PREDICTORS OF SUCCESS IN KAPPAPHYCUS SEAWEED FARMING IN RAMBUTSO ISLAND, MANUS, PAPUA NEW GUINEA

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ABSTRACT

This research examines the predictors of success in seaweed farming on Rambutso Island, Manus, Papua New Guinea. Utilising an interview-based approach, this study uses qualitative insights from interviews with farmers to identify the key factors influencing farming outcomes. Preliminary findings suggest that access to quality seedstock, provision of adequate farming materials, training, and education significantly contribute to productivity. Market access has emerged as a critical determinant of financial success, underscoring the importance of establishing reliable market linkages. The research also explores the role of local cooperative structures in the effective distribution of resources and how community dynamics, such as local politics, affect farming practices. This study aims to develop a comprehensive understanding of the challenges and opportunities in seaweed farming within the unique socioeconomic and environmental contexts of Rambutso Island, offering valuable guidance for policymakers, development agencies, and local stakeholders striving to optimise seaweed farming as a sustainable livelihood strategy.

Keywords: Seaweed farming, Rambutso Island, Papua New Guinea, market access, sustainable livelihoods.

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1 INTRODUCTION

1.1 Background

The contemporary global market imposes exigent demands on local production capacities, with international buyers seeking reliable and consistent supplies that adhere to stringent quality standards (OECD, 2005). In Papua New Guinea, local seaweed farmers face the challenge of scaling up their operations to meet global expectations, especially with a fledgling seaweed industry, an endeavour that holds significant promise not only for revenue generation (Zamroni, 2021), but also for sustainable development (Harohau, 2020); (Gómez, 2013).

Seaweed cultivation, heralded for its low environmental footprint and high growth potential (Feng-qing, 2016), offers a unique opportunity for farmers to diversify and expand their economic activities (Ashok et al., 2022). As the industry gains traction, the implementation of advanced cultivation techniques and establishment of larger commercial farming operations are pivotal, particularly in areas with extensive potential for maritime farming. These initiatives must be designed to sustain production while harmoniously incorporating customary marine ownership practices unique to the South Pacific region (Adams et al., 2001).

Furthermore, the rapid development of seaweed cultivation technology, characterised by its simplicity, cost-effectiveness, and resilience to extreme land conditions, underlines the potential of regions such as Papua New Guinea to bolster the competitiveness of their aquaculture sectors (Sabila, 2021). Past attempts at establishing aquaculture enterprises have generally focused almost exclusively on the technical and commercial aspects of development, without adequate consideration of sociocultural aspects (Pickering, 2006). This highlights the need to better understand how governments, businesses, and other stakeholders can best support the economic development of coastal communities.

The purpose of this study is to examine the multidimensional factors that influence participation in new aquaculture ventures within the distinctive context of PNG's remote island communities. This research is predicated on the notion that while aquaculture can offer an alternative to declining wild fish stocks and enhance food security, its adoption and success are underpinned by a confluence of facilitative and inhibitive factors ranging from access to resources and training to local governance structures and cultural practices.

Particularly in PNG, where the remoteness and variability of infrastructure pose significant operational challenges, understanding these factors is of heightened importance. Economic opportunities may not always align with environmental stewardship or social cohesion, thereby requiring a detailed understanding of the local conditions and constraints. It is crucial to consider how external influences, such as variability in market access and the impact of climate change, interact with internal community dynamics and individual decision-making processes.

By exploring these factors through empirical research, this study aims to contribute to a growing body of knowledge that seeks to illuminate the path towards sustainable aquaculture practices that are both economically viable and socially equitable. The resulting insights will benefit not only local stakeholders but also policymakers, non-governmental organisations, and investors looking to support aquaculture as a vessel for sustainable development in Papua New Guinea.

1.2 Seaweed Farming in Papua New Guinea

Seaweed farming of Kappaphycus alverazii is an emerging alternative fishery that supports the livelihoods of communities in Papua New Guinea. It is the only product exported from the aquaculture sector, and it continues to be promoted by the National Fisheries Authority to benefit impoverished coastal and island communities.

The initial farming of this seaweed began in 2010 using the tambalang variety and employing floating longlines and off-bottom farming systems in Milne Bay province. In 2012, a different variety (Maumere) was introduced from the Solomon Islands, and farmers in the Autonomous Region of Bougainville (AROB) began cultivating it. These ventures successfully propagated sufficient seeds for distribution to farmers in their respective provinces, resulting in exports to China in 2012 and 2017. At its peak, approximately 1,500 farmers were involved in seaweed cultivation, producing approximately 150 tons (dry weight) ((Gómez, 2013); (Singh, 2016).

Despite a successful start, seaweed farming in Papua New Guinea currently faces challenges that prevent it from reaching its full commercial potential. The main limitations identified are primarily related to the limited skills and expertise in seaweed farming, harvesting strategies, and processing techniques. This is because seaweed farming is still relatively new in PNG, and these limitations affect the entire supply chain. Other factors that must be considered for quality and processing techniques include adaptation to local environmental conditions, such as fluctuations in water temperature and salinity, as well as high levels of rainfall.

Figure 1. Map showing seaweed farming locations (red circled) in Papua New Guinea.

Additionally, past interventions have seen farmers receive less support in terms of policy and finance, which has hindered the development and expansion of the seaweed sector. Furthermore, farmers face challenges in accessing cash, markets, and equipment, which impedes their ability to effectively farm seaweed. The inherent remoteness of markets and main ports has hindered development, leading to high transportation costs and inadequate storage of seaweed products over extended periods, thereby diminishing their quality.

The National Fisheries Authority (NFA) of Papua New Guinea has prioritised the commercialisation of seaweed production in its Fisheries Strategic Plan for 2020-2030. To achieve this, the NFA has focused on expanding commercial-scale seaweed farming throughout the country.

The NFA has paid significant attention to mariculture, particularly in creating and refining the necessary legal and support frameworks for large-scale seaweed farming ventures. These efforts aim to support the growth and sustainability of the sector while also considering the socioeconomic benefits for coastal communities involved in seaweed cultivation. Rambutso, an island located southeast of the main island of Manus, serves as a case study that demonstrates the substantial potential for the commercial development of seaweed farming. Its proximity to Lorengau town, the provincial capital, is advantageous, as it is only a short dinghy ride away, taking approximately 1 hour and 45 minutes.

In 2019, development efforts began with the establishment of nursery farms at three trial sites within the Manus region: Liuliu Village, Ndrova Island, and Mbuke Island. These sites were chosen to leverage the experience and seedstock of an established farming site in Milne Bay Province. Among the trial sites in Manus, Liuliu Village achieved remarkable success due to strong community engagement in farming extension and maintenance. This success led to the expansion of the Liuliu site to commercial operations. Consequently, seaweed farming practices spread throughout Rambutso, fundamentally transforming the mariculture landscape of the region. The initiative's growth continued as trained local fisheries teams from Rambutso extended farming trials to other Manus islands, diversifying and strengthening the seaweed cultivation network. Expansion efforts reached as far as the Pak, Baluan, and Pam Islands within the Balopa LLG, as well as various islands to the northeast, northward to the Admiralty Group, each with varying degrees of success. Because of these deliberate and systematic efforts, almost one-third of the islands in the Manus region are now actively involved in the cultivation of Kappaphycus seaweed, establishing the region as a thriving hub for commercial seaweed farming.

1.3 Rational

The Fisheries Strategic Plan for Papua New Guinea 2020-2030 is a comprehensive roadmap that aims to guide the sustainable development of the nation's fisheries sector. Recognising the importance of fisheries in contributing to food security, economic growth, and livelihoods, the strategic plan takes a multifaceted approach with a strong focus on the development of aquaculture and coastal fisheries. The primary goal is to strengthen incentives that provide technical assistance, financial support, and capacity-building programs for local communities to participate actively in aquaculture ventures. Seaweed farming has emerged as an environmentally friendly and economically viable form of aquaculture that offers various benefits, such as the provision of raw materials for food, cosmetics, pharmaceuticals, and biofuels, as well as contributing to carbon sequestration and habitat restoration. However, the success of seaweed farming is not guaranteed and can be influenced by a range of biological, environmental, social, economic, and policy-related factors. It is crucial to understand these determinants of success to ensure that the development of seaweed aquaculture meaningfully contributes to the livelihoods of coastal communities while remaining ecologically sustainable.

This study aims to identify, characterise, and quantify the predictors of success in seaweed farming ventures. By analysing various variables, such as seedstock quality, growing conditions, market access, and community engagement, this study will develop a comprehensive model that can forecast the potential outcomes of seaweed farming operations. The outcomes of this study are as follows:

i. Providing stakeholders with actionable insights into optimisation strategies for farming techniques, resource allocation, and risk management.

ii. Facilitating the design of policies and initiatives that support sustainable aquaculture practices and promote industrial growth.

iii. Enabling the scalability of seaweed farming ventures by identifying critical success factors and addressing bottlenecks.

iv. Enhancing socioeconomic benefits to coastal communities by connecting empirical evidence to developmental interventions.

Ultimately, this project will fill a knowledge gap regarding the factors that contribute to successful seaweed aquaculture, thus assisting investors, farmers, policymakers, and development agencies in making informed decisions that enhance the industry's sustainability and profitability. The insights gained from this research could potentially be applied to similar aquaculture systems, further supporting efforts to develop responsible and productive seafood cultivation practices.

2 OBJECTIVES:

This study aims to investigate the factors that either facilitate or impede the effective development and success of seaweed farming by local communities in Rambutso Island, Manus, Papua New Guinea

Specific objectives are as following:

1. To identify barriers that impede community engagement in seaweed initiatives.
2. To explore the enablers that facilitate active participation in seaweed farming projects.
3. To analyse the impact of these factors on the success and sustainability of mariculture ventures implemented in Rambutso.

