12 Diverse Seaweed Farming Livelihoods in Two Indonesian Villages

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Abstract

The Indonesian marine seaweed industry has expanded dramatically over the past two decades and now supports the livelihoods of approximately 62,000 households. The production sector is dominated by smallholder seaweed farmers that operate in diverse agroclimatic and social landscapes. Understanding their production and marketing systems is fundamental to both industry development efforts and understanding associated livelihood impacts. This chapter provides an in-depth description of seaweed production, marketing, and livelihoods in two Indonesian villages, drawing on a household survey of 273 seaweed farmers and extensive qualitative research. It extends previous studies through a focus on heterogeneity in production and marketing systems derived from a rich set of quantitative and qualitative data. We show that there are substantial differences in seaweed livelihoods both between and within study locations, which is reflected in different forms of integration into broader seaweed value chains.

Keywords

Smallholder · Livelihood · Seaweed · Farming · Indonesia

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12.1 Introduction

The Indonesian seaweed industry has grown rapidly over the last two decades and is now estimated to support the livelihoods of approximately 62,000 coastal households (BPS 2022a, b, p. 47). Indonesian seaweed production is almost completely dominated by coastal smallholder farmers, who work around seasonal and tidal variations and typically employ limited capital but high labor inputs. Understanding household seaweed production is important for several reasons. First, the scale of the development issue in terms of the number of livelihoods it supports is significant. Second, unlike most other agricultural sectors, seaweed is almost completely dominated by smallholders, with only a few cases of corporate production. Thus, households supply virtually all the raw materials required for the functioning of the international industry and downstream actors. Third, the household sector is a central component in the pursuit of social and policy objectives, including employment, economic growth, social stability, and government tax receipts.

Seaweed farming brings a range of social and economic benefits to a large number of farmers in diverse ways (Aslan et al. 2015, 2018; de La Torre-Castro et al. 2017; Langford 2024; Larson et al. 2020; Mariño et al. 2019; Neish 2013, 2015; Nuryartono et al. 2021; Salayo et al. 2012; Suyo et al. 2020), although the economic benefits of seaweed

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livelihoods are variable (Rimmer et al. 2021; Langford et al. 2023b) and linked to broader relations in national industries and global value chains (Komarek et al. 2023; Permani et al. 2023; Zhang et al. 2023). Households in the sector range from those with small plots, limited capital, and marginal profits to very large, high performing, and well capitalized farmers who enjoy bargaining power in the sale of their products. The diversity of farmers must be accounted for in understanding and improving the livelihood aspects of seaweed farming and their incorporation into different seaweed value chains.

This chapter provides insights into seaweed growth, post-harvest handling, and marketing practices in two seaweed farming locations to explore the diverse livelihoods in these areas and the implications for their incorporation into the Indonesian seaweed value chain. It combines a detailed survey of 273 seaweed farming households in two villages with insights gained through 16 months of ethnographic observation and semistructured interviews by four of the authors of this study. This analysis reveals the diversity of farmers and farming practices in these locations with implications for policy and technology development targeting the Indonesian seaweed value chain.

12.2 Methods

12.2.1 Study Location

The study villages are in South Sulawesi, the largest seaweed-producing province in Indonesia, which produces approximately 20% of the global supply of carrageenan seaweed (Ministry of Marine Affairs and Fisheries, Republic of Indonesia 2019, p. 320–321; FAO 2023). South Sulawesi has recently been the site of a major foreign investment in seaweed processing capacity by the Chinese carrageenan producer Shanghai Brilliant Gum Company (BLG), and its capital, Makassar, is undergoing major new international port development to facilitate the direct export of products such as seaweed from Eastern Indonesia. As such, it is a province in transition to become an increasingly commercialized exporting region. Within South Sulawesi, the regency of Takalar is the largest seaweed producer and is also widely considered the most established, having a long history of seaweed production, intensive production, and established production methods. These features make Takalar an important site for understanding the development of the carrageenan seaweed industry. The regency of Pangkajene dan Kepulauan (Pangkep) is a relatively less established seaweed farming area. While Takalar lies to the south of Makassar, Pangkep lies a similar distance to the north and exhibits different agroclimatic conditions. Pangkep has a long history of export-oriented aquaculture but has only recently transitioned to seaweed farming. The province also includes many small islands off the coast, some of which are quite distant from the mainland. This location provides an interesting contrast to Takalar and insight into more recent and ongoing seaweed farming transitions (Fig. 12.1).

12.2.2 Methodology

This study combines mixed qualitative and quantitative research methods in two case study locations (Fig. 12.2). The field research team consisted of four of the authors of this article, who relocated to the study villages lived in the village undertaking participant observation for 16 months. Two of the researchers worked in the regency of Pangkep and two in Takalar in South Sulawesi. The first step was a study of the village characteristics in the two regencies of Takalar and Pangkep to assess the seaweed production characteristics of these areas and to select villages for detailed analysis. Second, a detailed quantitative survey was conducted on 273 seaweed farming households in two villages. Third, this information was supplemented and cross-verified with ethnographic data collected by four researchers living in the two villages over a period of 16 months. Fourth, detailed interviews were conducted with value chain actors (including farmers, local and regional traders, and government officials). The combination of these quantitative and qualitative methods allows for a detailed and rigorous analysis of patterns in seaweed production practices and differences between households and between villages. The qualitative data provide in-depth insights into the reasons for these patterns and the way that these characteristics are experienced and negotiated in practice. This provides an understanding of the social and economic factors affecting the management of seaweed farms in these two villages and the way that they translate into broader economic relations in the Indonesian seaweed industry.

12.2.3 Village Survey

To select the case study villages, mainland coastal villages in both provinces (17 villages in Pangkep and 15 villages in Takalar) were included in an initial survey of village characteristics. This involved visiting village offices, consulting with village leaders, consulting with local seaweed industry experts (facilitated by the existing connections of one of the authors of the study with long-term experience in the seaweed industry in this region), collecting data from local government, and reviewing satellite imagery of seaweed production in the region. Island villages were excluded due to practical limitations and because analysis of satellite

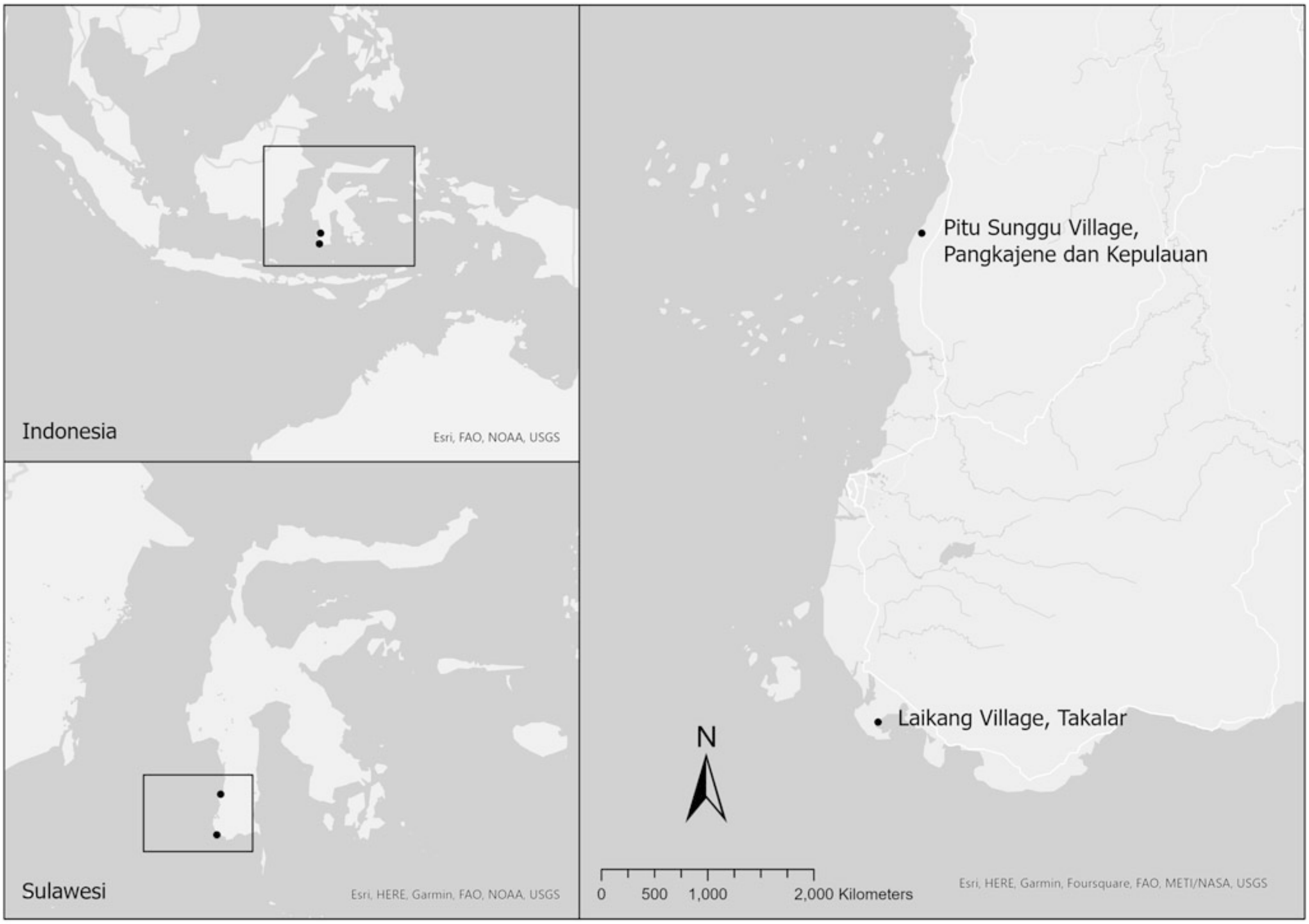

Fig. 12.1 Study site locations

imagery suggests that seaweed farming is concentrated around the mainland (Langford et al. 2021).

