforestry; Nutmeg; Species Diversity; Bio-Physic; SWOT Analysis

1. Introduction

Agroforestry is a land-use practice that involves integrating agricultural and forestry plants to generate benefits that can be used to boost a community's income. In [1,2], agroforestry is defined as an integrated land-use system that incorporates social and ecological factors. This system is achieved by combining tree cultivation with agricultural and livestock (animal) cultivation activities, both subsystemically and commercially, to ensure that plant and animal products can be obtained optimally and sustainably from a single unit of land.

Communities generally have a close relationship and reliance on the natural resources in the vicinity of the forest. Their endeavors to manage natural resources in the vicinity of the forest area are consistently initiated by positive experiences with the environment, which provides them with strong support during the implementation process. In this instance, the traditional knowledge that is transmitted from generation to generation is inextricably linked to the community's dependence on the environment, specifically forest resources. Additionally, the forest area's resources can be sustainably managed and utilized [3,4,5].

The income of farmer households in the regions of Sumatra, Kalimantan, and Sulawesi can be substantially increased by agroforestry practices, with a range of 38% to 76%. Additionally, agroforestry contributes to the preservation of food

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security and the provision of nutrition by diversifying agricultural products [6,7]. Traditional agroforestry systems, such as "mamar," in NTT, incorporate a variety of local trees and food products. This system not only ensures food security but also safeguards local biodiversity and wisdom [8]. Other research has demonstrated that agroforestry producers in Ciamis, Tasikmalaya, and Sumbawa maintain adequate food security, regardless of economic crises or pandemics. Food consumption is stabilized and diverse through the implementation of agroforestry systems [9]. Agroforestry is employed by Indigenous Papuan communities (Manokwari, South Sorong, and Fak-Fak) to manage their yards, which involves the integration of forestry vegetation with agriculture. This system enhances carbon stock potential, sustainable environmental management, food security, biodiversity and conservation, and land productivity [10].

The utilization of forest areas in Murano Village, Kaimana District, Kaimana Regency, for agricultural purposes is capable of cultivating a variety of food commodities, including bananas (*Musa pradisiaca*), sweet potatoes (*Ipomoea batatas*), tallas (*Colocasia esculenta*), cassava (*Manihot esculenta*), and vegetables. The community also cultivates plantation commodities, including coconut (*Cocos nucifera*), gaharu (*Aquilaria malaccensis*), masoi (*Cryptocarya massoia*), and nutmeg (*Mrystica argentea*). In West Papua, this management is typically implemented through the establishment of Village Forests, Community Forests, Community Plantation Forests, and Customary Forests in social forestry. These practices have also been implemented in Fak-Fak and Maluku, which are centered on the superior local commodity of nutmeg [11,12].

The agroforestry development in Murano Village is conducted based on the community's existing local knowledge, and there has been no examination or analysis of the biophysical, social, and economic potential, as well as the institutional potential, of agroforestry in the area. For generations, the community has employed and passed down this local knowledge in their daily lives. Furthermore, agroforestry in the form of gardens is used as a source of inspiration and a highly intriguing model for the development of sustainable agricultural and forestry patterns that integrate economic, social, protection, soil fertility, and biodiversity conservation benefits [13]. In addition to engineering and biophysics, the development of agroforestry necessitates the formulation of government policies and regulations regarding the use of agroforestry systems, which are crucial for advancing agroforestry and sustainable forest management [14].

Agroforestry development is significant in that it has the potential to increase farmers' income, expand employment opportunities, and contribute to the economic well-being of families and regions. It is also believed to be able to address the challenges of food security, biodiversity, conservation, and community income in Murano Village. Consequently, this investigation examines the potential of biophysical, socio-cultural, economic, and institutional factors in implementing agroforestry in Murano Village, as well as the development of strategies and policies for agroforestry in the village, with the aim of managing sustainable forests [15, 16].

2. Material and methods

2.1. Study area

Murano Village is situated at an altitude of 0 to 100 meters above sea level, with coordinates of 0°20.90' to 0°40.20' South Latitude and 132°75' to 135°15' East Longitude. Murano Village neighbors Sisir Village to the west, Jarati Village to the north, Foroma Jaya Village to the east, and the Arafura Sea to the south. The soil type on a slope of 5-10% with a clay and clay structure, facilitated by karst. The average monthly rainfall is 100 mm, and the average wind speed is 4.97 knots. The average temperature is 27-28 °C, with a humidity level of 83%. The total number of households is 79, with 197 male residents and 185 female residents.

Land administration in the village is based on the level of area assigned to the lineage or "keret", which is determined by the boundaries inherited by the progenitors. Similarly, the clan determines the extent of the agroforestry system that each family manages. Accessing land use is challenging due to the presence of dense forests, gorges, and mountains in the region. Consequently, indigenous peoples exclusively oversee land situated in lowlands that are accessible for subsistence activities and economic systems, where agricultural and plantation products are utilized to meet the needs of their families. Indigenous communities also sustainably manage their land by using local knowledge that has been passed down through generations, as evidenced by the development of agroforestry based on nutmeg. This study was conducted in six significant communities: Tapnesa, Surawy, Naguasai, Nasua, Raiya, and Mejoi, whose nutmeg plantations have been administered for over 30 years. The sampling plots for each nutmeg plantation were as follows: 20 m x 20 m for the tree level, 10 m x 10 m for the pole level, 5 m x 5 m for the sapling level, and 2 m x 2 m for the seedling level. Samples were collected using these plots (Figure 1).