3 LITERATURE REVIEW:

Aquaculture, including seaweed farming, has emerged as a significant sector with the potential to contribute to economic development and environmental sustainability (Oktopura, Fauzi, Sugema, & Mulyati, 2020) However, the successful implementation and widespread adoption of aquaculture initiatives depend on various factors that can either impede or facilitate community participation in these ventures (Bulkis, Arief, & Arfah, 2021).These factors can be grouped into several categories, including economic factors, social factors, environmental factors, and institutional factors.

3.1 Economic factors:

A study by (A Syukur1, 2021), has identified lack of access to financial resources can impede community participation in aquaculture ventures. Economic factors that impede participation in seaweed aquaculture largely stem from the complex interplay of market dynamics, inadequate financial support, and insufficient economic incentives. Challenges include low income resulting from volatile market prices and the dominance of low-value products, such as carrageenan, which command lesser prices compared to products for direct consumption (Feng-qing, 2016). The lack of infrastructure for domestic processing can constrain value addition, leading to dependency on export markets and resulting in farmers receiving lower compensation for their product due to added export costs (Feng-qing, 2016). The initial investment required for farming equipment and resources can be prohibitive, particularly for small-scale or individual farmers without access to credit or government loans (Feng-qing, 2016). Additionally, the absence of regulatory support and economic incentives, such as tax deductions or financial incentives that acknowledge the environmental benefits of seaweed farming, may further disincentivize farmers from investing in this aquaculture sector (Feng-qing, 2016). Overall, these economic factors create a barrier to entry and discourage expansion, which can be mitigated through diversified product development, community programs, and government interventions that address these financial hurdles and create a more equitable market for seaweed products.

3.2 Social Factors

Social factors that impede participation in seaweed farming aquaculture include traditional gender roles that often limit the involvement of women, as they may lack access to necessary resources such as boats and equipment, further confined to working at low tide and in shallow waters (Sultana et al., 2023). Additionally, community dynamics and social capital play a role; areas with low social cohesion may experience challenges in cooperative efforts and information sharing, which is vital for the success of aquaculture practices (Nor et al., 2016). The lack of public awareness and acceptance of seaweed farming as a viable industry can also hinder individuals from engaging in or supporting the sector. Another social impediment might be the insufficient transfer of knowledge due to a lack of formal training programs, mentorship, and extension services that would facilitate skill development and the adoption of new technologies (Sultana et al., 2023). Furthermore, tensions between local communities, migrant workers, and government agencies can result in a lack of trust and collaboration, necessary for coordinated development efforts (Nor et al., 2016). These social hurdles require targeted interventions to improve community engagement, empower marginalized groups, and cultivate an environment that promotes inclusivity and shared knowledge in the seaweed farming sector.

3.3 Environmental Factors

Environmental factors present significant challenges that can impede participation in seaweed farming aquaculture. One of the primary concerns is the degradation of local ecosystems, which can result from pollution, overfishing, and habitat destruction that reduce water quality and consequently affect seaweed growth. Seaweed farms rely on specific water conditions, and large spatiotemporal variability in ocean nutrients, as well as the presence of heavy metals in polluted waters, can be detrimental to seaweed cultivation. Climate change poses another considerable barrier, with rising seawater temperatures, ocean acidification, and increased

frequency of extreme weather events negatively impacting seaweed growth rates and farming cycles. The competition with wild habitats for nutrients and light, the potential for spillover of diseases, invasive species, and genetic pollution from seaweed farms to the wild environment can also be a concern. Moreover, the physical structure of the farming installations may inadvertently lead to the entanglement of marine fauna, affecting biodiversity. These environmental challenges require careful management and the adoption of sustainable farming practices to mitigate their impact and ensure the long-term viability of seaweed aquaculture (Feng-qing, 2016).

3.4 Institutional Factors

Institutional factors that impede participation in seaweed farming aquaculture encompass regulatory, legal, and bureaucratic obstacles. Regulatory frameworks may be underdeveloped, lacking specific guidelines for seaweed farming, which can lead to confusion and discourage potential farmers from entering the industry. Permits and licenses necessary for aquaculture operations might be difficult to obtain due to complicated application processes or unclear requirements. In regions where policies do exist, they may be restrictive or not well-adapted to the unique needs of seaweed farming, thereby hindering growth and innovation in the sector. Furthermore, inadequate government support and a deficiency in enforcing existing regulations can result in uneven playing fields, where small-scale farmers struggle to compete with larger, established operations. Insufficient institutional support also manifests in the lack of investment in research and development, which is crucial for advancing sustainable aquaculture practices and technologies. This can lead to a disconnect between research institutions and farmers, where knowledge and innovation fail to reach practical application. The absence of cohesive international agreements or standards for seaweed farming practices and product quality can also limit market access and reduce competitiveness. Addressing these institutional barriers is essential for fostering an environment that encourages participation and the sustainable development of the seaweed farming industry.

Others have mentioned limited knowledge and skills in seaweed farming techniques and practices can hinder community participation (Ibon Galparsoro, 2020). Access to necessary infrastructure such as water sources, storage facilities, and processing equipment is crucial for successful seaweed farming (Zamroni, 2021). The presence of a stable and profitable market for seaweed products can incentivize community participation in aquaculture ventures (Mazur, 2008). Supportive government policies, regulations, and assistance programs can facilitate community participation in aquaculture ventures by providing resources and technical guidance (Mazur, 2008). Additionally, the willingness of local stakeholders to embrace and support aquaculture initiatives is an important factor. The engagement and cooperation of local communities, including their willingness to adopt new practices and technologies, can significantly facilitate the establishment and development of aquaculture ventures in the area (A Syukur1, 2021), Clear and secure access to suitable coastal areas for seaweed farming is essential for community participation in aquaculture ventures (Zamroni, 2021), (A Syukur1, 2021). Access to training and extension services can provide communities with the necessary knowledge and skills to engage in seaweed farming effectively (Zamroni, 2021), Strong social networks, community cohesion, and cooperation among individuals and groups can facilitate knowledge sharing, resource pooling, and collective decision-making, which can support the participation in aquaculture ventures (Hsiao & Chen, 2021).

4 METHODOLOGY:

4.1 Study Location

The study location considered for this present study is Rambutso Island in the Rapatona Local Level Government (LLG) of Manus Province Papua New Guinea. The survey is carried out in ten (10) different communities within Rambutso Island that are involved in seaweed farming. All communities are similar in the following ways:

i. They were all exposed to seaweed farming at the same time.
ii. They all live within the main Island of Rambutso.
iii. They all have same travelled distance to town.
iv. They all have diversity of available resources both land and sea based.
v. Have alternatives other than seaweed farming alone.
vi. Rambutso is the bigger and highly populated Island in Manus.
vii. Have the highest production of seaweed in the country.

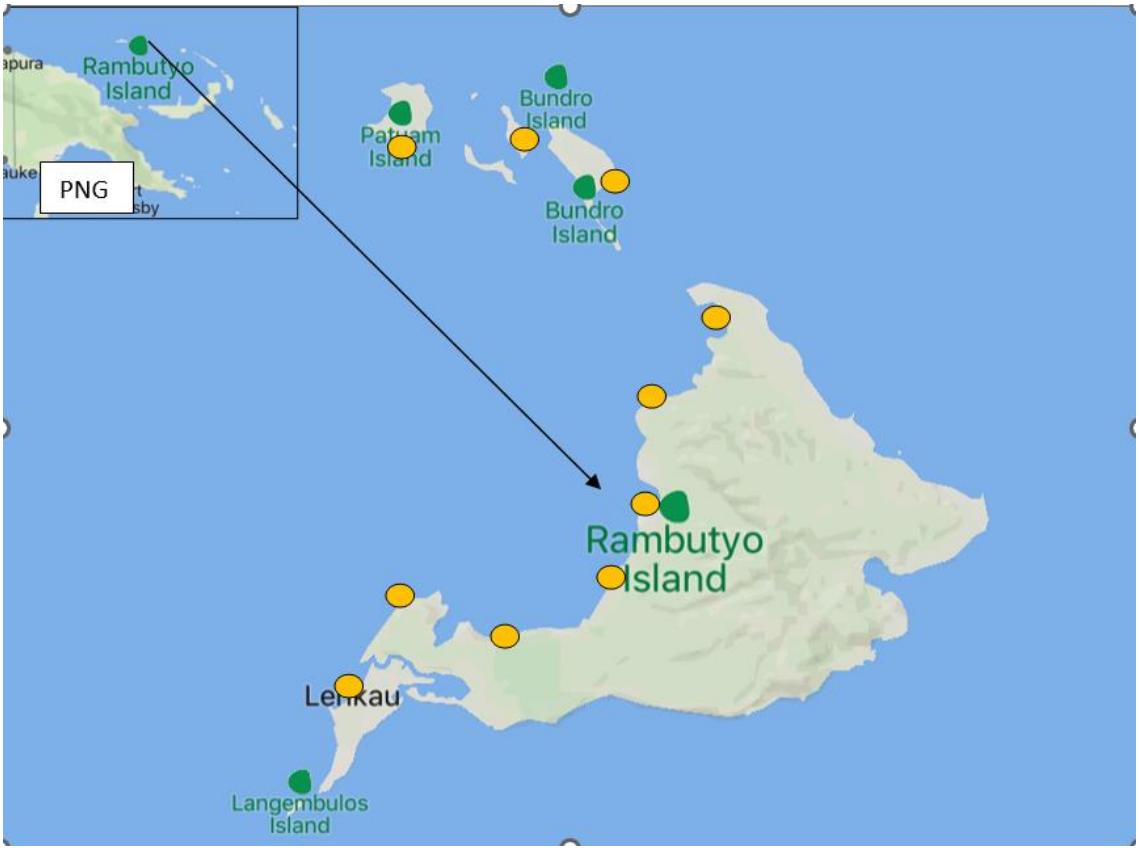


Figure 2: Map of the study sites showing individual villages involved in the survey.

The communities of Rambutso are familiar with various other past government interventions however, no attempts have been made to understand the differing socio-economic drivers within the communities and the levels of support or governance within the communities remains to be understood. For this purposeful sampling will be carried out to select participants involved in seaweed projects in Rambutso Island, ensuring diversity in roles and experiences.