The villages were assessed based on criteria that fall into two categories. The first is the characteristics of the villages (the number of seaweed farming households, the proportion of households in the village that engage in seaweed production, the prevalence of other income sources, the number of fishing households, the volume of seaweed production, and the year that seaweed farming commenced). The second was the suitability of the village as a long-term study site and residence for the four researchers embedded in the villages (interest of the village leader and households in the study, the availability and willingness of local leaders to participate in the study, the condition of roads to facilitate regular travel

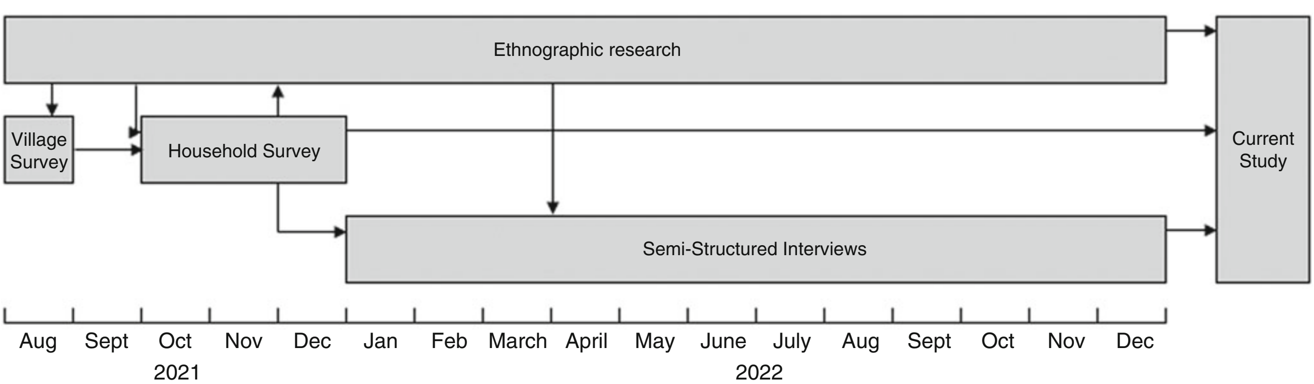

Fig. 12.2 Research methodology schematic

between the capital city and the village and Internet access to facilitate research work while living in the village, and the availability of a suitable residence with a seaweed farming family). Villages were assigned suitability scores from 1 to 5 for each parameter and were ranked relative to each other using these scores.

In Pangkep, of 17 mainland coastal villages, 11 were found to produce significant amounts of seaweed. The ranking exercise identified suitable villages as Pitu Sunggu, Pitue, and Tamangapa. Of these, Pitu Sunggu was selected for the following reasons. First, Pitu Sunggu is a relatively specialized aquacultural village. Unlike other villages in the area, Pitu Sunggu has limited agricultural land, and most households are involved in marine and/or inland pond aquaculture. Households in Pitu Sunggu generally live close to the coast and are highly reliant on marine activities for livelihoods with few alternative options. Second, local government information indicates that Pitue and Pitu Sunggu villages were early bases for the establishment of seaweed in the region, which has continued with higher levels of seaweed production than in surrounding villages. As a result, these villages are active seaweed cultivators, and a large proportion of local labor is employed in the industry. In addition, and importantly given the long-term nature of this study, local leaders and residents of Pitu Sunggu expressed enthusiasm for the study, and field researchers were offered a residence for the duration of the research.

In Takalar, 15 villages are located along the coastline; however, only 4 of these have significant seaweed production areas. The ranking exercise identified suitable villages of Laikang and Ujung Baji. Of these, Laikang was selected for a number of reasons. First, it is located in a large bay in which large areas of seaweed are intensively cultivated, alongside a range of other marine aquacultural activities. It is also an established seaweed production area where seaweed has been cultivated for several decades and farming techniques are well established. In addition, the local government responded favorably to the proposed study, and field researchers were offered a residence for the duration of the research.

12.2.4 Household Survey

During the village survey, basic data on Pitu Sunggu and Laikang were collected (Table 12.1) and used to design the survey of seaweed farming households. Lists of seaweed farmers in each village from 2018 were obtained, which listed 561 active seaweed farming households in Laikang and 136 in Pitu Sunggu. A survey sample of 30% of seaweed farming households was set for Laikang for a total of 181 households. The smaller number of overall seaweed farmers in Pitu Sunggu required a higher proportion of farmers to be surveyed. Households were selected by approaching every third household on the provided lists in Laikang and every household in Pitu Sunggu. In Laikang, if the target household was not available, the household directly below it on the list was approached as a replacement. This led to a total of 281 responses across the two villages. Of these, 8 indicated that they no longer farmed seaweed, for a total sample of 273 seaweed farming households, representing 31.6% of Laikang seaweed farmers and 73.5% of Pitu Sunggu farmers. At a confidence level of 90% and a response distribution of 50%, the margin of error in Laikang is estimated at 5.12% in Laikang and 4.53% in Pitu Sunggu, both of which are regarded as acceptable (Raosoft calculator, http://www.raosoft.com/samplesize.html).

Members of the village government in both locations shown in Table 12.1 indicated that they suspected that these figures were likely to be lower than current numbers, as increasing numbers of people have returned to the villages to undertake seaweed farming in recent years. In addition, farmer numbers are difficult to calculate precisely because farmers are listed based on their participation in farmer groups (which newer farmers may not be part of), and there is no clear differentiation between different categories of sea users at all levels of government data collection.

The results from the household survey were organized into descriptive statistics split by location. Most survey questions used discrete multiple choice and Likert scale questions, but provision was made for other "other" options and open text response. For questions with large numbers of "other" responses, these responses were organized into groups of additional responses and added to the data. This enabled us to record any unexpected options that in several cases yielded important insights. The survey was designed in the program Alchemer (https://www.alchemer.com/) and administered by four of the authors of the study. Data were organized and analyzed using Microsoft Excel.

Table 12.1 Sample numbers in Laikang and Pitu Sunggu

	Laikang	Pitu Sunggu
Total number of seaweed farming households (2018 data)	561	136
Number of seaweed farming households interviewed	177	96
Proportion of seaweed farming households interviewed	31.6%	73.5%

12.2.5 Participant Observation

The field research team undertook participant observation for 16 months. Two researchers were located in Pitu Sunggu village and two in Laikang. The field research team is gender balanced to provide male and female perspectives and support gender sensitivity in interviewing. The field researchers undertook ethnographic observation, prepared field notes documenting their observations, undertook interviews, and discussed their observations with members of the wider research group. These qualitative observations are used to interpret the results of the household survey.

12.2.6 Semistructured Interviews

Semistructured interviews were conducted from January to December 2022 with value chain participants such as farmers and traders. These interviews involve open-ended questions on a series of topics. They were undertaken in either Indonesian, Buginese, or Makassar language, according to participant preference, and were transcribed in Indonesian (Buginese and Makassar language interviews were translated and transcribed simultaneously). Repeat interviews were undertaken where necessary. A total of 171 interviews were undertaken with an average duration of 40 min. Respondents who were uncomfortable with the recorded format were instead invited to discuss topics informally, and notes taken during these informal interviews were presented in fieldnotes.

12.3 Results

12.3.1 Seaweed Aquaculture in Two Indonesian Villages

Respondents in both villages were similar in age and gender, with 60% of respondents between the ages of 34 and 54. Approximately 22% were older than this, and 18% were younger, indicating lower participation in the industry in these demographic brackets. Notably, just 1% of respondents were aged 18–24, indicating low participation of youth in the industry. Survey participants were 90% male, as researchers asked for a household representative of the household's choice to complete the survey, and most households offered men to complete the survey, often with assistance from other household members. Women were deliberately included in ethnographic research and semistructured interviewing to ensure incorporation of their views.