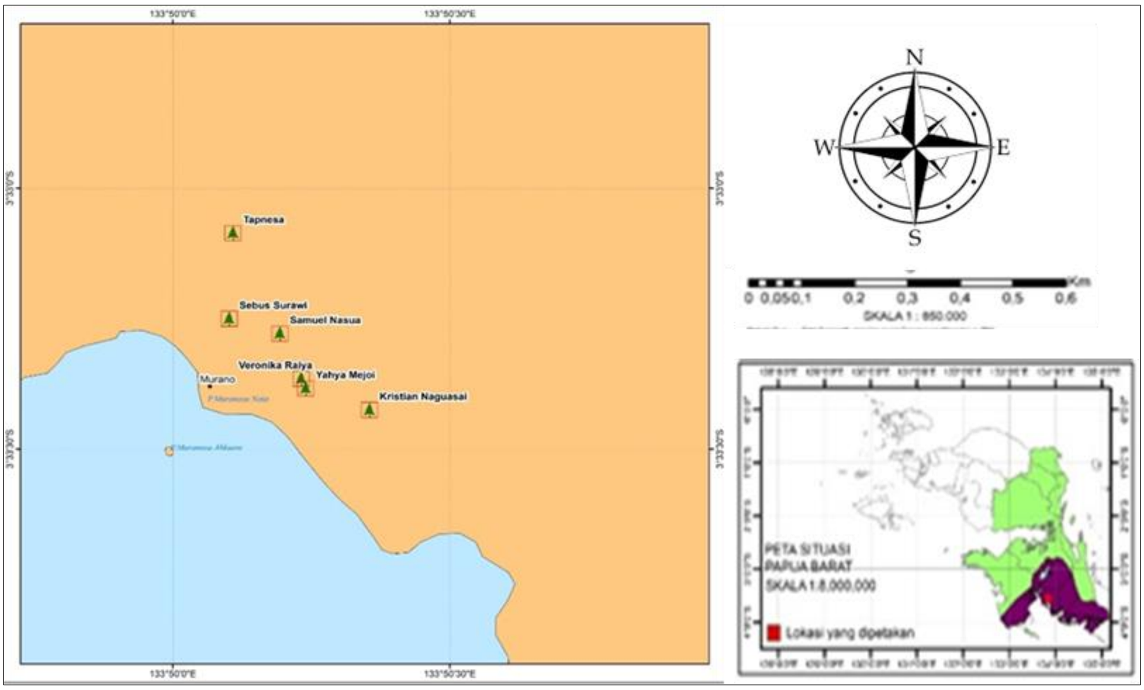

Figure 1 Research location of nutmeg-based agroforestry

2.2. Method of data analysis

Utilizing continuous strip sampling techniques in the gardens of indigenous peoples in Maruno District, the quantitative determination of species diversity is achieved through the determination of agroforestry biophysical data. Qualitative methods are employed to collect social, economic, and institutional data through semi-structured interviews that use a predetermined list of queries. The SWOT analysis employs a hybrid method that incorporates qualitative data to gather internal and external factor data from the findings of the FGD. Additionally, utilize quantitative techniques based on the Likert scale to determine the weight and scoring of strategies and policies required for the development of nutmeg-based agroforestry, drawing on indigenous practices in Murano Village.

2.2.1. Bio-physic Data

Vegetation analysis

The structure and composition of vegetation during each growth phase can be categorized into the Importance Vegetation Index (IVI) [17,18] and subsequently classified as high, medium, or low dominance using the following formula

$$\text{Density (D)} = \frac{\text{number of individuals}}{\text{area of measurement plot}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

$$\text{Relative Density (RD)} = \frac{\text{density of a species}}{\text{density of all species}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

$$\text{Frequency (F)} = \frac{\text{number of plots where a species is found}}{\text{total number of plots}} \ldots\ldots\ldots\ldots\ldots 3$$

$$\text{Relative Frequency (FR)} = \frac{\text{frequency of a type}}{\text{frequency of all plots}} \ldots\ldots\ldots\ldots \quad 4$$

$$\text{Dominance (Do)} = \frac{\text{area of the base of a type}}{\text{area of the plot}} \ldots\ldots\ldots\ldots\ldots\ldots \quad 5$$

$$\text{Relative Dominance (RDo)} = \frac{\text{dominance of a species}}{\text{dominance of the entire plot}} \ldots\ldots \quad 6$$

$$IVI = RD + FR + RDo \ldots\ldots\ldots\ldots\ldots$$

The variability patterns of abundance measurements among species are assessed using the species diversity index (H' value) in biodiversity analysis [19,20]. the species diversity index is computed using the Shannon-Wiener formula [21]:

$$H' = -\sum (pi \times ln\, pi) \text{ ....8}$$

with H: the species diversity index, ∑: the total number of species inside the community, and Pi: the proportion of species i relative to the overall number of individual species in the community (N). The H-index value requirement is categorized as follows: high (> 2.0), medium (1.6 < < 2.0), low (< 1.6), and very low (< 1.0) [22].