4.2 Interviews and Sampling Considerations:

This research uses interview-based data collection methods. Ethical approvals are sought through the usual community fisheries development approaches by the National Fisheries Authority of Papua New Guinea. Different interview questionnaires are used for different demographics. This allows more appropriate questions to be asked ensuring diversity in roles and experiences in the community. It will also allow triangulation of information received and to uncover key issues concerning different groups of people in the community. Licensed Seaweed exporting companies and government officers are also interviewed to understand how sales and market agreements are made with communities on seaweed farming.

4.2.1 Seaweed Farmers

Seaweed farmers are people directly engage in seaweed activities as their primary source of income. Famers are interviewed one-on-one about the nature of their access rights to farm, their typical farming party (social dynamics) and equipment used, the processes of planting, harvesting, processing, seaweed, and what stipulations there may be for them, and how income earned from seaweed has affected their families (this aspect explores economic betterment).

4.2.2 Project inception and questionnaire refinement meeting

Interview questionnaires was drafted to meet the objective of the study. A series of online zoom meeting was held with the survey team in Papua New Guinea to refine the interviews and discuss the project amongst the team. This was done to ensure that there is a mutual understanding of the project overall purpose and allow for aspects such as community engagement, interview process, data recording protocols, and cultural sensitivities are discussed.

4.2.3 Field Work

The data collection methodology employed in the seaweed farming communities across Rambutso Island was meticulously designed for inclusivity and efficiency. The approach commenced with a preliminary survey involving one of villages—Liuliu in the Polobuli area. This initial phase, critical for knowledge sharing and capacity building, included all members from Manus Provincial Fisheries. The initial step was pivotal in adhering to correct survey protocols and promoting team familiarization.

Before the actual data collection, a two-week community consultation period took place in January 2024. This preparatory step involved visiting the communities to outline the project objectives to community leaders, providing clarity on their roles and selecting the target demographic for engagement. Such engagements are valuable as they grant community members ample time to prepare and align their perspectives prior to data gathering.

The main interview stage spanned approximately three weeks, with the research team allocating two days to each community for conducting interviews. Interviews were conducted on a one-on-one basis, offering interviewees the discretion to choose a private setting, often in their own households, which likely facilitated openness and comfort during data collection.

4.3 Data Collection and Analysis:

Data collected from the interviews were entered into and excel spreadsheet and pooled together to describe the research variables through descriptive statistics in the form of frequency tables which include variables of age, level of education, experience, number of family members, area suitability, income, available farming area, capital, access and ownership to materials, farming intensity, social barriers, environmental concerns and policy and regulatory framework within the communities. The resulting percentages of the variables that emerged as having a difference in absolute value were further analysed using Chi Square Tables to see significant difference across gender and villages.

5 RESULTS

5.1 Demographic Characteristics

A total of 101 farmers from 10 villages in Rambutso were interviewed. The survey results showed that the majority of farmers were between the ages of 18 and 50, evenly distributed between genders. Many of the farmers surveyed were between the ages of 18-35 (n=36) and 35-50 (n=32) (see Figure 3). There were few farmers below the age of 18 (n=1), as they were primarily focused on education, although they occasionally helped out during school breaks or if they did not pursue further education after primary school.

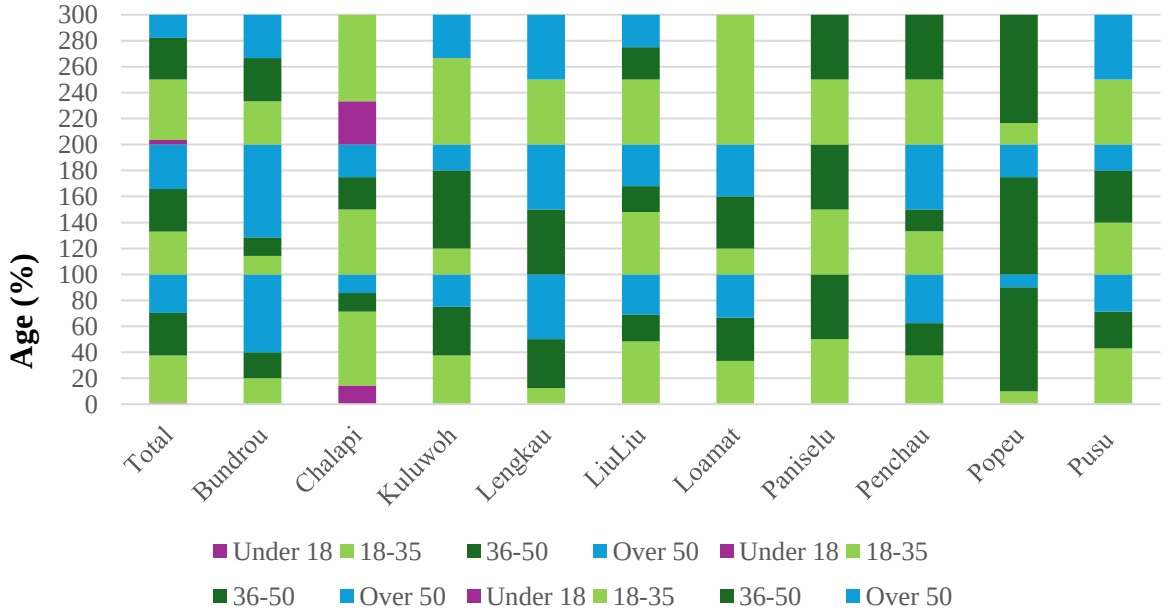


Figure 3: Different Age groups of the survey participants in the villages of Rambutso.

The survey found that there were fewer active farmers over the age of 50 (n=29), as they had passed on their farming responsibilities to their adult children. Despite personal accounts indicating high participation of women, the majority of the surveyed farmers in Rambutso were male. The survey results suggest that women were underrepresented in the data, with females comprising only 27% compared to males at 72%, possibly due to the survey method focusing on male household heads who are traditionally seen as decision-makers in the community (Figure 5, Appendix 1).

Many farmers in the survey only had primary education. Those who continued to secondary school often sought opportunities outside the local area, such as higher education or employment elsewhere. This explains the low number of farmers with secondary and tertiary education levels in the survey. As a result, the village's population primarily consisted of individuals who had not pursued education beyond primary school. They were responsible for managing agricultural activities, including seaweed farming (Figure 6, Appendix 1).

Family farms, typically consisting of a husband, wife, and children, dominated the farming landscape, reflecting a larger proportion of married couples (48%) among the seaweed farming population (see Figure 7, Appendix 1). In addition to seaweed farming, the communities were engaged in various income-generating activities, such as fishing (34%), gardening (21%), and sago processing (12%). Some pursued more profitable trades, such as selling betel nuts (3%) using private boats, while others were involved in creating artisanal goods like woven baskets, coconut oil, and shell jewelry, constituting self-employment (25%) (see Figure 8, Appendix 1).

Regarding aquaculture experience, the responses indicated that older respondents may have been referring to traditional forms of aquaculture that were distinct from seaweed farming, such as fish herding and milkfish rearing, which were less commonly practiced by the younger generation (See Figure 9, Appendix 1). This suggests a shift in traditional practices over time within the community, indicating a potential transition of skills and income sources from historical methods to more contemporary forms of aquaculture, such as seaweed farming.

5.2 Socioeconomic Factors

5.2.1 Resource and Access

Interviewed farmers from Rambutso indicated that they have a large and suitable coastal area for cultivating seaweed. This resource is available to individuals of all genders across various villages (see Figure 10, Appendix 1). The ample coastal space allows farmers to use different farming methods such as stake-and-line, float-and-line, or bamboo/PVC rafts. The potential for commercial-scale production is promising due to the extensive coastline in these villages.

In terms of resource ownership, many of the interviewees reported having control over specific sea areas for farming purposes. This control is typically structured through ownership (34%), lease arrangements (32%), or user rights (33%). These arrangements reflect the community's traditional clan-based governance system that manages land and sea territories (see Figure 11, Appendix 1). A small number of major clans hold legal ownership, while others have rights to use these areas. This distinction has implications for future considerations as seaweed farming intensifies and the population grows. It could potentially lead to disputes or conflicts over resource access.

It is important to note that ownership and control of these areas are more critical to males, as females usually relocate upon marriage and adapt to their husband's community rights. The Government's initiative under the FSP Plan 2020-2030 has significantly improved farmers' access to farming materials. By importing and distributing these resources, the government ensures that all active farmers have the necessary tools. The positive response to this initiative is evident, as many farmers report owning sufficient farming equipment (100%) (refer to Figure

12, Appendix 1). Additionally, plans are underway to establish seaweed cooperatives in each village, aiming to enhance coordination and resource allocation. LiuLiu will have a primary cooperative with comprehensive facilities, and other village cooperatives can register as clusters to streamline operations. While the cooperative structure has been communicated briefly through village Councillors and Ward Development Committees (WDC), varying opinions on the matter (refer to Figure 34, Appendix 1) imply that individual preferences will play a role in the level of engagement in seaweed farming and the success of cooperative endeavors.

As part of the FSP Plan 2020-2030, the National Fisheries Authority has taken significant steps to support seaweed farmers in Rambutso. They have constructed a large storage warehouse in LiuLiu village, which serves as a centralized distribution and collection point. Farmers are encouraged to form groups and coordinate with the chairman of the seaweed cooperative for the supply of necessary materials. This system ensures that resources are allocated to those actively engaged in farming and not diverted for other purposes. Many farmers, regardless of gender, find it relatively easy to access these materials. However, some may encounter challenges due to local village politics or interpersonal issues with members of the LiuLiu community, which can complicate the distribution process (refer to Figure 14, Appendix 1). Financial access is a significant obstacle for communities, as indicated by survey responses across villages and genders (see Figure 15, Appendix 1). Local financial institutions are hesitant to offer services to rural farmers in agriculture and fisheries due to perceived high risks and their inability to meet strict banking policies. To address this issue, the National Fisheries Authority has stepped in and guaranteed the opening of personal and cooperative bank accounts for seaweed farmers at Rambutso, facilitating their financial inclusion. However, despite these efforts, farmers still struggle to access credit due to stringent bank requirements, as licensed financial institutions in the country do not offer credit lines for agricultural ventures. Survey responses from communities further highlight this difficulty (see Figure 16, Appendix 1), revealing that while farmers understand loan repayment, they lack the confidence to apply independently and require tailored financial programs to assist them. In response, initiatives have focused on providing financial literacy training and developing easy-to-follow guides to empower farmers. These initiatives aim to build confidence and competence among seaweed farmers, equipping them to navigate the financial aspects of their business more autonomously and effectively.