The most common species of seaweed grown were *Kappaphycus alvarezii* (known colloquially as "cottoni") and *Kappaphycus striatus* ("sacol"), with the majority of farmers in both villages growing both species. Cottoni was grown by 85% of Laikang farmers and 100% of Pitu Sunggu farmers. Sacol was grown by 93% of Laikang farmers and 81% of Pitu Sunggu farmers. In Laikang, a notable group of farmers (40%) also grew *Eucheuma denticulatum* ("spinosum"). No farmers in Pitu Sunggu reported growing spinosum. Our respondents indicated that the differences in the choice of seaweed depend on local oceanic conditions (temperature and salinity levels), rainfall patterns, price incentives, and other productive factors, such as growing season lengths and ease of propagule attachments to ropes. Along the western coast of South Sulawesi, it is common to grow cottoni in the wet season and sacol in the dry season. Both types of carrageenan seaweeds are used to produce the kappa-type of carrageenan, have the same price, and are often mixed by local traders. Spinosum, on the other hand, produces the iota-carrageenan type and cannot be mixed with these species. It is a significantly lower value species of seaweed. In Laikang, 2% of households also produce *Caulerpa* ("sea grapes"). This type of seaweed is grown in coastal ponds rather than on ropes in the sea and is sold primarily fresh into domestic markets where it is eaten raw. This is a much smaller commodity that enters different value chains, is not a eucheumatoid seaweed, and is not the focus of this study. Across the two villages, 83% of seaweed farmers indicated that seaweed was their main source of income, and most of these indicated that it accounted for more than half of their total household income. The findings suggest that seaweed farming is a major contributor to household income, and most seaweed farming households are relatively specialized in that activity.

However, the two villages differ in important ways. In Laikang, seaweed farming has a long history. Most farmers (65%) have been cultivating seaweed for over two decades, with very few (7%) commencing seaweed farming less than a decade ago. In contrast, in Pitu Sunggu, only 6% of farmers have cultivated seaweed for more than two decades, and nearly half (48%) commenced less than a decade ago. In addition, the locations are also geographically and environmentally different, which influences the choice of farming activities. Figure 12.3 shows the main production activities of households before and after commencing seaweed farming.

In Pitu Sunggu, seaweed farmers are highly specialized in marine fishing (including a range of species of fish and crab) and pond aquaculture. A very low proportion produce a staple food such as corn or rice. In this village, widespread conversion of rice paddies to brackish water aquaculture was undertaken from approximately 1980 to 2000 to capitalize on the high price of tiger prawns at the time. This industry lasted only a few years before it collapsed as a result of white spot syndrome virus and ceased completely in the region. Vannamei shrimp (*Litopenaeus vannamei*) were released by the government to farmers in 2001 and distributed around the

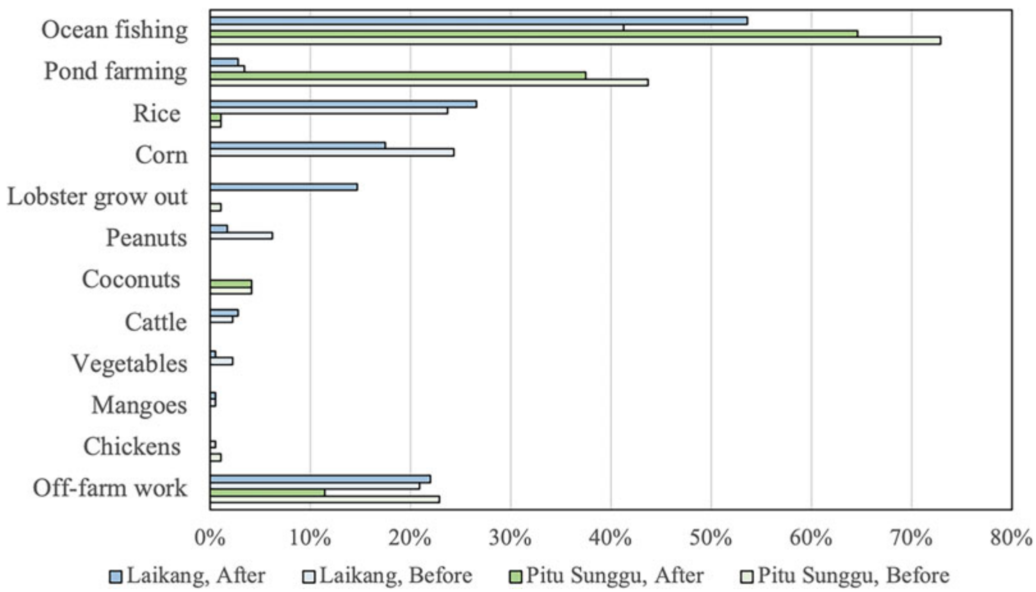

Fig. 12.3 Other major household activities before and after commencing seaweed farming

country, and it is this variety of shrimp that now dominates ponds in Pitu Sunggu, which with a few inland exceptions did not return to rice farming.

Prior to commencing seaweed farming, approximately 23% of seaweed farmers reported that they had earned a significant proportion of their household income from off-farm work, but this has now decreased by more than half. Many older village residents commented on this, noting that during the rice farming era in Pitu Sunggu, many people struggled to survive on the agricultural activities available in the village. With a distinct dry season and a lack of irrigation, only one rice crop was planted per year, which limited food and income and induced farmers to seek off-farm work-off farms in other seasons. As a result, Pitu Sunggu farmers pursued an agricultural development pathway based on specialization in marine capture and marine and brackish water aquaculture. Today, just 1% of seaweed farmers consider the production of a staple food such as rice to be a major household activity.

The mix of agricultural activities differs considerably in Laikang. Very few participate in land-based pond farming. Their land-based activities focus on food production, where 31% of seaweed farmers also grow a staple food such as corn or rice. Just over half also engage in ocean fishing for both food and sale. Another significant activity is the growth out of lobsters, which involves purchasing juvenile lobsters from nearby cities and growing them out in marine cages. Of the seaweed farmers interviewed, 15% reported participation in this activity, which appears to be a significant increase over recent years. Lobster grow-out is a lucrative activity but has higher capital costs than seaweed farmers, so it is being taken up by higher-income, entrepreneurial farmers or those who receive support from the government. Like Pitu Sunggu, it appears that many rice farmers in Laikang had also struggled to make a decent living from a single annual rice crop and sought to fill the gap through off-farm work. The production of commercial coastal products appears to have enabled farmers to pursue year-round, on-farm livelihood strategies.

The scale of production is an important indicator in the analysis of production and livelihood aspects of seaweed systems. The average scales of production were similar in the two villages (1.63 tonnes per household year in Laikang and 1.66 tonnes in Pitu Sunggu). There were, however, major differences in range. Laikang has an overall lower median level of production but several very large outlying producers (Fig. 12.4). This suggests the presence of highly entrepreneurial farmers who have managed to claim large areas of sea space for production.

The ability to farm seaweed is closely linked to ownership of a boat and engine, as well as rights to use marine space. Government aid in the form of boats, boat engines, and mariculture apparatus is common in both villages and indeed is a contentious topic of discussion in the villages. Some farmers appear to be regular recipients of aid, while others feel that they have missed out. In addition, in Pitu Sunggu, several farmers had dropped out of seaweed farming after their boat or engine broke, and they lacked the capital to replace it and hoped that the government would provide aid to enable them to return to seaweed farming.

Most farmers in both locations (91% overall) indicated that they plan to expand seaweed production in the next 5 years. The most commonly cited reason was good prices