The total quantity of species in a community or ecosystem, irrespective of the size of any individual species population, is referred to as species richness. [23] argues that this is a critical indicator of biodiversity, particularly in terms of the species composition of a designated area. The discovery of additional species results in an increase in the richness value of a region. Evaluation criteria: species with populations exceeding 100 are classified as high category (3), species with populations between 30 and 100 as medium category (2), and species with populations below 10 as low category (1) [24].

Evenness is the degree of homogeneity in the distribution of distinct species within a community. Across all existing species, the evenness rating denotes the homogeneity of individual distribution. If all species have nearly identical populations, the evenness score will approach the maximal value of 1. If one or more species exhibit substantial dominance, the evenness score will approach zero (minimum) [25,26]. The following formula is provided for Evenness (E)

$$E = H'/ln\, S \text{ ....7}$$

with E: the Evenness value, H’: the Shannon-Wiener diversity index, and S: the number of speciesThe E value requirements are defined as follows: <0.25 is categorized as very low, 0.26-0.50 as low, 0.51-0.75 as moderate, and 0.76-1.0 as high [27].

Social and cultural data employ semi-structured questionnaires that emphasize variables such as customary rights to ownership, indigenous knowledge in crop rotation and soil conservation, spiritual values, the advantages of agroforestry species cultivated by indigenous communities, and cultural changes resulting from external program interventions [28,29].

The economic data use B/C ratio analysis [30] using the following formula:

$$B/C\ ratio = \frac{(Total\ Benefit)}{(Total\ Cost)} \text{ ....8}$$

- B/C> 1, then the business is profitable, so it is worth continuing.
- B/C < 1. then the business is at a loss, so it is not worth continuing.
- B/C = 1, then the business is neither profitable nor loss (breakeven), so it is not worth continuing.

Institutional data were examined using a semi-structured questionnaire that encompassed variables related to the role of customary institutions in forest and land management, formal institutions involved, non-governmental institutions contributing, and institutions facilitating the development of agroforestry based on customary communities in Murano Village [30,31].

2.2.2. Strategy and Policy for Local Agroforestry Enhancement

SWOT Analysis

SWOT analysis (Strengths, Weaknesses, Opportunity, Threat) is a systematic process that identifies a variety of internal factors (Strengths [S], Weaknesses [W]), Internal Factor Evaluation (IFE) and external factors (Opportunities [O], Threats [T]), External Factor Evaluation (EFE) to determine the appropriate formulation and implement the most effective strategy based on the matrix in Figure 2 [32,33]. The internal strategy factor matrix (IFAS) and the external strategy factor matrix (EFAS) were employed to develop the model. The most influential factor is assigned a maximum weight of 3.00, while those deemed insignificant are assigned a weight of 1.00. The variable rating is a scale of 1 (very poor), 2 (awful), 3 (excellent), and 4 (very good). The variable with the highest influence value in comparison to the influence values of other variables is the most influential. Agroforestry development strategies and policies are classified according to the results of the calculations included in the IFAS and EFAS matrices.

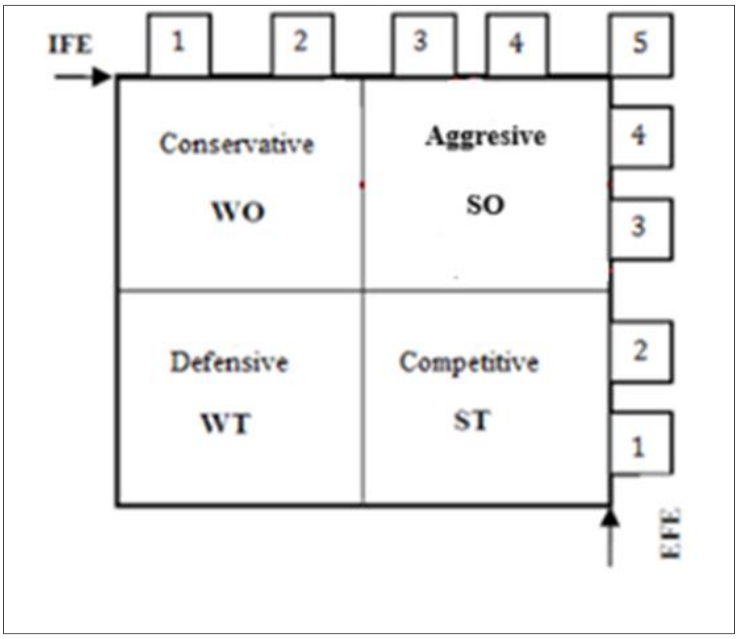

Figure 2 Quadruple matrix of IFE and EFE

3. Results and discussion

3.1. Bio-physic Data

3.1.1. Vegetation analysis

The sample for this study was drawn from six families that have been operating an agroforestry system for an extended period, specifically over 30 years. Nutmeg (*Myristica argentea*) dominated the results of the entire garden with the highest IVI value, with a value exceeding 200. Additionally, the following MPTS were discovered: masohi (*Cryptocarya massoia*), lawang (*Cinnamomum culilawan*), durian (*Durio zibethinus*), cempedak (*Artocarpus integer*), rambutan (*Nephelium lappaceum*), mango (*Mangifera indica*), matoa (*Pometia pinnata*), langsat (*Lansium parasiticum*), and coconut (*Cocos nucifera*) (Table 1).