5.2.2 Training and Knowledge

Survey responses from the seaweed farming community indicate a strong preference for hands-on training, which has been instrumental in teaching farmers the practical aspects of seaweed farming—ranging from planting to processing and market delivery—despite the lack of formal certification-level instruction. Over the past three years, this approach has enabled farmers to become proficient in various farming activities, though there is recognition of a gap in understanding the biological aspects of seaweed that are typically conveyed through theoretical education.

The training has been carefully designed to accommodate variable literacy levels among community members, with a clear focus on the acquisition of practical skills rather than theory. This aligns with the preferences expressed across different villages and genders, showing an overwhelming support for experiential learning. Additionally, financial literacy and bank account management training have been integrated into the program to enhance the business

acumen of farmers, with individuals from LiuLiu village being employed as national trainers to disseminate this knowledge throughout Papua New Guinea.

Overall, the response to these training efforts from the seaweed farming communities has been positive, with participants finding the practical learning experiences both adequate and well-suited to their needs. The adaptability and impact of these programs have contributed to building a group of seaweed farmers who are confident and capable, enabling them to participate effectively in the industry within the rural coastal context of Papua New Guinea.

5.2.3 Economic and Market Access

In Rambutso, the seaweed industry is showing promise as a sustainable economic activity. Survey responses indicate that seaweed is the primary source of income for 76% of the respondents (see Table 1 below), highlighting its integration into traditional income sources such as fishing and gardening. The high level of engagement in seaweed farming demonstrates that the groundwork laid has been successful in gaining the community's trust in the long-term viability of this venture. However, this shift has had an impact on traditional practices, as families have redirected their efforts towards seaweed, resulting in neglected gardens that have become overgrown. Furthermore, the communal strategy and collective effort of the farmers in producing 100 tons of dry seaweed for export highlight their hard work and the lucrative nature of this industry. The potential income from seaweed far exceeds that of other income-generating activities, with individual earnings ranging from 1300-2600 USD per export cycle. This economic allure has played a crucial role in drawing the community towards seaweed farming.

When asked about their sales method, many farmers indicated that they sell directly to arranged buyers (70%) (see Figure 19, Appendix 1). This confirms the strategic approach of establishing a cooperative that centralizes buying, processing, and exporting responsibilities. This system aims to alleviate the burden on farmers by allowing them to focus on production, while storage, transport, and market access are taken care of. It also provides a more predictable income by ensuring farmers can sell their products without having to search for buyers.

The overarching goal of this initiative is to offer an organized alternative source of income through collective business models like cooperatives, which would enhance cash flow in local communities. Aside from its economic benefits, seaweed farming serves as a catalyst for community development and can attract government attention and services to remote areas. The survey responses reflect the community's economic optimism, with participants identifying income generation and source diversification as the primary incentives for engaging in seaweed farming (see Table 1). This motivation is consistently observed across genders and demonstrates the community's recognition of seaweed farming as a promising economic opportunity. In terms of the main economic challenges faced, a higher percentage of the response (37%) indicates that low market pricing and access to markets (19%) are anticipated to be pivotal challenges (refer to Table 2).

Table 1: Main Economic Challenges with Seaweed farming faced by Villages in Rambutso

Village Name	Competition with other seaweed farmers	High production costs	Lack of access to markets	Lack of economic incentives or subsidies	Low market prices	Other	Transportation and logistics costs
Bundrou	6%	0%	6%	5%	63%	6%	15%
Chalapi	0%	14%	17%	10%	31%	0%	29%
Kuluwoh	0%	10%	27%	4%	38%	0%	21%
Lenkau	0%	19%	19%	3%	44%	0%	16%
Liuliu	4%	5%	19%	7%	30%	15%	21%
Loamat	17%	0%	17%	8%	33%	17%	8%
Paniselu	13%	0%	21%	0%	33%	25%	8%
Penchal	13%	6%	42%	0%	23%	13%	4%
Popeu	15%	0%	5%	0%	40%	15%	25%
Pusu	0%	0%	33%	0%	50%	17%	0%
Average	6%	5%	19%	4%	37%	11%	16%

The assisted buying, arranged through Government intervention, pays USD 0.65 per kilogram, which is an improvement compared to the USD 0.26 per kilogram ten years ago. This price per kilogram is higher than the current buying price of copra, which is set at USD 0.18 per kilogram on the island. However, seaweed farmers must work for six to eight weeks before they can sell their product, as seaweed is an export product that relies on volume. As a result, farmers need to stockpile until they have enough volume for an exporter to purchase and export. This delay, combined with the low-price offers, has led farmers to perceive the market price as low. However, it is important to note that compared to traditional cash crops like copra, the current pricing of seaweed is competitive and outperforms them. The difference lies in the expectation of immediate payment for produce among the farming community. Introducing seaweed as a new livelihood requires a cultural shift, especially for the younger generation who are not accustomed to waiting for their earnings from a harvest. However, farmers with experience in other cash crops can compare and understand the advantages of seaweed farming, recognizing its suitability for Rambutso and the reasonable farm gate price. Despite concerns about payment delays, efforts are being made to improve the situation through governmental initiatives and the cooperative business model. These initiatives aim to streamline capital flow and establish more reliable payment structures. The cooperative also helps to mitigate risks associated with market fluctuations, and financial support mechanisms may ensure a minimum price for seaweed to maintain income stability for farmers.

The establishment of seaweed farming has already brought infrastructural development, service opportunities, and financial assets to the community, with many local members benefiting significantly (98%) (see Figure 22, Appendix 1). Personal accounts reveal tangible impacts on the quality of life, such as enabling higher education for children, thanks to income from seaweed farming and related services. The focus on creating seaweed cooperatives is a decisive step towards enhancing market access and equipping farmers to achieve better prices through improved processing standards suitable for the international market. This was reflected overwhelmingly through their response, with many farmers mentioning market access

assistance (44%), followed by subsidies (20%) and grants (14%), as their main financial support concerns (see Figure 23 in Appendix 1).

In tandem, training in financial management is expected to play a crucial role, as reflected in anticipated survey results which are likely to highlight the need for continued support in marketing and financial literacy. This comprehensive approach aims to not only secure better economic returns for the Rambutso community but also to foster resilience in the face of market unpredictability.

5.2.4 Social and Community Factors

The social fabric and community dynamics of Rambutso are crucial for the successful implementation of seaweed farming. Survey results, illustrated in Figure 24, Appendix 1, indicate strong community support. A key factor in fostering this support is the existing "community line" system, which encourages active participation and collective decision-making among villagers. This system was instrumental in recognizing the potential of seaweed cultivation and promoting cooperation from the start. The initial evaluation of community cooperation, especially in LiuLiu village, proved successful, leading to continuous engagement and the establishment of seaweed farming as Rambutso's main mariculture project. The inclusive nature of the community is evident in the perception of active participation of women (97%) and the feeling of personal support (70%) for seaweed farming activities, as demonstrated in Figures 25 and 26, Appendix 1. Personal accounts confirm that women are heavily involved in various aspects of farming, such as planting, processing, sun-drying, and sorting seaweed. This involvement complements the labour-intensive tasks traditionally undertaken by men, including harvesting, farm maintenance, and transportation. The balanced participation of both genders, along with the personal benefits experienced, aligns with the expectation of substantial involvement of women in Rambutso's seaweed cultivation.

Compared to other island communities in Manus, Rambutso distinguishes itself with exceptional community support for seaweed farming initiatives. This is partly due to substantial investments made in the region, which include providing farming materials, seedlings, and infrastructure development such as storage warehouses. These contributions have positioned seaweed farming as a significant catalyst for community development. The sense of social cohesion and cooperative spirit observed in families working together on large-scale seaweed farms exemplifies the unity of the community.

Survey responses have echoed these positive community dynamics, with 90% of respondents indicating substantial contributions from seaweed farming to local development. Both genders noted these contributions, as shown in Figure 27, Appendix 1. The multifaceted benefits experienced by the community, not just from direct sales of seaweed, but also from various spin-offs and service hires generated within the community, contribute to the favourable view of seaweed farming as an engine for communal prosperity.

However, despite the strong community support, the survey also uncovered important social barriers to seaweed farming. A lack of interest (53%) and personal reasons (26%) were identified as the main social barriers, as shown in Table 3 below. This indicates a need for further exploration at the village level. Both genders expressed similar sentiments, highlighting a shared perspective that requires attention in future investigations.

Table 2: Main Social barriers faced in seaweed farming in the villages of Rambutso.

Village Names	Cultural attitudes	Educational barriers	Lack of interest	Workforce availability	Other
Bundrou	10%	0%	50%	0%	40%
Chalapi	0%	0%	86%	0%	14%
Kuluwoh	0%	0%	63%	0%	38%
Lenkau	11%	0%	61%	6%	22%
Liuliu	14%	7%	34%	11%	34%
Loamat	0%	0%	83%	17%	0%
Paniselu	0%	0%	63%	25%	13%
Penchal	0%	0%	50%	38%	13%
Popeu	0%	0%	40%	40%	20%
Pusu	0%	0%	67%	0%	33%
Average	6%	2%	53%	14%	26%

Despite these barriers, the community-led initiative in seaweed farming, as seen in Figure 30, Appendix 1, is expected to continue as efforts expand. This includes the need to establish additional seaweed cooperative groups across villages (see Figure 31, Appendix 1). Although most communities have not yet received necessary cooperative support from the NFA team, the collaborative approach in LiuLiu, supported by financial literacy training, demonstrates a successful model. Trained individuals are expected to pass on their knowledge within the community, although there may be gender variations in training uptake. Survey responses have highlighted the demand for increased community-based training, while also underscoring the importance of bolstering market and technical support for seaweed farming communities (refer to Table 4). Understanding this, it is imperative to make continuous efforts to improve market accessibility and support systems to ensure the enduring prosperity of seaweed farmers in the province. Addressing these needs remains a central focus in ongoing development plans.