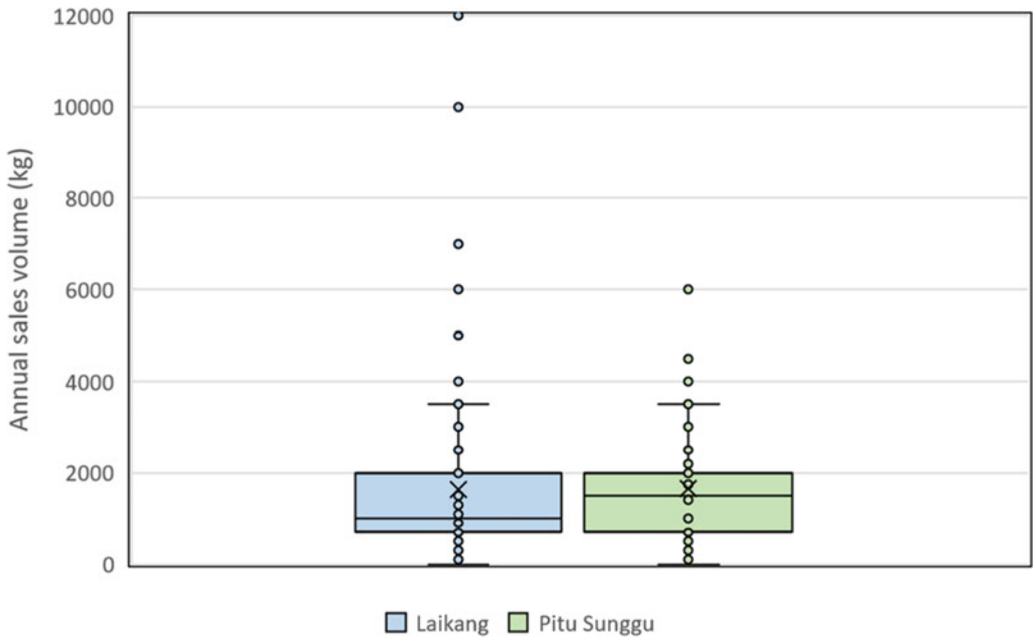

Fig. 12.4 Seaweed sales quantity over the last year

of seaweed at the time of survey in late 2021 (70%), followed by the potential to earn higher incomes from increased production (25%). However, in both locations, rising prices from June 2021 to August 2022 drove extensification of farming areas and led to shortages of sea space that enforced hard limits to expansion. Favorable seaweed cultivation areas were widely considered "full" in both villages by mid 2022. As one farmer put it, "the sea looks wide and empty, but actually, it is already full of other people's land stakes." Farmer understandings of marine tenure are based on local histories of seaweed farming establishment and, in many cases, are marked by conflict between seaweed farmers and other ocean users, such as fishermen and lobster growers. In both villages, sea space was traditionally a public good and could be used by anyone. However, with the introduction of seaweed farming, farmers needed to claim exclusive rights to areas and prevent those areas from being used for other activities, such as boat travel or crab fishing. A small number of farmers began claiming portions of the sea for seaweed farms and installing permanent anchors to mark and maintain their sites. This often occurred alongside conflict with other sea users, but over time, the conflict dissipated, and the right of individuals to claim parts of the sea in this way began to be acknowledged.

Today, the rights of seaweed farming plot owners to exclusively use the sea are widely acknowledged by convention within the village. Seaweed farming plots are defined by anchors installed by farmers, and local governance systems of different degrees of formality protect an informal form of property rights over these areas. The right to use an area may be sold or leased to another farmer, but in both villages, residents do not consider it possible to "own" the sea. Rather, they conceptualize these rights as being based on capital investment in setting up the anchors needed to farm seaweed in any given location. As one farmer put it, "the sea does not belong to us, but we have the right to use it to stay alive." These histories of negotiation over rights to use the sea have led to a situation in which the current "owners" of seaweed farming plots are mostly those who claimed parts of the sea early in the establishment of the seaweed farming industry when seaweed prices were much lower. These sea use rights become much more valuable when seaweed prices are high.

The general features presented in this section indicate that both villages have long (>2 decades) histories of reliance on commercial aquaculture but different patterns of engagement in different industries. Laikang has a longer history of marine seaweed farming and more large, specialized farmers, while Pitu Sunggu has lower participation in land-based crops, instead being more specialized in pond farming of fish and shrimp. The next section examines differences in seaweed production methods in these two villages.

12.3.2 Production Methods

12.3.2.1 Longline Systems

All farmers in both villages use the longline production method, which is suitable for deeper waters (Fig. 12.5).

Fig. 12.5 A longline seaweed farm in Pitu Sunggu with insert: individual seaweed longlines

This method involves tying seaweed cuttings to ropes (typically 25 m in length in Pitu Sunggu and 40 m in length in Laikang). These ropes are hung in the ocean at approximately 1 m spacing and are floated to the surface most often using plastic bottles. The ropes are attached to permanent anchors on the ocean floor.

A seaweed farming cycle goes through planting, growth, and harvest stages. During the planting stage, small seaweed cuttings are attached to the ropes using smaller ties. Plastic bottles are also attached to the ropes at regular intervals, and these ropes are then placed in the ocean and attached to permanent anchors on the ocean floor, which define the permanent location of individual farming plots. During the growth cycle, seaweed is left in the ocean for a period of time that varies by location, season, farmer, and species. We received reports of growing times as short as 20 days (for spinosum) and up to 60 days (for cottoni and sacol). Seaweed is typically harvested younger if it is to be used for seeding a new crop, while it may be left longer if it is to be dried or if required by the ocean conditions.

During the growth period, the seaweed might be cleaned of epiphytic algae if it is formed by ocean conditions, and farmers may add additional floats to the seaweed lines to maintain buoyancy as seaweed grows and becomes heavier. After this time, the seaweed is harvested by bringing in the longlines with the seaweed and bottles still attached. The seaweed is removed from the longlines by running the line between two pieces of wood to break off the seaweed. Depending on the quality of the seaweed and the purchase of the seaweed, a portion of the seaweed may be recovered and used to seed the next farming cycle. The remaining portion is sun-dried and sold to local traders.

12.3.2.2 Seasonality

In the two case study villages, farmers reported similar seasonal patterns, although with some notable differences. Laikang farmers reported lower participation in seaweed production in the middle of the year (Fig. 12.6), which may reflect a more distinct seasonality of many of the Laikang plots and/or socioeconomic factors, such as the availability of marine space and of other income-generation activities. Farmers also work different lengths of time during different seasons. In Pitu Sunggu, farmers report working an average of 7.4 h per day and 6.2 days per week in the high season, compared to 4.3 h per day 4 days per week in the low season. In Laikang, farmers report working on average 7.9 h per day and 5.5 days per week in the high season, compared to 3.8 h per day and 2.6 days per week in the low season.

It is notable that farmers do not all agree on seasonal patterns. Even within a single village, farmers cultivate seaweed in defined areas of the ocean that exhibit a wide range of growing conditions. Although February was widely considered the best month for seaweed farming, some farmers report it as the worst month, and others do not farm at all. The difference depends on the species cultivated (sacol or cottonii) and the conditions in the specific plots farmed by different farmers, as even plots in close proximity to each

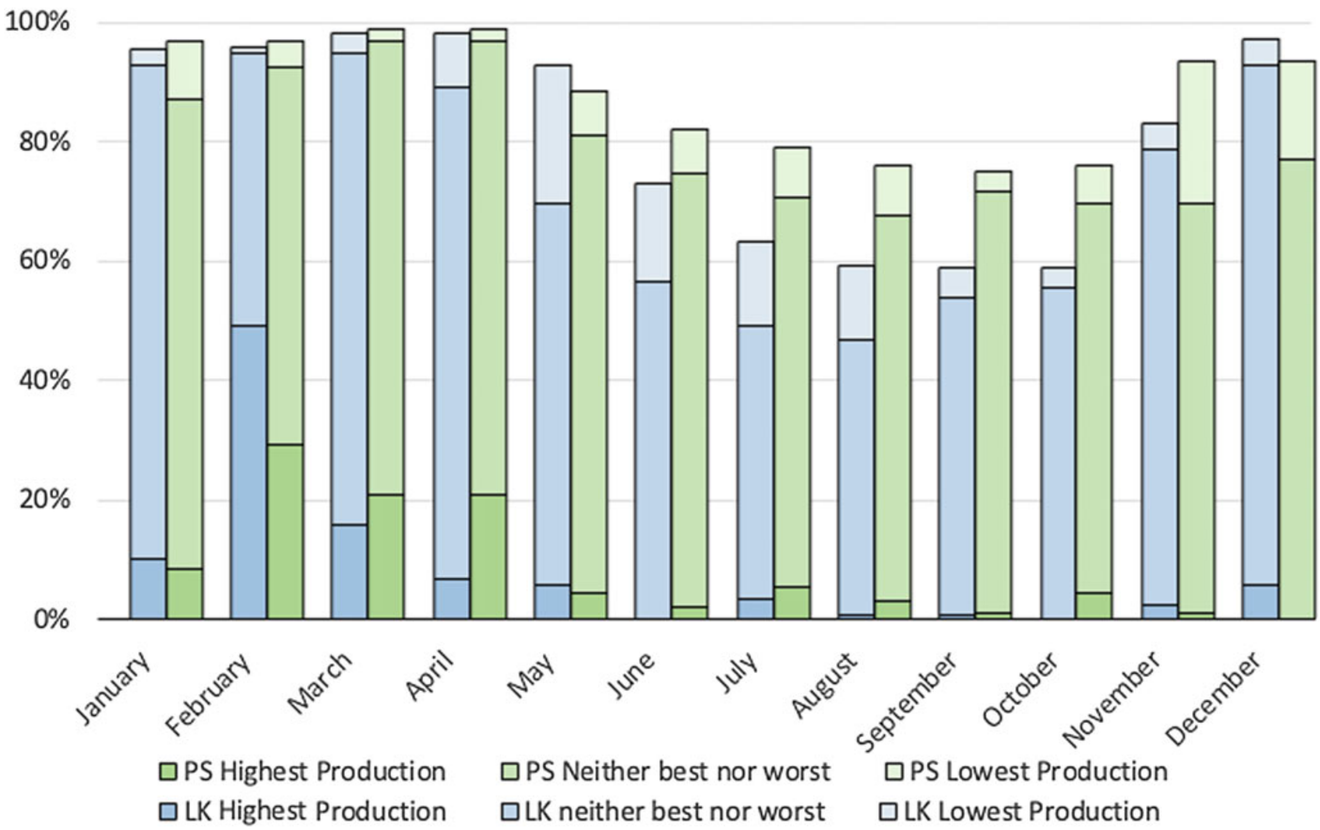

Fig. 12.6 Seasonality of production in Pitu Sunggu (PS) and Laikang (LK)

other can exhibit conditions suitable for the growth of different types of seaweed at different times in the year.