Table 1 IVI of nutmeg-based agroforestry in Murano Village

Species	N sample	N/ha	F	D	DR	FR	DoR	INP
Tapnesa Clan								
Myristica argenta	16	400	1.00	48183.76	64.00	96.76	42.86	203.62
Cinnamomum culilawan	5	125	0.33	207.01	20.00	0.42	14.29	34.70
Pometia sp	1	25	0.33	31.85	4.00	0.06	14.29	18.35
Theobroma cacao	1	25	0.33	25.80	4.00	0.05	14.29	18.34
Cocos nucifera	2	50	0.33	1348.41	8.00	2.71	14.29	24.99
Total	25	625	2.33	49796.82	100.00	100.00	100.00	300.00
Surawy Clan								
Myristica argentea	16	400	0.63	8.96	80.95	76.92	84.77	242.64
Cryptocarya massoia	2	50	0.03	0.24	3.17	3.84	2.27	9.29

Durio zibethinus	4	100	0.06	0.62	6.35	7.69	5.87	19.91
Artocarpus integer	3	75	0.05	0.45	4.76	5.77	4.26	14.79
Nephelium lappaceum	1	25	0.02	0.04	1.59	1.93	0.38	3.89
Myristica fragrans	1	25	0.02	0.20	1.59	1.93	1.89	5.41
Citrus Sinensis	1	25	0.02	0.06	1.59	1.93	0.57	4.08
Total	28	700	0.8254	10.57	100.00	100.00	100.00	300.00
Naguasai Clan								
Myristica Argentea	16	400	1.00	57327.63	98.99	80.00	99.12	278.11
Cocos nucifera	1	25	0.25	509.55	1.01	20.00	0.88	21.89
Total	17	425	1.25	57837.19	100.00	100.00	100.00	300.00
Nasua Clan								
Myristica argentea	16	400	1.00	48946.38	95.83	57.14	98.62	251.60
Lansium parasiticum	1	25	0.25	223.65	1.04	14.29	0.45	15.78
Nephelium lappaceum	3	75	0.50	461.47	3.13	28.57	0.93	32.63
Total	20	500	1.75	49631.49	100.00	100.00	100.00	300.00
Raiya Clan								
Myristica argentea	16	400	0.75	73134.00	91.84	33.33	94.78	219.95
Durio zibethinus	1	25	0.25	2754.46	1.02	11.11	3.57	15.70
Nephelium lappaceum	3	75	0.25	1105.57	3.06	11.11	1.43	15.61
Metroxylon sagu	1	25	0.25	71.66	1.02	11.11	0.09	12.22
Pandanus conoideus	1	25	0.25	1.99	1.02	11.11	0.00	12.13
Citrus Sinensis	1	25	0.25	31.85	1.02	11.11	0.04	12.17
Musa sp	1	25	0.25	62.42	1.02	11.11	0.08	12.21
Total	24	600	2.25	77161.94	100.00	100.00	100.00	300.00
Mejoi Clan								
Myristica argentea	16	400	1.00	26752.87	88.89	50.00	98.62	237.51
Durio zibethinus	3	75	0.33	306.53	4.76	16.67	1.13	22.56
Nephelium lappaceum	1	25	0.33	62.42	1.59	16.67	0.23	18.48
Mangifera indica	3	75	0.33	4.54	4.76	16.67	0.02	21.45
Total	23	575	2	27126.35	100.00	100.00	100.00	300.00

High importance values distinguish the types that play a role in a community, as they are the aggregate of Relative Density (KR), Relative Frequency (FR), and Relative Dominance (DR) [34]. The dominating species (those in power) in a plant community have a high importance value index, as explained by [35]. Consequently, species with a dominant importance value index have the highest importance value index.

The implication of Table 5 is that nutmeg is highly competitive with other plants in the garden and is highly dominant in the structure and composition of the vegetation of the agroforestry system in Murano Village. Therefore, it can serve as the foundation for establishing agroforestry based on locally superior nutmeg commodities, promoting the well-being of farmers and village communities. Furthermore, nutmeg has the potential to generate substantial economic value due to its high export value and superior status as a spice commodity.

The nutmeg is an endemic species of Papua that has adapted exceptionally well to the local agroclimatic conditions in Fakfak and Kaimana. The cultivation of this plant by local communities has been a tradition for tens to hundreds of years, including in Naguasai's garden, which has lasted for 80-90 years. Consequently, nutmeg is a significant component of the cultural identity of indigenous peoples, particularly in Fakfak and Kaimana, as well as the local agroforestry system. Nutmeg is highly valued in both national and international markets, particularly for its use in spices and essential oils, from an economic standpoint. Nutmeg is the primary source of income for the communities in Fakfak and Kaimana, and it also represents the most significant contribution to the agricultural sector's exports. The local government has expressed concern about the need to elevate nutmeg to a strategic commodity of higher importance in local commodity-based development planning [36, 37, 38, 39].

The diversity of flora types in an ecosystem can be interpreted as the type of vegetation and plant composition. This is a floristic inventory of plant types that comprise a community, as determined by the results of the description [40]. The floristic list is a valuable tool for vegetation analysis, as it is one of the parameters used to ascertain the diversity of plant types within the community. At the tree level, the woody vegetation in the forest area of multiple 20 m x 20 m garden samples in Murano Village is composed of 16 species that belong to 11 families. The *Myristicaceae* family is the most prevalent family across all growth stages, with a total of 137 trees (Table 2).