Table 3: Main kind of support needed in seaweed farming by the villages in Rambutso.

Village Names	Educational programs	Infrastructure development	Marketing and sales support	Financial assistance	Networking opportunities	Technical support	Other
Bundrou	3%	5%	26%	0%	20%	16%	0%
Chalapi	0%	5%	12%	5%	43%	19%	0%
Kuluwoh	0%	9%	23%	8%	14%	13%	0%
Lenkau	0%	9%	15%	4%	29%	20%	0%
Liuliu	9%	6%	24%	6%	6%	19%	2%
Loamat	0%	6%	13%	4%	22%	38%	0%
Paniselu	0%	3%	24%	6%	19%	22%	0%
Penchal	2%	11%	23%	4%	6%	20%	0%

Popeu	2%	7%	28%	5%	0%	25%	0%
Pusu	0%	11%	29%	7%	0%	13%	0%
Average	3%	7%	22%	5%	14%	20%	1%

5.2.5 Environmental Conditions

Rambutso Island is an ideal location for seaweed cultivation, specifically the Kappaphycus species. Survey responses show that there is ample coastal space for farming (see Figure 34, appendix 1), and personal accounts confirm that the island has the right environmental conditions for growing Kappaphycus seaweed, including shallow, sandy seas with plenty of sunlight and favourable water currents (see Figure 35 and 36, Appendix 1). Additionally, the island's proximity to Lorengau, the provincial capital and a base for exporters, provides accessible market routes that are only about 1 hour and 45 minutes away by boat, making seaweed farming more viable. Furthermore, there are plans to establish a coastal fisheries hub in the province, which will streamline the processing and packaging process for the international market.

The Kappaphycus species cultivated in Rambutso is like those grown in neighbouring regions like the Solomon Islands, Fiji, Kiribati, Indonesia, and the Philippines. While these countries may have different strains that potentially yield higher quantities, there have been no reports of negative environmental impacts from seaweed farming in Rambutso (see Figure 37, Appendix 1). In fact, there are accounts of positive secondary effects, such as fish being attracted to the seaweed farms and the purification of water in cultivated areas. Seaweed farms provide habitats for fish and cephalopods like squids and cuttlefish, enhancing nighttime fishing opportunities for the community. These benefits, along with the absence of reported environmental impacts, affirm the positive perceptions of the respondents.

The Rambutso seaweed farming community has faced environmental challenges, particularly extreme weather events. High king tides have caused significant damage to seaweed farms, resulting in widespread destruction due to strong winds, high sea swells, and driftwood from the open ocean. These events highlight the vulnerability of the seaweed farming infrastructure to natural disasters. Concerns about this vulnerability have been noted through multiple incidents, with the most recent occurring in January 2024 (See Figure 38, Appendix 1). Environmental stewardship is highly valued within the community, with farmers receiving instructions on sustainable farming practices for seaweed cultivation. These practices are vital for preserving the environment and supporting marine habitat. The overwhelming response from farmers demonstrates their commitment to these practices, as confirmed by interview results (see Figure 39, Appendix 1). Anecdotal evidence suggests that cultivating Kappaphycus seaweeds in PNG has improved local water quality and provided habitats for juvenile fish.

Table 4: Main Social barriers to implementing environmental safety practices in the seaweed farming villages in Rambutso.

Village Names	**Cultural/Community resistance**	**Economic viability**	**Insufficient regulatory support**	**Lack of knowledge**	**Lack of resources**	**Other**
Bundrou	0%	0%	0%	45%	15%	40%

Chalapi	7%	14%	7%	29%	14%	29%
Kuluwoh	0%	0%	13%	25%	13%	50%
Lenkau	6%	0%	33%	6%	11%	44%
Liuliu	11%	8%	7%	35%	24%	16%
Loamat	0%	17%	0%	42%	8%	33%
Paniselu	6%	13%	13%	31%	25%	13%
Penchal	0%	19%	0%	56%	13%	13%
Popeu	10%	0%	3%	68%	18%	0%
Pusu	17%	0%	0%	42%	42%	0%
Average	7%	7%	8%	38%	19%	23%

It is important to note that there is little involvement from NGOs or external agencies in guiding or supporting seaweed farming in Rambutso (see Figure 40, Appendix 1). The National Fisheries Authority is independently working on developing environmental guidelines, resulting in a consensus across villages and genders that their practices are not influenced by external guidelines at present (see Figure 41, Appendix 1). Technical knowledge and infrastructural support are recognized as crucial for successful seaweed cultivation. This includes emphasizing optimal growing conditions, seeding techniques, and harvesting methods tailored to specific seaweed species and community locations. The community has observed innovations, such as the use of floating and longline cultivation systems to enhance productivity. However, it is acknowledged that not all community members fully understand the technical aspects and infrastructure requirements (see Figure 42, Appendix 1).

The response from villagers indicates a willingness to participate in further training on sustainable seaweed farming, with many expressing a desire to learn and improve their practices. This eagerness aligns with the expectation that communities are open to new opportunities that add value, particularly in areas where they already have some experience, such as seaweed farming (see Figure 43, Appendix 1).

5.2.6 Policy and Institutional Framework

The policy and institutional framework for seaweed farming in Rambutso and the broader Manus region is currently being developed in line with the strategic vision outlined in the Fisheries Strategic Plan 2020-2030. Presently, there is no specific policy or guideline exclusively for seaweed farming in PNG, and this is evident based on the survey responses (see Figure 44, Appendix 1). In Manus, the initial strategy focused on using Rambutso as a base to establish seaweed cultivation practices and serve as a model for neighbouring island communities. The plan includes targeted interventions and support mechanisms to ensure the successful establishment and sustainability of seaweed cultivation in Manus.

Community perception of fisheries policies is influenced by past experiences and ongoing developments, with many community members holding a neutral or optimistic view (see Figure 45, Appendix 1). When asked about the type of policy changes that is needed the most in the community, many mentioned that improved market regulations (46%), followed by financial subsides (19%) and infrastructure (13%) (see Table 6). Extensive awareness campaigns and ongoing efforts to build relationships have aimed to foster positive attitudes towards the

emerging fisheries policies. Unfortunately, these efforts are not felt by the communities (see Figure 46, Appendix 1).

Table 5: Type of Policy support needed by the seaweed farming villages of Rambutso.

Village Names	Environmental protection laws	Financial incentives or subsidies	Training and education programs	Improved market regulations	Infrastructure development	Simplified licensing procedures	Other
Bundrou	5%	20%	7%	55%	12%	0%	0%
Chalapi	0%	31%	24%	21%	24%	0%	0%
Kuluwoh	7%	13%	17%	44%	19%	0%	0%
Lenkau	2%	25%	20%	27%	20%	6%	0%
Liuliu	2%	24%	12%	49%	10%	1%	1%
Loamat	3%	45%	12%	37%	3%	0%	0%
Paniselu	3%	19%	15%	38%	13%	13%	0%
Penchal	3%	3%	16%	47%	19%	13%	0%
Popeu	4%	4%	4%	79%	9%	0%	0%
Pusu	0%	4%	10%	43%	10%	33%	0%
Average	3%	19%	13%	46%	13%	5%	0%

Intervention strategies in Rambutso are tailored to meet the specific needs of each village. For example, efforts have focused on LiuLiu to develop the necessary infrastructure to operate as a cooperative base for seaweed farming, including material supply, community training, and seedling distribution. Community responses indicate an expectation of tangible developmental support and recognition of government involvement, which is generally viewed favourably.

The lack of involvement from other agencies or NGOs in the region's seaweed farming initiatives has been observed (see Figure 48, Appendix 1). However, work on collaboration with the banks, financial institutions, and the commerce and industry sectors are actively pursued to establish support systems and supply chain partnerships or training programs that benefit seaweed farmers (see Figure 49, Appendix 1). Questions about past fisheries projects and current interventions reveal that, while many responses indicate continuity with previous experiences, the success of seaweed farming will depend on collaborative efforts moving forward (see Figure 50, Appendix 1). The confidence in these interventions and the necessity for government support are echoed by the farmers, who recognize the government's crucial role in facilitating the transition to seaweed farming and the need for ongoing guidance and support systems until the industry becomes more self-sustaining and firmly established on the ground (see Figure 51, Appendix 1).

5.2.7 Future Plan

Perceptions of the future of the seaweed farming community are based on optimism and a shared vision of prosperity (see Figure 52, Appendix 1). The community's confidence in the support provided for seaweed cultivation aims to encourage active participation and long-term planning. Authorities plan to establish cooperative arrangements, assessing community interest

and commitment to partnering with these cooperatives for a sustainable future in seaweed farming.

Motivations for future participation are being thoroughly examined, with factors such as personal and family reasons (46%) and the availability of resources (34%) emerging as crucial influences (see Table 7 below). The insights gathered will directly shape strategic interventions, ensuring that they align with the community's values and priorities. Identifying these key motivating factors is essential for establishing support structures and fostering community engagement in mutually beneficial wealth and happiness through seaweed cultivation.

Table 6: Main Factors influencing decision to expand or not to expand seaweed farms in the villages of Rambutso.