A large range of factors contribute to these differences in seaweed growth throughout the year, including rainfall and river water runoff (which produce small-scale differentials in ocean salinity and turbidity), light, temperature, nutrient levels, and pH (Azanza and Ask 2017). Human activities also affect oceanic conditions. For example, in Laikang, lobsters are fed fish in semicontained ocean nets, releasing organic matter into the surrounding area and contributing to high levels of epiphytic algae growth on nearby seaweed. As seaweed farms are in fixed locations, farmers have little control over these environmental and human activities affecting seaweed growth in their plots. Thus, the seasonality of seaweed farming varies by location, both between and within villages. This has a direct effect on seaweed characteristics such as growth rate and color, and the effect can be pronounced even over small areas. Seaweed is highly morphologically plastic, and seaweed grown in different areas with different oceanic conditions can have vastly different appearances (Simatupang et al. 2021), including different colors, stem thicknesses, and degrees of branching. Variation in seasonal conditions can be managed by cultivating different seaweed species at different times of the year. It is common for farmers in these locations to primarily cultivate cottonii in the wet season and transition to sacol in the dry season to allow year-round cultivation.

12.3.2.3 Propagation

The semiannual transition between seaweed species creates a need for the distribution of new seaweed propagules (often colloquially referred to as "seeds" and known as "bibit" in Indonesia) at the start of each planting season. These seeds are often sourced from different districts where ocean conditions are different. After the first planting cycle, propagules are more likely to be supplied by other farmers. These are typically grown in the ocean for less time than the regular planting cycle before they are harvested, divided, and used to seed new longlines. After farmers have produced sufficient seeds to fill their seaweed farming plots, they will grow seaweed for sale. After harvest, seaweed suitable for propagation will be selected to seed the next planting cycle,

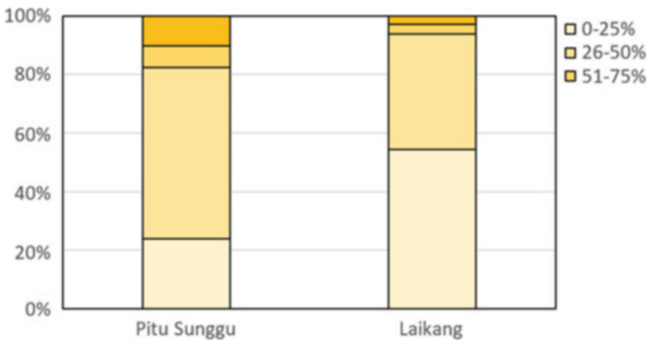

Fig. 12.7 Propagule frequency of purchase

while the remainder is dried for sale. In both villages, most farmers purchased less than half of the cuttings that they used. Overall, Laikang farmers used their own cuttings more often than Pitu Sunggu farmers (Fig. 12.7). The alternative is to use carry over from own production as seeds.

There is a government program run by the Brackishwater Aquaculture Development Centre in Takalar, which aims to produce improved seaweed propagules using tissue culture. The program is operational and distributes seeds to farmer groups around South Sulawesi; however, farmers in our study sites did not report receiving seeds from this channel. Tissue-cultured propagules are expensive to produce using current laboratory-scale methods but are reported to grow more quickly than mature propagules sourced from farmers. Lower-cost seed production could be achieved using spores; however, this method requires further research and development to become operational in South Sulawesi. Further research into intravillage propagule distribution patterns, growth rates, and selection practices could support more sustainable propagule value chains.

12.3.2.4 Floats

All farmers use disposable plastic water bottles to keep their seaweed lines afloat. Occasional use of Styrofoam was also common across both locations, used by 33% of farmers, as was the use of Jerry Cans, used by 31% of farmers. These larger floats are typically used only at the edges of farms to hold the ropes connected to the anchors, while plastic bottles are used at regular intervals along the ropes to keep the lines afloat. Buoys were used by just 7% of farmers, and those that used them indicated that they were used on less than 25% of their ropes. These floats are typically used only on the edges of the plots where longlines are attached to the anchors. Farmers were asked to indicate why they chose not to use permanent floats. The most common response given by 53% of farmers was that they are too expensive. Other common responses were that no one sells them, they easily break away and are lost, are heavy and difficult to use, and are likely to be stolen.

The use of smaller, permanent floats in place of plastic bottles was not observed in any cases. When asked about this option, farmers said that plastic bottles are not only cheaper but also better in many ways than permanent floats. Their main benefit is that they are small and light. This is important because seaweed is not removed from the ropes at sea; rather, the rope with floats and seaweed still attached is brought to shore, where the seaweed is removed and separated into cuttings and seaweed for sale. The ropes are then cleaned, and new seaweed cuttings are attached to them before they are returned to the sea. This needs to happen in a single day, as the seaweed is highly perishable, and if left too long out of the sea, it will not grow again. In addition, single-use plastic bottles are light and sway with ocean currents, which farmers report reduces the stress on seaweed cutting and makes them less likely to contribute to breakages than permanent floats.

Farmers use these plastic bottles in innovative ways. One important benefit of plastic bottles is that they can be filled partially or completely with water to reduce their buoyancy, allowing them to sink their seaweed lines if they wish to. This is an important feature after heavy rains when rivers flow into the sea. As fresh water is lighter than salt water, high rainfall leads to a layer of fresh water on the ocean surface that can destroy seaweed. Some farmers therefore travel to their seaweed farms and sink their seaweed lines after periods of heavy rain in an attempt to minimize the impact of freshwater on their crops.

However, the use of single-use plastic bottles poses risks to marine ecosystems. Approximately 83% of farmers reported that they last two seaweed farming cycles or less (approximately 6–13 weeks) before they need to be replaced due to breakage. These plastic bottles degrade in sensitive coastal marine ecosystems, which also serve as habitats for edible market fish. There may be opportunities for the development of alternatives; however, any technology aiming to replace single-use plastic bottles would need to be designed with careful consideration of the way that these bottles are used. Their prevalence reflects not only a lack of alternatives but also their suitability as a result of being light, low-cost, easily transportable, and containing a buoyancy adjustment mechanism.

12.3.2.5 Labor

Households reported similar patterns of involvement in different activities across both villages (Fig. 12.8). With regard to gender roles, in both villages, male household heads tended to perform the physically demanding ocean-based roles of maintaining, installing, and harvesting seaweed lines and to be involved in drying, bagging, and selling the seaweed. Female household heads reported working mainly on tying seaweed to lines, drying, bagging, and selling the seaweed in both villages. A notable difference between the villages was that men in Pitu Sunggu were more likely to be