Table 2 illustrates that the species diversity index (H ') in the complete land area of agroforestry gardens I, II, III, IV, V, and IV is 1.33. This value falls within the moderate category, indicating that the community is characterized by a limited number of plant species and a small number of dominant species [41]. This is demonstrated by the Shannon-Wiener category, which holds the value of $1 < H' < 3$. The median category contains 16 species, as indicated by the number of species (richness). The garden sample's aggregate species evenness (E) is 0.48, which falls within the median category. This is consistent with the assertion made by [42] that the species evenness value will be low-moderate in a community where a single species dominates.

The ecological significance of this value is that the high dominance of nutmeg suggests the system's tendency to be semi-monoculture. The ecosystem is at risk of becoming more susceptible to parasites, diseases, and climate change due to the low level of functional diversity. This suggests that other species are either not developing optimally or are solely "companions" due to the moderate Evenness and high richness. According to [43] and [44], nutmeg is a primary and indispensable commodity; however, its dependence is excessively high, which may result in adverse consequences in the event of production failure. Less productive companion species suggest that the potential for agroforestry has not been fully realized. Agroforestry is designed to be more stable, productive, and sustainable by integrating primary commodities with fruit, medicinal, wood, soil protection, and other functions [45,46].

In other regions, numerous studies have been conducted on nutmeg-based agroforestry systems that incorporate coconut, areca nut, durian, and medicinal plants in Aceh Besar. These studies have yielded H', richness, and E values of 1.4, 18, and 0.61, respectively [47]. In North Minahasa, mixed nutmeg agroforestry with fruit and wood plants also achieved H', richness, and E values of 1.5, 21, and 0.68, respectively [48]. Consequently, the semi-monoculture nutmeg-based agroforestry in Maruno Village must be adjusted to align with the ecological perspective of agroforestry, which is associated with richness.

Table 2 H', richness and E of nutmeg-based agroforestry in Murano Village

No	Species	Family	Garden						N sample	Diverstiy Index				
			I	II	III	IV	V	VI		Pi	Ln Pi	Pi * Ln Pi	H'	E
			N											
1	*Myristica argentea*	Myristicaceae	16	16	16	16	16	16	96	0.70	-0.36	-0.25	1.33	0.48
2	*Durio zibethinus*	Malvaceae		4			1	3	8	0.06	-2.84	-0.17		
3	*Nephelium lappaceum*	Sapindaceae		1		3	3	1	8	0.06	-2.84	-0.17		
4	*Mangifera indica*	Anacardiaceae						3	3	0.02	-3.82	-0.08		
5	*Cinnamomum culilawan*	Lauraceae	5						5	0.04	-3.31	-0.12		
6	*Pometia pinnata*	Sapindaceae	1						1	0.01	-4.92	-0.04		
7	*Theobroma cacao*	Malvaceae	1						1	0.01	-4.92	-0.04		
8	*Cocos nucifera*	Arecaceae	2		1				3	0.02	-3.82	-0.08		
9	*Cryptocarya massoia*	Lauraceae		2					2	0.01	-4.23	-0.06		
10	*Artocarpus integer*	Moraceae		3					3	0.02	-3.82	-0.08		
11	*Myristica fragrans*	Myristicaceae		1					1	0.01	-4.92	-0.04		
12	*Citrus sinensis*	Rutaceae		1			1		2	0.01	-4.23	-0.06		
13	*Lansium parasiticum*	Meliaceae				1			1	0.01	-4.92	-0.04		
14	*Mtroxilon sagu*	Arecaceae					1		1	0.01	-4.92	-0.04		
15	*Pandanus conoideus*	Pandanaceae					1		1	0.01	-4.92	-0.04		
16	*Musa sp.*	Musaceae					1		1	0.01	-4.92	-0.04		
	Total		25	28	17	20	24	23	137					

3.1.2. Socio-economic analysis

Consequently, a discrepancy exists between the national government's regulations and the municipal level's recognition of customary rights. Prolonged conflicts between indigenous peoples, the government, and corporations that possess business permits in the forestry, plantation, and mining sectors are frequently precipitated by this disparity. This conflict has the potential to cause environmental damage due to exploitation practices that disregard the sustainability of Papua's forest ecosystem and local wisdom, in addition to impacting the social and economic aspects of local communities [49, 50, 51].

Land possession is a significant issue in agricultural development, spanning from lowlands to highlands. A legacy from progenitors that has been passed down from generation to generation in Murano village is the conversion of land, including the transformation of commodities in littoral areas to highlands, for agricultural purposes. The division of land proprietorship is typically based on clan, keret, and family, as the land has historical significance. Furthermore, the land is generally allocated to the descendants of the clan bearers or patrilineal [52,53].