Village Name	**Anticipated market demand**	**Current economic conditions**	**Environmental concerns**	**Personal/family reasons**	**Policy and regulatory environment**	**Availability of resources**	**Other**
Bundrou	11%	1%	6%	31%	11%	31%	0%
Chalapi	0%	21%	0%	43%	14%	21%	0%
Kuluwoh	0%	35%	4%	38%	0%	23%	0%
Lenkau	0%	30%	0%	48%	11%	4%	0%
Liuliu	1%	10%	4%	46%	4%	34%	2%
Loamat	0%	8%	0%	25%	0%	67%	0%
Paniselu	0%	38%	0%	19%	0%	44%	0%
Penchal	0%	31%	0%	25%	13%	31%	0%
Popeu	0%	0%	0%	40%	0%	60%	0%
Pusu	0%	33%	0%	0%	25%	42%	0%
Average	1%	18%	2%	35%	7%	35%	1%

In addition to cooperatives, there is a plan to diversify income sources by integrating seaweed farming with other aquaculture activities, such as sea cucumber, milkfish, and mud crab farming, which the community sees as a positive development (see Figure 54, appendix 1). The approach is to firmly establish seaweed farming before introducing these complementary livelihoods.

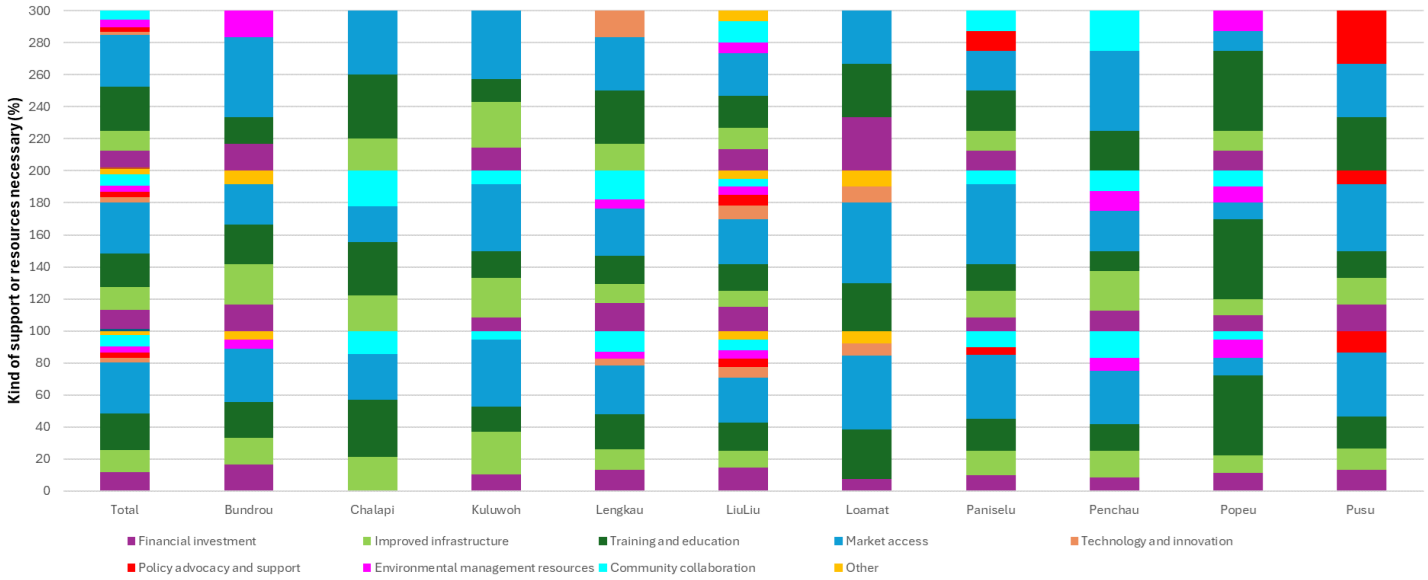
Market access (52%) is a primary concern for the communities (see Figure 4), as they recognize it as a crucial aspect for fully committing to seaweed farming. By understanding this priority, government implementers can make informed decisions about the necessary interventions to amplify the community's potential and commitment. The overwhelming optimism towards seaweed not only indicates satisfaction with current initiatives but also a desire to expand and fully embrace seaweed aquaculture as a significant part of their livelihoods (See Figure 56, Appendix 1). The fact that community members would recommend seaweed farming to other communities is evidence of the positive impact and confidence in the crop's potential (See Figure 57, Appendix 1). This shared belief reflects an acknowledgement of the benefits derived from seaweed farming, setting a positive precedent for current and future endeavors in the region.

Figure 4 Kind of support or resources needed in seaweed farming in the villages of Rambutso.

5.3 Technical Capacity

5.3.1 Knowledge and Skills Assessment

Perceptions on the technical capacity of the seaweed farming in the communities regarding the cultivation of Kappaphycus seaweed (also commonly known as "Eucheuma cottonii"), varies among farmers (see Figure 58, Appendix 1). While there is a general awareness of the seaweed due to the government's efforts, a comprehensive understanding of Kappaphycus biology is still developing (see Figure 59, Appendix 1).



Some farmers claim to have experience in seaweed farming, but this needs clarification as there is no record of previous seaweed cultivation in Rambutso before the introduction of Kappaphycus in 2019. This discrepancy highlights the need for further education on the specifics of Kappaphycus seaweed farming (see Figure 60, Appendix 1).

The trainings provided to the farmers focus on important aspects such as the 45-day growth cycle of Kappaphycus, as well as optimal harvesting, drying, and processing techniques. Through hands-on experience in day-to-day farm management, farmers are becoming familiar with the growth conditions necessary for successful cultivation (see Figure 61, Appendix 1).

Additionally, farmers have been educated on environmental factors that affect the health and productivity of Kappaphycus, including sunlight exposure, water temperature, salinity levels, and freshwater content. They have also been instructed on how to identify and manage stress indicators, such as the "ice-ice" disease that causes white spots on the thalli. While not all farmers may possess in-depth botanical knowledge, practical training has provided them with a basic understanding of farm management practices required to maintain healthy seaweed crops and effectively address common issues like "ice-ice" (see Figure 62, Appendix 1).

5.3.2 Technology and Tools Usage:

Perceptions of the farming methods used by communities have identified three primary types of farming methods, specifically designed to accommodate different environmental conditions and scales of operation. The selection of technology and tools utilized demonstrates the community's flexibility and willingness to embrace new methods for enhancing their seaweed cultivation practices.

The first method, known as stake and line cultivation, is favoured for its simplicity and ease of setup. It is most suitable for individual and family-sized farms located in waters up to 3 meters deep. The preference for this method is due to its compatibility with smaller-scale operations and the community's comfort with technology that does not require significant resources or expertise.

For deeper waters, the community has learned to employ the floating raft method, which allows for the use of materials such as bamboo or PVC. This technique is adaptable for individual to family-sized farms situated in water depths exceeding 3 meters, providing an effective solution for farming in deeper reef pools.

The third approach is the long line pressure float system, which caters to larger farmer groups or cooperatives operating farms of one hectare or more. This extensive method effectively utilizes water depths ranging from 3 to 10 meters and represents the community's efforts to scale up their farming operations (see Figure 63, Appendix 1).

In terms of ingenuity, the community has demonstrated creativity by using local materials to craft tools that facilitate various tasks such as rope work, planting, drying, and packaging for storage. This resourcefulness exemplifies their proactive spirit and ability to innovate within the limitations of available resources, resulting in improved efficiency and effective management of their operations (see Figure 54, Appendix 1).

Although the government utilizes water monitoring tools to assess site suitability when introducing seaweed to new locations, these assessments are not carried out on a daily basis. Therefore, the regular use of advanced monitoring technologies is not currently a part of the community's routine practices (see Figure 65, Appendix 1). However, the existing approaches

demonstrate a community that is resourceful and adaptable, willing to embrace technologies and methods that suit their unique farming context and requirements.

5.3.3 Training and Extension Services:

Survey responses indicate that the training and extension services provided to seaweed farming communities have primarily been informal (see Figure 66, Appendix 1). However, these services have proven effective in imparting basic knowledge and essential skills related to seaweed farming activities, such as planting, harvesting, drying, and processing. Although there have been no specific formal training sessions on seaweed farming itself, the community has benefitted from practical, hands-on training, which has contributed to their operational proficiency.

Importantly, formal training has been conducted on financial management and cooperative formation, highlighting the community's recognition that economic and organizational skills are crucial to the success of their farming operations. This approach suggests that the community's training needs are multifaceted, encompassing both the technical aspects of seaweed cultivation and the economic principles that support sustainable agribusiness.

The community's access to extension support, particularly from the Provincial Fisheries Capacity, has been limited. This challenge has been attributed to the underfunding and understaffing of the Provincial Fisheries Department, compromising its ability to provide robust support and extend services to the farmers. As a result, the community's expectations for support align with the current state of these services, indicating an awareness of the systemic challenges faced by the extension system (see Figure 67, Appendix 1).

There is a clear recognition of the need to collaborate with regional organizations, such as the Secretariat of the Pacific Community (SPC), and donor funders to introduce higher levels of technical expertise. Such partnerships can facilitate more structured and accredited training programs in seaweed aquaculture, which the communities perceive to be lacking (see Figure 68, Appendix 1). Anticipated future training efforts aim to fill the current gaps and strengthen the community's technical capacity in seaweed farming.

5.3.4 Farm Management:

In terms of farm management, most farmers in Rambutso have low skill levels in organization and record-keeping (refer to Figure 69 in Appendix 1). This aligns with the education level and training preferences of the communities. However, these skills are crucial for the successful operation of cooperatives and the implementation of financial and bookkeeping strategies. Although many farmers do not keep detailed records, there are a few who diligently document their farming activities, especially those already involved in small businesses like trade stores. These farmers see seaweed farming as an additional business venture.

One perception within the community is that relying too much on external support can discourage farmers from taking initiative. To counter this, the community emphasizes the importance of being responsible and self-reliant in their farming operations, rather than attributing every challenge to government shortcomings.

When it comes to labour management, there is variability among respondents. The majority either work independently (52%) or verbally assign tasks (48%), as shown in Figure 70 in Appendix 1. However, when labour-intensive tasks arise, farmers seek assistance from youth or other community members and provide compensation for their work. In family-run farms, labour primarily comes from within the family, with clearly defined roles and tasks.