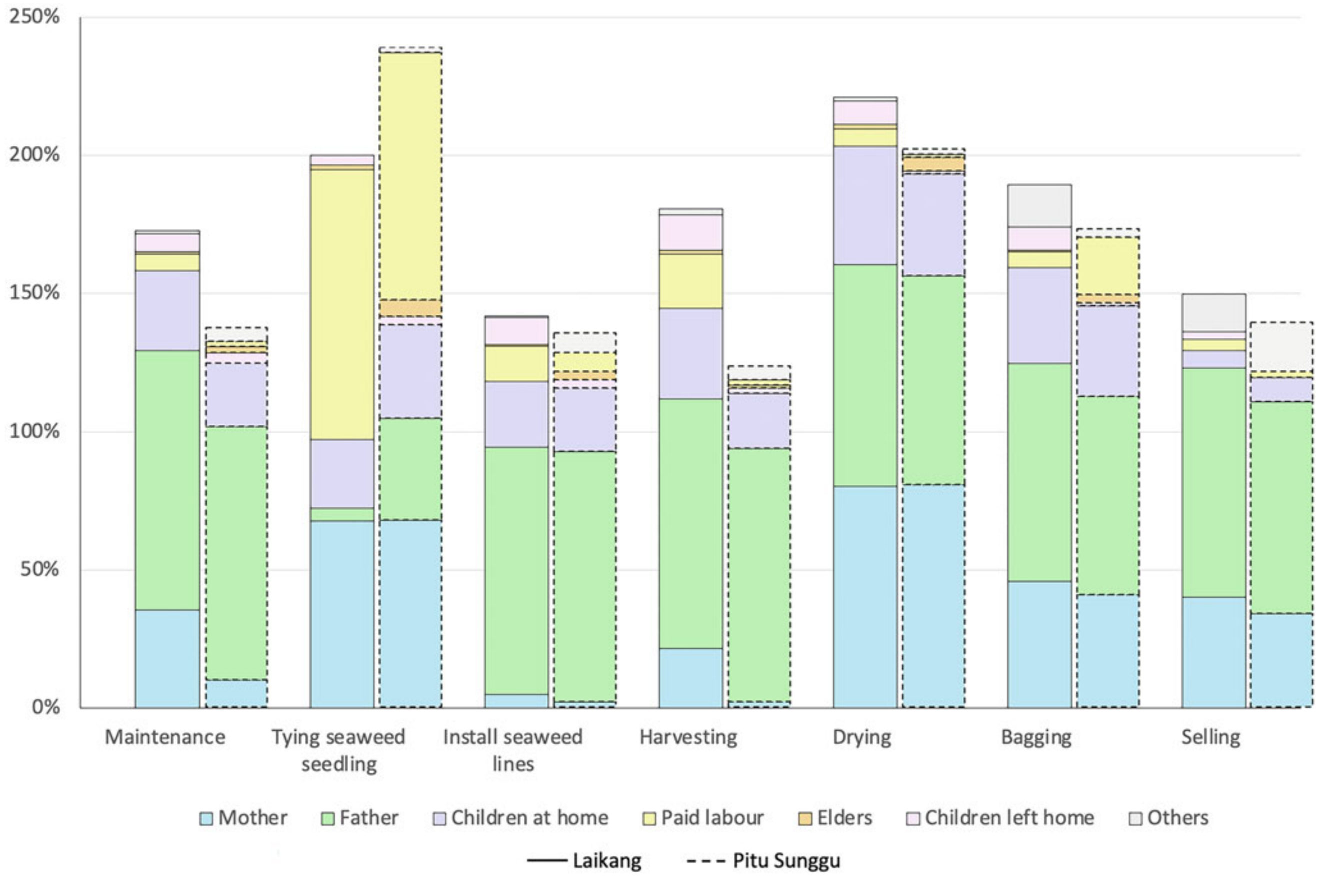

Fig. 12.8 The involvement of different family members in common seaweed jobs. Note that the y-axis shows the proportion of household members in each category reporting participation in these jobs and that these are stacked and therefore exceed 100%

involved in tying seaweed to lines (39% of male household heads did this work, compared to just 5% in Laikang). Women in Laikang were more likely to be involved in seaweed line maintenance and harvesting (36% of female household heads participated in seaweed maintenance and 21% in seaweed harvesting, compared to just 10% and 2%, respectively, in Pitu Sunggu). In both villages, respondents did not appear to consider gender roles to be rigid; rather, there were tendencies toward involvement in different types of work. Binding is a job that can be done while caring for young children, so it was more frequently done by women, while working on the ocean or in the ponds tended to be done by men.

The tying of seaweed cuttings to ropes is a particularly labor-intensive task, and the use of paid labor for this work is common. When an area of seaweed farm is harvested, the rope with the seaweed still attached is brought to shore, where the seaweed is removed from the lines, and some is selected for replanting if suitable. This seaweed is cut into smaller pieces and then tied back onto the longlines using small ropes. This seaweed binding work is very time-consuming—one binder can typically tie seaweed to one longline of approximately 25 m in approximately 1 hour. A group of five people working for 6 h could therefore be expected to complete just 30 longlines. Since farmers need the work completed in a single day so that the seaweed can be returned to the sea before it perishes, they often require the assistance of a team of five or so seaweed binders to complete the work within a day. This means that binders are often hired from outside the household and work in groups, which reportedly also makes the work more enjoyable.

In busy periods, it is common for binders to work long hours, virtually every day of the week, rotating between tying different farmers' crops. At the start of 2022, high rainfall led to crop losses of seaweed, and as a result, many farmers had to harvest and replant their seaweed, which increased the demand for binding labor. During periods of very high demand for labor and high seaweed prices, binders may negotiate higher prices. Some binders report that these prices are maintained even after demand has dropped. However, access to labor is dependent not only on price but also on relationships. Many farmers use their family relationships to

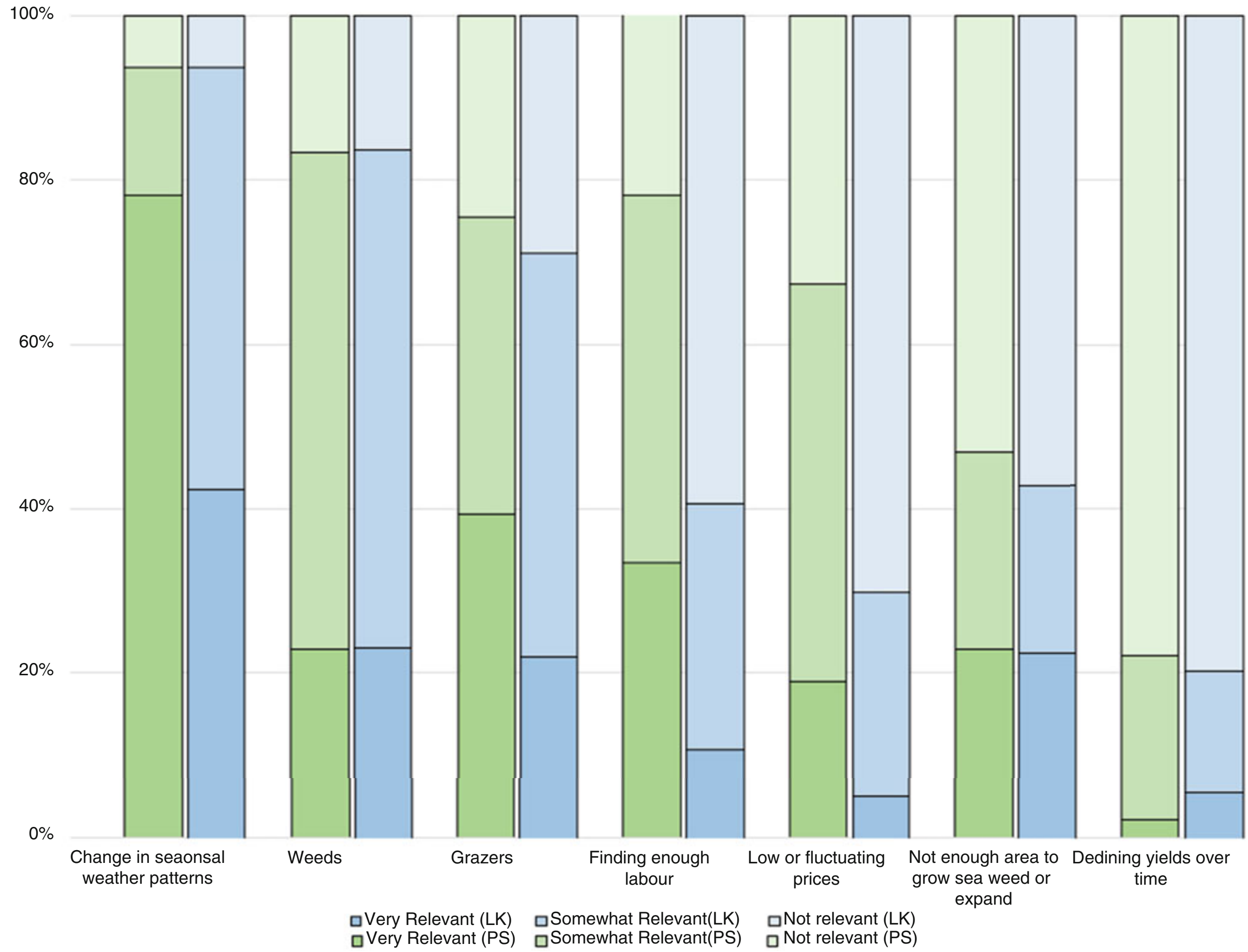

Fig. 12.9 Major production challenges faced by farmers

secure access to binding labor when needed. Some farmers book a group of binders for a few days or weeks during busy periods to ensure their availability.

Seaweed binding is therefore a common and important job in and close to seaweed farming communities, and binders tend to specialize in this work. Many of them do not have other sources of income. As one worker described, "This is my only job, nothing else. If I don't do this, I eat nothing." Binding work provides income to some members of the village who may not otherwise have work, including widows, disabled persons, and people who do not have capital or land. It can also be undertaken by women while they are caring for young children. The work requires no capital or special skill sets. However, it requires binders to sit in the same position for long hours, and binders commonly report mild to severe skin irritation from the work, which some avoid by wearing gloves.

12.3.2.6 Production Risks and Geographic Diversification

Farmers report a range of problems in seaweed production, including highly seasonal and variable weather patterns, weeds, grazers such as fish, binding labor shortages, low and fluctuating prices, a lack of sea space, and declining yields over time (Fig. 12.9). Of these, the most significant production problem reported by farmers is managing around weather patterns, primarily rainfall. During periods of very high rainfall, environmental stress causes seaweed to turn white and die. Known as an "ice-ice" syndrome, it appears to be caused by environmental stressors such as salinity changes, temperature, or sedimentation of the water (Ward et al. 2021).