When relatives in the village are involved in the process of clearing land to be used as a garden, the pattern of social relations between farmers in Murano Village is evident, as they are assigned tasks based on their capabilities. Initially, the indigenous community cleared vegetation, including shrubs, supports, poles, and small trees that were unsuitable for their use. Additionally, large trees that are unsuitable for use are felled, dried, and subsequently incinerated. The apparatus employed is still simplistic, consisting of machetes, hoes, and crowbars. Additionally, some individuals employ chainsaws (tree-felling devices). The initial plants that are planted to satisfy domestic food requirements are bananas, tubers, and vegetables. After the felled timber has cured and been incinerated, it is purified. Nutmeg, cardamom, coconut, and fruits, including durian, rambutan, cempedak, mango, and bananas, are the primary sources of revenue for the community [54,55].

Income is also influenced by the cost of nutmeg-based agroforestry cultivation in each respondent's garden. Due to the necessity of producers to maintain optimal production costs, the income obtained decreases as business costs increase. The average annual cost of farming is typically between US$ 64.71 and 88.24. The average cost of the nutmeg-based agroforestry system in Murano Village is US$72.06. The profit received by the village community is the result of the reduction of the income obtained from these expenditures. The nutmeg agroforestry garden sample has a B/C ratio that exceeds 1, indicating that the community's efforts are still viable (Table 3) [56,57].

Table 3 B/C ratio of nutmeg-based agroforestry system in Murano Village

No	Clan	Cost (C)/year (US$)	Income/year (US$)	Benefit (B)/ year (US$)	B/C ratio
1	Tapnesa	70.59	4,181.62	4,111.03	58.23
2	Surawy	64.71	5,529.41	5,464.70	84.45
3	Naguasai	88.24	2,647.06	2,558.82	29.00
4	Nasua	70.59	3,470.59	3,400.00	48.17
5	Raiya	73.53	4,782.35	4,708.82	64.04
6	Mejoi	64.71	3,970.59	3,905.88	60.36
	Total	432.37	24,581.62	24,149.25	
	Average	72.06	4,096.94	4,024.88	57.38

3.1.3. Institutional analysis

Farmer institutions in Fakfak, recognized as the hub of West Papua's nutmeg production, have been relatively well-developed, as evidenced by the existence of cooperatives like the Tomandin Cooperative and numerous farmer organizations that the Plantation Service has sponsored. These farmer groups bolster the technical capacity of cultivation, product management, and market access. Nevertheless, [58] has identified disparities between villages, where the majority of peasant groups are formal and have not been effectively fulfilling institutional functions. In the interim, the institutions of nutmeg farmers in Kaimana remain relatively feeble, with the majority of farmers continuing to operate in informal groups or individually. Farmers' bargaining position is weakened, and they face challenges in accessing government programs and broader markets due to the absence of cooperatives or special nutmeg associations. Limited assistance, low organizational capacity, and minimal support for affirmative policies significantly contribute to the vulnerability of farmer institutions in Papua, including Kaimana, according to research conducted by [59].

The extension institution in Fakfak has been established with the availability of agricultural extension personnel who are specifically responsible for assisting nutmeg producers in multiple production center districts. Extension personnel have initiated participation in quality mentoring programs, post-harvest, and the reinforcement of farmer institutions. Nevertheless, the intensity of assistance is irregular because the ratio of extension workers to the area of nutmeg plantations and the number of producers remains far from optimal [58]. In the meantime, the number of extension workers in Kaimana remains highly restricted, and the majority lack specialized technical expertise in the field of nutmeg commodities. Consequently, initiatives to enhance farmer institutions, improve cultivation knowledge, and streamline product processing have not been fully executed. This condition is indicative of the inadequate extension system in Papua, particularly in the case of premium commodities like nutmeg.

Capital institutions in Fakfak have access to formal financial institutions, including Bank Papua, cooperatives, Village-Owned Businesses, and various capital programs, including People's Business Credit. Despite numerous producers implementing this financing scheme to establish nutmeg plantations, the primary challenges remain the administrative requirements and the need for collateral. There are still farmers who rely on the ijon system or loans from intermediaries, which are often detrimental to farmers [58]. The availability of capital in Kaimana is significantly restricted, with only a small number of producers having access to formal financial institutions. The majority of producers continue to depend on their own capital or informal loans, which are typically insufficient to expand nutmeg production. This limitation is partly due to the absence of socialization and support in terms of capital access [60].

In Fakfak, marketing institutions, often disguised as nutmeg sales channels, are relatively well-organized, with the presence of cooperatives, collectors, and access to national exporters. Fakfak is recognized as the hub of Papua's nutmeg marketing, which gives it superior bargaining leverage compared to other regions. Nevertheless, price fluctuations continue to pose a challenge, particularly for small producers who are not affiliated with formal marketing institutions [61]. Conversely, the marketing of nutmeg in Kaimana remains inconsistent and heavily reliant on local intermediary merchants. The absence of cooperatives or marketing associations leads to a dependence on regional markets, low selling prices, and feeble bargaining positions for producers. The nutmeg producers in Kaimana are unable to increase their income due to a lack of access to export markets or broader marketing networks [60].

3.2. Nutmeg-based Agroforestry Enhancement Strategy

3.2.1. SWOT analysis

SWOT analysis is predicated on a logic that can optimise strengths and opportunities while concurrently minimising weaknesses and threats. Using internal and external matrices, the predetermined parameters are assigned weights and ratings to determine a value (score). This value will offer guidance on the prospects for the development of agroforestry. Tables 4 and 5 illustrate the scoring outcomes for the Internal Strategic Factors Analysis Summary (IFAS) and External Strategic Factors Analysis Summary (EFAS).