The training provided to the farmers has focused on basic aspects of seaweed cultivation, such as different bottom cultures, including "stake and line," "raft and anchorage systems," and more intensive "long-line pressure float systems" for larger-scale production. Responses received have indicated a mixture of perceptions. Around 28% of responders mention implementing sustainable farming practices, while 34% do nothing, and approximately 24% regularly evaluate and update their farming practices (see Figure 71, Appendix 1).

It is important to note that farmers have been instructed in improved harvesting methods to minimize labour, reduce stress on seaweeds, and prevent damage to infrastructure. Additionally, processing techniques have been taught to ensure better product quality.

There are plans to introduce more practical strategies for the farmers, including the use of technology for farm monitoring, resource optimization, biotechnological advances, processing innovations, selective breeding, and polyculture practices. However, it is crucial that these strategies are actually implemented on the ground. Currently, many farmers do not see the practical application of these strategies (see Figure 72, Appendix 1). Currently, farmers in the Rambutso seaweed farming community use a longline pressure float system. It may initially seem tedious but with time and exposure, they become proficient and integrate these practices into their farming operations. This approach aligns with a broader vision to enhance the community's abilities, promote sustainability, and increase productivity in seaweed farming.

The farm management approach in the Rambutso community has evolved over time. Initially, communal farms were collectively managed on 1-hectare areas. However, challenges like the free rider problem led to a shift towards individual family unit farms. Materials are now distributed to each family, allowing for personalized management and accountability. Some cluster groups still use the longline pressure float system for larger farms.

Currently, most farmers operate on a smaller scale with farms under 50m x 50m. These farms produce under 500kg of dried product per cycle. In contrast, larger farms of one hectare or more can yield over a ton per cycle, indicating a relationship between farm size and productivity. Quality control measures include harvesting crops after 45 days for proper maturation, improved quality, and pricing. Farmers are also taught handling, washing, sun drying, baling, and storage practices to prevent and treat common diseases like "ice-ice". However, the community does not participate in certification or third-party verification schemes.

Currently, there is no formal written plan or guideline for seaweed farming activities in Rambutso but plans to establish guidance are in progress. Ensuring seaweed quality through processing and storing methods is crucial. After harvesting, the community primarily uses sun drying with specially built dryers and follows proper storage measures to maintain quality. These practices align with existing methodologies and the community's training and resources (see Figure 75, Appendix 1).

5.3.5 Innovation and Adaptability

Innovation and adaptability are integral to the evolution and sustainability of seaweed farming practices, as evidenced by the farming community's learning curve in Rambutso. The introduction of improved farming strategies such as “pressure float long line systems” was an initial step towards increasing yields and optimizing productivity. However, the community's adoption of these strategies does not fully encompass the potential for innovation, as more advanced techniques involving technology, enhanced seaweed strains, and biosecurity measures are yet to be implemented. Farmers may have unrealized expectations for further training and improvements, which can be interpreted from their responses indicating a lack of adoption of novel strategies (see Figure 79, Appendix 1)

Adaptation to environmental changes poses another challenge, particularly in response to annual climatic shifts like king tides and inclement weather from November to February. While these events routinely cause farm destruction, there is a reliance on guidance for adjusting farming activities to circumvent these issues (see Figure 80, Appendix 1). Despite this dependency, the community has demonstrated a willingness to adjust, which allows for the introduction of farming rotation cycles to strategically evade adverse weather conditions.

Moreover, there is an eagerness within the community for diversification and improvement in aquaculture practices. Planned initiatives to integrate co-culture of seaweed with other marine species such as sea cucumbers, milkfish, and mud crabs indicate a readiness to embrace multifaceted aquaculture systems. This openness to new methodologies signals a positive attitude towards progress and a recognition of the benefits that such complementary projects could bring to the existing seaweed farming operations. The community’s response is a testament to their perception of aquaculture’s potential and desire for growth and innovation in their practices (See Figure 82, Appendix 1).

5.3.6 Strength, Weakness, Threats, and Opportunities for Seaweed farming in Rambutso

An analysis of the responses that have come out from the survey can reveal the strengths, weakness, threats, and opportunities in the seaweed farming value chain in Rambutso that can be used to plan and improve the practices or guide for future interventions:

Helpful

Harmful

Strenghts(internal)	Weakness (internal)
• Consistant supply of farming materials including assets and infrasture support by NFA • Greater community support and cooperation • Greater access to suitable sea areas in the communities for seaweed farming • Basic knowledge and undersding of farming processes and post-harvest handing • Buidling mommentum through cooperative support and arrangment • Reduced law and order and other social issues • Cleans water and attract fishes closure to shore	• Lack of proper training and education about seaweed farming and processing • Lack of interests due to price comparisions with other alternation • Misinformation about pricing • Trust issues in the community • Competeing priorities with other livelihoods • Limitation of farming scale strategy due to low of manpower concerns • Weak management skills and financial literacy
Opportunities(external)	**Threats(external)**
• Development of local cooperative to enter into bussiness and export • local employment opporunities for seaweed trainers to other islands • development of skilled work force in the community • attract investments and government support • Spin off business • Carbon sink	• Low volume to supply international market demand • Competing interest from people with ulterior motives • Bad weather destroying seaweed farms • Weak market regualtion and support • Lack of access to finance and credits • Lack of financial trainning support • Delay in payment for seaweed

SWOT

Table 7: SWOT analysis of the seaweed farming impacts in the villages of Rambutso Island, Papua New Guinea

6 DISCUSSIONS:

The development of seaweed farming on Rambutso Island in Manus Province, Papua New Guinea, has been shaped by the dynamic context of local fisheries and regulatory interventions. Seaweed farming was introduced as a response to the decline of the sea cucumber or bêche-de-mer fishery, which experienced continued moratorium commencing in 2007 (Cathy Hair a, o.fl., 2020). The moratorium, introduced by the PNG National Fisheries Authority, aimed to recover the depleted sea cucumber stocks but left coastal communities searching for alternative sources of income. Seaweed farming emerged as an economically promising activity, with its low startup costs, uncomplicated cultivation technology, rapid production cycle, and the processed product's extended shelf life (Fahmida Sultana et al, 2023).

Historically, the communities engaged in seaweed farming in PNG have demonstrated oscillating commitment to seaweed cultivation, largely influenced by regulatory changes affecting more traditional and lucrative fisheries. The introduction of a moratorium on sea cucumber trade had prompted many to pivot towards seaweed farming, only to abandon it once the moratorium was lifted, revealing a pattern of dependency on higher-return activities (Garcia-Gomez, 2018). This behaviour deeply impacted the seaweed export market, which relies on consistent, high volumes of production to remain economically viable. When faced with the option, communities have shown a preference for returning to the established sea cucumber fishery, highlighting the tension between the allure of immediate financial gains from traditional practices and the establishment of new, alternative livelihoods that may offer long-term sustainability but require steady investment and development (Kinch, 2024). As a result,

this past behaviour underscores the critical need for persistence in production to sustain seaweed export viability, as well as the inherent challenges in changing local economic behaviours towards new industries with different profit models and market dynamics (UNCTAD, 2024).

The introduction of seaweed as a new livelihood in isolated farming communities presented a multitude of challenges. Due to the novelty of this aquaculture practice, there was a steep learning curve for farmers, who needed to acquire efficient farming techniques to succeed. However, their limited initial understanding of these techniques was not adequately addressed by the fisheries departments, which themselves faced constraints in providing comprehensive support and training. Geographic isolation further complicated the situation, as it hindered access to both markets and farm sites, which is crucial for the success of such ventures. This isolation also posed logistical issues, increasing transportation costs, and potentially affecting the quality and market competitiveness of the seaweed product (Gómez, 2013). Overall, these factors collectively impeded the development of a robust and sustainable seaweed farming industry within these communities.

Within this context, the new Fisheries Strategic Plan for 2020-2030 launched by the National Fisheries Authority presents an optimistic future for aquaculture, including seaweed farming in Papua New Guinea. The plan underscores the role of aquaculture in contributing to food security, economic stability, and sustainable livelihoods (National Fisheries Authority, 2021). It is focused on providing technical support, financial initiatives, and capacity-building programs necessary for local communities to engage in and manage aquaculture ventures more effectively. By addressing the limitations previously faced, the FSP aims to elevate and expand the practices of seaweed farming, not only in established locations such as Rambutso but to other similar communities in other coastal areas throughout PNG as well who are farming seaweed.

The research into the development of seaweed farming within the community of Rambutso Island sought to capture the intricate perceptions of the sector and identify both barriers and catalysts affecting and success. It focused on understanding the full spectrum of factors from production inputs and outputs to support functions like training and transportation, as well as institutional and environmental barriers and the influence of personal agency. By dissecting these perceptions, the study aimed to craft strategic interventions that could mitigate the identified barriers and bolster factors contributing to success, ultimately increasing community participation, and establishing seaweed farming as a sustainable livelihood.

In-depth interviews with 101 seaweed farmers from ten villages on Rambutso Island, which holds considerable potential for commercial-scale farming due to its proximity to the provincial capital of Lorengau and its expansive suitable marine areas, were instrumental in this research. This group of farmers represented roughly 28% of the Rambutso´s total number of seaweed cultivators (n=347). The investigation revealed discernible trends and perceptions from these communities, identifying specific predictors of success that delineate whether a community might be apt or inept for seaweed farming. These insights are critical in understanding the current state and future trajectory of seaweed farming in Rambutso, guiding efforts to firmly establish it as a key component of the local economy.

Seaweed farming initiatives in PNG communities have experienced a range of outcomes dependent on the level of engagement and action taken by the local populations. In Manus, where growth trials were conducted across three island communities, seaweed showed promising growth in all sites. However, the success of farming varied with community involvement. At Rambutso's LiuLiu site, the community took an active role in maintaining and developing their seaweed farms, leading to its popularity and a thriving operation. Conversely, at the Ndrova and Mbuke community sites, despite similar efforts in awareness and training from the outset, the communities did not show the same degree of oversight, resulting in less favourable outcomes.