At the start of 2022, farmers experienced several very high rainfall events that led to extensive seaweed losses. In Pitu Sunggu, after 3 days of rain, one farmer reported that he had visited his seaweed site where he had deployed approximately 600 longlines just a week before to find the stems white and rotting on half of these lines. The farmer's wife estimated the value of the loss at 10 million rupiah ($1000) and noted that they had still not paid the binders who had worked on the ropes. One very large seaweed farmer with 1200 seaweed ropes that were 1 month old reported losing approximately 50 million rupiah ($5000). In Pitu Sunggu, one farmer reported two losses in January. He had been forced to harvest the seaweed after only 10 days because it had been ruined by the fresh water. In the earlier freshwater event, he had lost 200 ropes that he had planned to use as seeds in the following cycle.

Farmers manage this risk in a variety of ways. One is by responding to events to protect the seaweed by bringing the seaweed in quickly after a rain. As one farmer described, "If the seaweed has been hit by a flood, it must be brought in the same day. If left too late, the farmer will have only the rope, without its contents." This means that after a large rainfall event, farmers are very busy going back and forth to the sea, as they need to quickly retrieve hundreds of stretches of seaweed rope. They work from morning to night at this job. Another strategy to reduce losses from high rainfall is to sink the seaweed below the freshwater layer on the top of the ocean by filling the plastic floats with water. This can be a useful approach in some cases, but if submerged for too long, the seaweed will become covered in barnacles and other shellfish that are difficult to remove.

Another common risk reduction strategy used in both villages is for farmers with multiple plots to geographically diversify their plots. By farming seaweed in a range of different locations, which are likely to be differently affected by weather patterns such as high or low rainfall or temperature, farmers manage their exposure to environmental risks.

12.3.2.7 Technology Uptake

Of the 273 farmers surveyed in the two villages, 118 reported implementing at least one new management technology in the last 5 years. The technologies considered most effective were the use of different species in different seasons (18% of all farmers) and the use of the "double rope" technique (reported by 25% of farmers). Notable technologies perceived to be ineffective were the use of bamboo rafts/cages for seaweed cultivation (reported by 4% of farmers). Follow-up interviews indicate that farmers found this technique much more expensive than the longline method, and some farmers indicated that they felt the cages hinder the growth of the seaweed by restricting the flow of ocean currents around it.

Most farmers reported getting information about seaweed production techniques and innovations from traders (88% of Pitu Sunggu farmers and 72% of Laikang farmers) or other farmers (49% of Pitu Sunggu farmers and 73% of Laikang farmers). Just five farmers reported that government extension services were a key channel of information, although it may be the case that a significant amount of information reported as coming from other farmers may have originally derived and spread from extension workshops. Internet groups such as the Facebook group "Rumput Laut Centre" provide a public space for sharing information on prices, propagule purchases, and seaweed sales, as well as to discuss important issues. Although only 3% of farmers report using the Internet to access information, it is likely that Internet-based information has been spread through word of mouth through personal contact with a wider cohort of farmers. One farmer described the importance of this word of mouth to technology uptake: "the farmer learns by eye. Even though they could listen all day to explanations about the potential of . . . [a new production technique or technology], if they hadn't seen other farmers earning a lot, they wouldn't have done it. Except those who have money and are willing to bet."

12.3.3 Marketing

12.3.3.1 Postharvest Handing

The first step in the postharvest handling of seaweed is drying. Households dry seaweed after harvest using a range of methods and to varying degrees. This is a critical postharvest activity, as wet seaweed is highly perishable and difficult to handle (Ali et al. 2017). As traders and processors for traditional processes (carrageenan production) are only interested in purchasing dry seaweed, the purchase (by weight) of seaweed with high moisture content imposes costs in yield, handling, and transport. Traders are often required to redry seaweed to lower moisture contents at various stages. As a result, traders attempt to estimate the moisture content of the seaweed—along with other nonseaweed content such as salt, sand, and soil—and adjust offer prices accordingly.

Moisture content is assessed visually by eye using techniques such as squeezing the seaweed, breaking it open to see if the stem is dry the whole way through, or observing the extent of salt crystallization on the dried product. For example, one trader reported extensive salt crystallization in their experience, indicating moisture contents close to 35%, while a glossy surface and an absence of salt crystallization indicated moisture contents of 40–45%. Traders spend the majority of their time working with dried seaweed and thus become quite attuned to subtle differences in appearances that indicate different moisture contents. This is important because there are substantial risks associated with purchasing seaweed with a high moisture content, as this product will shrink and effectively reduce in volume. Managing moisture contents and prices is therefore a core aspect of risk management in the supply chain (Mulyati and Geldermann 2017; Langford et al. 2023a). Traders often manage the risk associated with uncertainty in the quality and consistency of the products they buy by offering discounted prices for high moisture content seaweed; however, offering higher prices for seaweed exceeding moisture standards is not common. Farmers have a price incentive to use adequate postharvest handling methods to avoid receiving a discounted price but not to exceed quality requirements.

Farmers dry their seaweed in a variety of locations. The drying apparatus favored by most farmers is para-para or bamboo platforms. The platforms allow water to drip off through the spaces in the bamboo floor while the seaweed dries in the sun. A total of 66% of farmers reported that they dried their seaweed at least partially on a platform. Other options for seaweed drying are on the pier or roadside (in Pitu Sunggu) or on nets near the beach (in Laikang). Laikang farmers appear to make greater use of drying platforms and benefit from a long sandy coastline over which a large number of drying platforms are built. This coastal space allows farmers to dry seaweed directly after bringing it in from the sea. In contrast, in Pitu Sunggu, the coastline is a mangrove environment, and there are few drying platforms constructed along the shore. As a result, most drying is confined to a small space on the pier or is moved inland between houses and brackish water ponds. In both locations, it is common for farmers to dry their seaweed on drying platforms for only 2 days before transferring it to the ground to finish the drying process, making space for new seaweed on the platform. Drying on the ground can also be quicker due to higher thermal conductivity. It does, however, increase the incidence of sand or soil contamination.

During the wet season, rainfall is frequent, and almost all farmers (99%) protect their seaweed from fresh water by covering it with a tarp. Failure to do so will reduce the seaweed quality and in extreme cases result in loss of the crop. In Laikang, 30% of farmers reported losing a crop in the last 5 years, and this had happened on average three times. In Pitu Sunggu, these rates were almost double, with 62% of farmers reporting a loss, and this happening on average 2.9 times. These rates are relatively low, indicating that the system for drying seaweed works adequately. However, this drying system produces products of varying quality as measured by salt and dirt content. Alternative drying methods producing cleaner, drier seaweed are available and known to farmers (Stone et al. 2023), especially the hang-drying process where lines with seaweed still attached are hung directly for several days until the seaweed is dry. However, farmers did not view this method favorably for three reasons. First, they did not want their seaweed to be too dry, as they felt they would not receive a higher price per kilogram for dryer seaweed. In this case, the incentives are to sell seaweed with a moderate moisture level to maximize weight and overall revenues per harvest. Second, farmers report that hang drying requires longlines to be in use for drying for several days, preventing them from using them for the next cycle and thereby creating redundancies in their equipment. This was a major downfall of the method, as ropes were considered to be a considerable capital expenditure. Third, farmers report that hang drying is time-consuming since the dried seaweed is reportedly more difficult to remove from the rope than wet seaweed, and plastic bottles often must also be tied and untied. It is possible that these difficulties are a result of suboptimal use of the hang-drying method; however, they are nonetheless key reasons for the persistence of other methods of drying. Farmers are also aware of other drying technologies, such as various types of solar and electric ovens, but consider these prohibitively expensive and time-consuming. As a result, they had little interest in alternative drying technologies and considered the combination of bamboo drying platforms followed by ground drying to be ideal.

12.3.3.2 Product Attributes

When asked about perceptions on how product attributes such as moisture and sand or dirt content affected the prices, farmers in Pitu Sunggu were more likely to respond that these factors did not affect their price at all (34% for dirt and 27% for moisture). Less than 7% considered the impact to be significant (Fig. 12.10). In Laikang, however, 23% thought the impact was significant, and just 4% thought that moisture content would not affect their price. These perceptions of price incentives translate into different postharvest handling methods, both between villages and individuals. As a more established and much larger producing region, there are more traders in Laikang that buy more seaweed. There are also larger and more capitalized farmers that can be expected to have better postharvest infrastructure and practices and more incentive to take up price-grade differentials if offered by traders. In Pitu Sunggu, there is a similar diversity in drying practices; however, there are a larger number of farmers who have limited access to drying space. This may mean that Laikang traders have greater scope to offer price-grade differentials.