Table 4 IFAS nutmeg-based agroforestry in Murano Village

SWOT	Strategic Factors	Weith	Rating	Score
Strengths	1. Farmers produce a significant amount of nutmeg	0.07	3.9	0.28
	2. The availability of a huge amount of land	0.07	3.6	0.25
	3. The motivation of farmers to develop nutmeg commodities	0.06	2.6	0.16
	4. Availability of high-quality nutmeg seeds	0.07	3.4	0.23
	5. The yields and diversity of vegetation varieties in agroforestry land	0.07	3.5	0.23
	6. The results of agroforestry are highly reliant on the impact on communities	0.07	3.5	0.24
	7. Climate and topography are supportive	0.07	3.4	0.24
	8. Nutmeg product diversification	0.07	3.4	0.22
	Total Strengths	0.54		1.86
SWOT	**Strategic Factors**	**Weith**	**Rating**	**Score**
Weaknesses	1. Technology for the production of nutmeg is not yet available	0.05	2	0.10
	2. Inadequate post-harvest management of nutmeg	0.06	1.6	0.09
	3. Insufficient human resources for nutmeg producers	0.06	2	0.12
	4. Limited agricultural capital	0.05	2.2	0.12
	5. Absence of land expansion	0.05	2.5	0.14
	6. Minimal support from technical agencies and services	0.06	2.3	0.13
	7. Lacking pruning, fertilization, fumigation, and maintenance	0.06	1.4	0.09
	8. Deficient utilization of agroforestry land	0.06	1.6	0.10
	Total Weaknesses	0.46		0.89
	Total IFAS			2.75

Table 5 EFAS nutmeg-based agroforestry in Murano Village

SWOT	Strategic Factors	Weith	Rating	Score
Opportunities	1. Nutmeg Development Program of the Kaimana District Government	0.08	3.7	0.28
	2. Extensive marketplace	0.07	3.6	0.26
	3. Availability of Agricultural Extension Workers	0.05	2.4	0.13
	4. Significant consumer interest in the demand for nutmeg as a commodity	0.08	3.6	0.27
	5. Nutmeg seed stability and its complete price	0.07	3.4	0.25
	6. Expansion of plantation land	0.07	3.6	0.25
	7. Enhancing the grade of nutmeg after harvest	0.07	3.4	0.22
	8. The application of grafting technology, among other things.	0.07	3.5	0.25
	Total Opportunities	0.55		1.91
SWOT	**Strategic Factors**	**Weith**	**Rating**	**Score**
Threats	1. Excessive production expenses	0.04	2	0.09
	2. Scarcity of high-quality nutmeg seeds	0.06	2.3	0.13
	3. Minimal counseling and training from relevant organizations	0.06	2.2	0.13
	4. Inadequate pests control	0.06	2.8	0.17
	5. Insufficient market information	0.06	2	0.12
	6. Climate change	0.05	2.6	0.14
	7. Limited innovation and abilities	0.06	2.4	0.13
	8. Lack of guidance for Micro, Small, and Medium Enterprises at the District and Village levels	0.06	1.9	0.12
	Total Threats	0.45		1.01
	Total EFAS			2.92

The preferred scenario will be chosen from four accessible alternatives: aggressive, competitive, cautious, and defensive, following the completion of the SWOT analysis. [62] describe the optimal strategy for enhancing nutmeg-based agroforestry in Murano Village by evaluating internal and external parameters. The appropriate matrix can be employed to assess and differentiate between internal and external components through various expression approaches. The nutmeg-based agroforestry management system of the indigenous people of Murano Village is described in the evaluation matrix. The final score of the internal factor evaluation matrix is displayed on the vertical axis. In contrast, the final score of the external factor assessment matrix is displayed on the horizontal axis. This matrix simplifies the process of selecting strategies and policies to enhance the agroforestry system that is based on nutmeg. [63].

The internal components have a cumulative score of 2.74, while the external elements have a cumulative score of 2.92, as illustrated in Tables 4 and 5. These scores determine the suitability of the nutmeg-based agroforestry system. The internal and external factor matrices, along with their respective scores, are depicted in Figure 3. The agroforestry system founded on nutmeg demonstrates its aggressive nature. Consequently, the approach strategy can be employed to capitalize on both internal strengths and external opportunities [64,65]. This enables the system to expedite the enhancement of the nutmeg-based agroforestry system in response to the vulnerabilities and threats it encounters.