The proactive approach of the LiuLiu community in Rambutso demonstrated the importance of local responsibility and consistent maintenance in realizing the potential of seaweed farming. Understanding the significance of establishing a local seedling farm to provide propagules, they prioritized this endeavour, showing foresight in overcoming challenges related to costly and complicated air freight logistics from bringing in the required planting materials from outside of the province. Their dedication paid off, allowing them to not only sustain local farms but to also support expansion to nearby areas. By progressing from nursery stage to a commercial-scale farm within a year, the LiuLiu community set a positive example of how close community engagement and proper farm management are vital for the sustained success of aquacultural endeavours.

Seeing the positive outcome at LiuLiu, the National Fisheries Authority capitalized on this momentum by purchasing seedlings from the local farms for redistribution to other island communities interested in seaweed farming within Manus Province. LiuLiu's community enjoyed early financial benefits from the sale of seedlings, which also contributed to their aim of reaching a production target of 100 tons. To support the scaling efforts, the National Fisheries Authority provided necessary infrastructure and resources to enhance efficiency. However, challenges arose as the farming activities became more labour-intensive, revealing issues like limited manpower, trust deficiencies, the "free rider" problem, and competing local priorities. These issues threatened the initial momentum and collaborative spirit. To address these problems and maintain productivity, both the NFA and the community agreed to restructure the farming system, transitioning from communal management to smaller family units. Each unit would manage manageable farm sizes, reducing internal conflicts over labour contributions.

There were also concerns regarding transparency in the management of community funds generated from sales. The move to family-based units was meant to mitigate these trust issues and ensure more direct control over individual financial outcomes. Furthermore, the community recognized that they had the capacity to manage up to five hectares of commercial farms but not beyond, due to the limited manpower available. These experiences from the Rambutso community illustrate the complexities of seaweed farming development and underscore the significance of adaptability, community cohesion, and tailored strategies in overcoming challenges and achieving economic and sustainable goals in aquaculture.

The trust issue uncovered is a major setback, disrupting communal efforts and threatening the sustainability of community-based strategies. Many farmers choose to work within their families due to a lack of accountability within larger groups. This preference has posed challenges to the National Fisheries Authority when attempting to establish cooperatives in

Rambutso's farming villages. In response, the NFA has initiated village-specific interventions. Liu Liu village, for example, has seen concentrated efforts to build the infrastructure necessary to function as a cooperative hub, such as the provision of materials, community training, and the distribution of seedlings. While Liu Liu anticipates these developments, other villages show a need for greater awareness and more significant efforts regarding planned interventions.

Market access emerged as a primary concern, pivotal for committing to seaweed farming. It is important for government agencies to comprehend this and tailor their support programs accordingly. Moreover, there is an evident skill gap in organization and bookkeeping among farmers, highlighting the need for financial management and managerial trainings – essential for the effective management of cooperatives. Climate change poses another looming threat, as evidenced by the destructive high tides in January 2024, which impacted the seaweed farms significantly. Local farmers are adapting by adjusting their farming cycles to weather patterns and avoiding farming during known periods of adverse conditions to mitigate potential damages to their livelihoods.

The ongoing strategic development of cooperative frameworks within the seaweed farming communities at Rambutso is instrumental for securing high production levels and establishing best management practices for the future. Cooperation among farmers is essential for pooling resources, sharing knowledge, and collectively navigating market dynamics to enhance productivity and profitability. When farmers unite under cooperative models, they gain bargaining power with buyers, leverage economies of scale in purchasing inputs and selling outputs and mitigate risks through shared learning and innovation. Furthermore, the establishment of such cooperatives can play a crucial role in the empowerment of underrepresented groups, such as women and youths, by providing access to resources, training, and support networks that might otherwise be inaccessible. It enables community-wide involvement in decision-making processes, ensuring that initiatives are tailored to local needs and take advantage of indigenous expertise or support there are within.

For sustainable progression, cooperatives should promote best management practices that focus on environmental stewardship, resource sustainability, and socio-economic upliftment of the community. These include adopting technologies that mitigate environmental impact; developing pest management strategies; and engaging in responsible, regulated cultivation to prevent over-harvesting. Equally important is fostering strong alliances with research institutions, government bodies, and non-governmental organizations that can provide technical support, facilitate access to funding, and guide policy development. Through these collaborative partnerships, seaweed farmers can be equipped with the necessary entrepreneurial and technical skills to innovate, diversify, and remain resilient against challenges.

As the industry grows, maintaining an emphasis on quality standards, traceability, and certification can help garner recognition in global markets, differentiate products, and potentially secure premium prices for goods. By integrating within larger business networks, cooperatives can also enhance the value chain, from production to processing and marketing, creating a robust system capable of adapting to changing market demands and environmental conditions. Collectively, the strategic formation and empowerment of cooperatives within seaweed farming communities will lay a solid foundation for achieving sustainable seagriculture, economic growth, and enhanced community well-being in the long term.

7 CONCLUSION

This study examines the factors that contribute to the success of seaweed farming in the villages of Rambutso. The aim is to identify the key inputs and outputs that determine the viability of this sustainable livelihood. On the input side, important factors for successful seaweed cultivation include access to farm materials, high-quality seedstock, practical training, supportive infrastructure and assets, sufficient capital, and collaboration between the community and government. On the output side, several benefits are observed, including income from local and export sales of seaweed, seedstock transactions, skill development, employment opportunities, and economic gains from local hires and related businesses. Together, these elements have established seaweed farming as a growing and integrated livelihood on the island.

There is an urgent need for advanced certificate-level training in post-harvest handling, farm management, environmental safety, and financial and managerial capabilities, as identified by farmers. The primary economic challenge is a low market price and limited market access. This indicates the necessity for strategic intervention and better-informed local marketing campaigns. Social barriers, such as a lack of interest and various personal reasons tied to family decision-making, have also been identified as potential obstacles that may hinder progress. This highlights the need for further research to gain a better understanding of these social dynamics and strengthen current interventions.

The communities perceive the National Fisheries Authority to play a significant role in ensuring the continuation of positive outcomes. To enhance the industry's resilience, the study recommends formalizing and strengthening local cooperative groups. This will address identified economic and social barriers, promote wider participation, and ensure long-term success in Rambutso's seaweed farming ventures.

8 RECOMENDATION

From the various socio-economic factors discussed, which can indicate the likelihood of success in seaweed farming, a set of recommendations can be constructed. Any new site opening for seaweed farming must seek to identify and follow these recommendations, as well as for the strategic interventions in the ongoing development throughout Rambutso Island in Manus.

8.1 New site opening:

1. Community support and initiative: Along with the usual site scoping for various biophysical parameters, sea conditions and proximity to market and town centres, it was very important to take into consideration the level of support from a receiving community and assess whether they can play an active role in maintaining and developing their seaweed nursery farms leading to a thriving operation.

2. Production unit and farm strategy: Assess the preferred production unit in the community. Will it be based on community farms, family farms or cooperative farms? The experience from Rambutso has shown that larger sized groups have proved unmanageable due to trust deficiency issue, “free rider” and low manpower concerns. Farming at larger scale is beneficial for high production output however, it requires greater cooperation and collective efforts of everyone involved to ensure sustainability of the outcomes. Outside of that, the family unit strategies have shown to work despite the low productivity and slower outcomes which can be inconsistent with market demands.

3. Commitment and Consistent Collaboration: The dedication and collaborative efforts in a close working relationship to achieve a shared outcome or target from start and throughout the various stages of the project is paramount to the successful establishment of the livelihood in the communities. By progressing from nursery stage to a commercial-scale farm within a year, the LiuLiu community set a positive example of how close community engagement and proper farm management are vital for the sustained success of aquacultural endeavours.

8.2 Strategic initiatives for the ongoing seaweed development in Rambutso:

4. Development or Empowerment of Local Cooperative: To navigate away from the issue of trust, “free rider” and manpower concerns within a communal group, it is recommended that a new approach be undertaken to identify and work with a pre-existing cooperative group in the villages. Pre-existing cooperative group would have already established themselves with some kind of local governance structures and having access to resources and manpower. Strategic Interventions for this should focus on adding value to the existing operations of the group, if not empower them to do more and run the seaweed production chain as an added business on top of their pre-existing operations. This approach is important to ensure effective management and accountability as well as maintain high productivity required for the growth of the seaweed farming throughout Rambutso and Manus.

5. Financial training and management skills: there is an evident skill gap in organization and bookkeeping among farmers, highlighting the need for financial management and managerial trainings – essential for the effective management of cooperatives.

6. Cooperative buying in arrangements: One of the main barriers identified in Rambutso is for Market access strategies to assist farmers – Here we propose creation of a community-run cooperative that acts as the central buying entity for all seaweed produced by members of sub cooperative and cluster groups throughout Rambutso. This cooperative can leverage collective bargaining power to negotiate better prices and terms with processors and exporters. Through this approach, both the NFA and the established cooperative group should collaborate and tailor specific strategies in support of the development priorities identified as given below:

    a. Volume Aggregation: The cooperative should aggregate individual farmers' produce to meet bulk order requirements. By selling larger volumes, the

cooperative can access markets that require high quantities, potentially securing a higher price per unit.

b. Quality Control and Standardization: Implement stringent quality control measures to ensure that seaweed meets the required market standards. This can help the cooperative to command higher prices and build a strong reputation with buyers.

c. Diversification of Markets: Explore various market options such as milling into semi refine carrageenan for exports, local processing into value-added products, or sales to domestic retailers. By not being dependent on a single buyer, the cooperative can reduce risk and potentially increase profits.

d. Strengthening Supply Chain Management: Invest in logistics and infrastructure to ensure the efficient transport of seaweed from farms to the buying centre and subsequently to the end markets. This could include investment in drying platforms, storage facilities, and transport vehicles like boats and trucks.

e. Buyer Relationships: Establish long-term relationships with reliable buyers, including processors, exporters, and retailers. The cooperative can host buyer visits to the farming areas to strengthen trust and relationships.

f. Financial Support: The cooperative may provide financial support or facilitate access to loans and credit schemes for its members, allowing them to invest in their operations and meet larger orders.

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