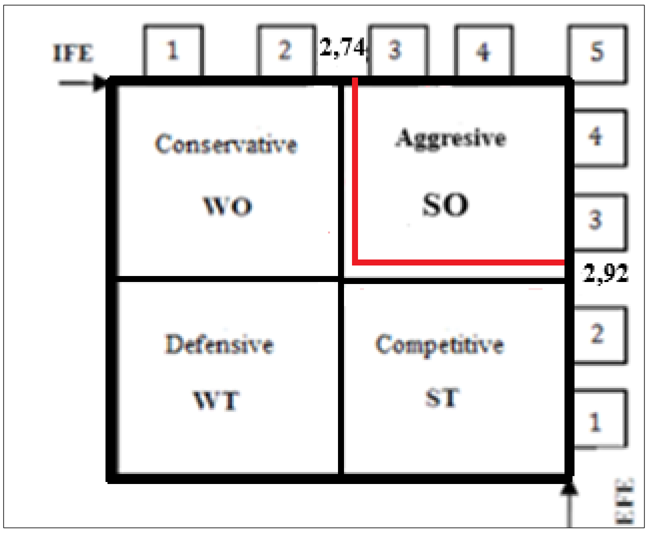

Figure 3 Strategy and policy matrix

3.3. Enhancement strategy

The most significant potential for scale-up is present in nutmeg-based agroforestry systems when implemented using SO techniques. Consequently, the primary goal of this aggressive strategy is to build on existing assets and opportunities to further develop agroforestry systems based on nutmeg. Consequently, Table 6 demonstrates an aggressive approach that is the outcome of a combination of these assets and opportunities. Agroforestry system architects combined eight strength variables with eight opportunity factors to develop a total of 64 SO tactics. Nevertheless, the majority of hybrid approaches necessitate the immediate implementation of a focused acceleration program. To expedite the development of nutmeg-based agroforestry systems, stakeholders in West Papua have identified six optimal and feasible solutions [66,67]. To preserve the quality of the harvest, the Kaimana Regency Government offers support in the following areas: legality, farmer institutions, funding, marketing, and dependable extension workers. Additionally, the government encourages farmers to expand their land management through the use of various capital facilities, diversify nutmeg-based agroforestry types, and develop downstream nutmeg products. It also increases farmer capacity through regular training and collaborates with local universities to develop new technologies. These are all priority strategies and policies for accelerating nutmeg-agroforestry systems. The objective of this methodology is to enhance the aesthetic appeal, economic feasibility, socio-cultural aspects, ecological functions, food security, and forestry sector mitigation efforts [68,69,70].

Table 6 Strategy and policy to accelerate nutmeg-based agroforestry system

Internal	**External**
Strengths	**Oppurtunities**
Farmers produce a significant amount of nutmeg	Nutmeg Development Program of the Kaimana District Government
The availability of a huge amount of land	Extensive marketplace
The motivation of farmers to develop nutmeg commodities	Availability of Agricultural Extension Workers
Availability of high-quality nutmeg seeds	Significant consumer interest in the demand for nutmeg as a commodity
The yields and diversity of vegetation varieties in agroforestry land	Nutmeg seed stability and its complete price
The results of agroforestry are highly reliant on the impact on communities	Expansion of plantation land
Climate and topography are supportive	Enhancing the grade of nutmeg after harvest
Nutmeg product diversification	The application of grafting technology, among other things
Aggresive Strategy (SO)	
SO1 Kaimana District Government offers assistance in the form of legality, farmer institutions, funding, marketing, and dependable extension personnel	
SO2 Promote the growth of agroforestry-based land management practices among farmers, facilitated by access to diverse, adaptable, and sustainable capital resources	
SO3 Nutmeg products require downstream processing	
SO4 Diversification of agroforestry varieties based on nutmeg	
SO5 Enhancing farmer capabilities through consistent training Development of SO6 Technology in collaboration with local universities to preserve the integrity of the harvest	

4. Conclusion

Biophysical data from Murano Village's nutmeg-based agroforestry systems showed that nutmeg (*Myristica argenta*) has the most excellent structure and composition with IVI > 200. Next, IVI was found in MPTS plants like masohi (*Cryptocarya massoia*), lawang (*Cinnamomum culilawan*), durian (*Durio zibethinus*), cempedak (*Artocarpus integer*), rambutan (*Nephelium lappaceum*), mango (*Mangifera indica*), matoa (*Pometia pinnata*), langsat (*Lansium parasiticum*), and coconut (*Cocos nucifera*). The Shannon-Wiener species diversity value (H') was 1.33, falling into the moderate category (1 < H' < 3). The species richness was 16 moderate species. The garden sample's species evenness (E) is 0.48, which is modest. The Social Forestry method, which addresses social concerns associated with local government land management, remains unavailable. Socially, Murano Village manages agroforestry through clans and keret—the most profitable with a diverse nutmeg and fruit system at US$ 5,529.41 per ha/year. Community costs are limited to US$ 88.24 for cleaning equipment and fertilizers. So that the B/C ratio is > 1, the nutmeg-based agroforestry system can be maintained and grown.

The SWOT analysis indicated IFAS and EFAS scores of 2.74 and 2.92, respectively. This suggests the matrix is in the aggressive quadrant, emphasizing internal strengths and external prospects. A combination of 8 strengths and 8 opportunities requires 64 combinations. Thus, the government must identify priority strategies and policies to expedite the development of the nutmeg agroforestry system in Murano Village and Kaimana Regency. The Kaimana Regency Government provides capital facilities to encourage farmers to promote the growth of agroforestry, diversify nutmeg-based agroforestry, and process downstream nutmeg products. It also increases farmer capacity through routine training, develops technology in collaboration with local universities to maintain harvest quality, and provides legality, farmer institutions, funding, marketing, and other extension services.

Compliance with ethical standards

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Disclosure of conflict of interest

There is no conflict of interest.

Statement of ethical approval

Ethical approval for field data collection is consistent with the Manual for Measuring Biodiversity of Agroforestry Systems developed by the ICRAFT, 1983 and SWOT Analysis by West Virginia University, 2013.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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