Other product attributes are also seen to affect the price of seaweed paid by local traders. Of the farmers in Pitu Sunggu and Laikang, 43% and 45%, respectively, responded that quality indicators such as color and age (indicated by thallus thickness and degree of branching) affected the price of seaweed. Of these, 10% of farmers in Laikang and 2% in Pitu Sunggu indicated that these quality attributes would affect the price significantly. An important determinant of the "quality" of seaweed (defined as carrageenan content) is the length of the growing cycle. A longer cycle of 45 days or more would be expected to have higher carrageenan content than a 30-day cycle. However, traders may not be able to accurately measure this content or reward the sellers through prices. Other physical attributes of the seaweed are somewhat out of the control of the farmers, as they are formed by prevailing oceanic conditions. In practice, traders conduct only a general assessment of seaweed quality, do not or

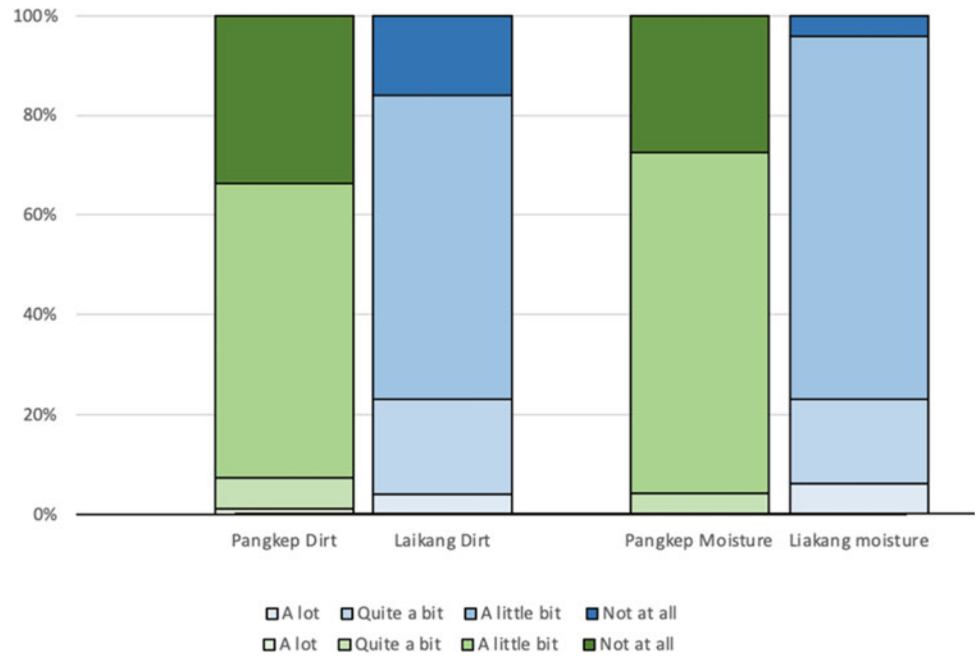

Fig. 12.10 Farmer perceptions of the effect of product attributes on prices

cannot assess other characteristics (such as carrageenan content, viscosity, and gel strength) through a highly differentiated grading system, and with high demand for seaweed, as is currently the case, are only likely to reject very unsuitable seaweed.

These findings support the conclusion of a price analysis (Langford et al. 2022), which found that while the Indonesian seaweed market shows a high level of spatial integration, it shows low levels of transmission of price-grade differentials between farmers and traders. Given the intrinsic difficulties of developing a marketing system to enable accurate pricing, the main form of "quality control" used by traders is to source seaweed from regions known for having good oceanic conditions. Outside of these areas, price incentives for improved postharvest handling appear to be limited.

12.3.3.3 Farmer–Trader Relations

After farmers produce and prepare seaweed, they sell it to a hierarchy of traders, from local to regional levels. The vast majority of farmers sell to a local trader located within their village or subvillage. Most farmers sell to just one trader—74% of Pitu Sunggu farmers and 51% of Laikang farmers. In Pitu Sunggu, the farmers that sell to more than one trader sell to 2–4 different traders, while Laikang farmers reported selling to up to 15 different traders. This may partially reflect differences in the operation of seaweed trading markets in these two villages, with a greater number of traders operating in Laikang and a much larger catchment area for traders. There are a number of small traders in Laikang who then sell to larger traders within the same village. Farmers select the traders they sell to on several criteria. Trust was an important feature in both villages (43% of Pitu Sunggu farmers and 50% of Laikang farmers) and was linked to the fact that the trader lived locally and was known to them. However, farmers reported that the most important factor in their choice of trader was existing credit relations, which drove trader choice for 88% of Pitu Sunggu farmers and 50% of Laikang farmers.

Seaweed farmers require access to credit for a number of reasons. Most commonly, they require credit to buy seeds at the start of the planting season. They may also need to replace ropes or repair drying platforms or boats. The vast majority of seaweed farmers report taking out loans (88% of Pitu Sunggu farmers and 72% of Laikang farmers). In both locations, a loan from a trader obliges a farmer to sell to that trader while they have outstanding debt. However, lending norms vary between villages. While neither location formally charges interest or has fixed maturity dates, in Laikang, farmers with outstanding debt are paid prices reduced by 1000–3000 Rp/kg (approximately 3–9%), whereas in Pitu Sunggu, farmers with debt are paid the same prices as those without debt. This price reduction does not reduce the loan principle but rather is a fee taken in lieu of interest. It has led to substantially lower satisfaction with traders in Laikang than in Pitu Sunggu. In Pitu Sunggu, traders therefore appear to be more interested in capturing supply, whereas in Laikang, traders appear to be more likely to seek to earn additional profits from the provision of financial services.

There are three established traders operating in Pitu Sunggu, and these traders report a sense of loyalty to each other, in that they refuse to buy seaweed from farmers who they know have an outstanding debt to another farmer—as one trader put it, they "don't interfere with each other." During the 2021-22 period of price increases, three new traders commenced operation in Pitu Sunggu, and was viewed unfavorably by existing traders, as the new traders offer farmers higher prices and capture product. One established trader noted that although anyone is free to trade seaweed, new traders have a moral obligation to avoid buying from farmers who have outstanding debts. One emerging trader (who appears to buy very small quantities of seaweed) described the difficulty he faced accessing seaweed supply as a result, noting that he needed to approach new farmers carefully to avoid creating problems. Farmers report being apprehensive about selling to new traders in case it compromised their relationship with their current trader. Pitu Sunggu therefore has a history of close one-to-one relationships between farmers and traders, although new entrants to trading are seeking to disrupt this.

In Laikang, almost half of seaweed farmers sell to multiple different traders, and many sell to a large number of traders. The system of trader credit provision is different and more formalized in Laikang, where prices paid to indebted farmers are typically reduced by a substantial amount (~1000 Rp/kg). Some Laikang farmers seek to avoid the more formalized and costly nature of the arrangement by accessing bank loans (bank loans had been used by 34% of Laikang farmers and 21% of Pitu Sunggu farmers). One Laikang farmer described how they began by borrowing money from a trader for inputs but became frustrated quickly with the system and now seek to save money from previous cycles to use as capital to start a new cycle—as they put it, “better to use my own money rather than rent from others, [then we are] free to sell our seaweed to anyone with the better price.” Another farmer reported that rather than borrowing from traders, he would access credit from a pawnshop, using gold jewelry as capital. He preferred this system, as he did not pay interest on the loan and was free to sell to any trader and thereby access better prices.

These different farmer-trader relations—along with the larger size of Laikang village—lead to very different market configurations. In Laikang, 66% of farmers said that price was a key factor affecting their selling decision. The proportion was only 11% in Pitu Sunggu, possibly reflecting obligations to traders. In Laikang, a few large farmers report that they are able to negotiate prices with traders because they have a strong reputation for producing high-quality seaweed. In addition, farmers may be able to negotiate higher prices if they do not have debt and/or are able to sell a large quantity of seaweed in one transaction, and some farmers try to accumulate large quantities before selling to improve their bargaining power. However, for the majority of (smaller) farmers, prices are dictated by traders, and their seaweed trader is preselected by existing credit relations. They maintain autonomy over the timing of sales and are able to store seaweed and wait for higher prices; however, they are typically not in a position to negotiate price.

12.4 Discussion and Conclusion

As this description of seaweed livelihoods shows, seaweed farmers are diverse. Their activities differ between locations, where ocean conditions, capital constraints, and the availability of other on- and off-farm work affect the way they farm seaweed. They are also extremely diverse within villages, including very small farmers, moderately sized farmers, and very large farmers, with different extents of specialization. Farmer extension work, policy recommendations, and technological interventions need to be cognizant of this heterogeneity and consider innovative ways to support seaweed farmer livelihoods that are locally appropriate and easily adopted. Four key findings emerge from this study.

First, seaweed farming villages vary in the diversification of their livelihood activities and, as a result, have different exposures to the risk of changes in the industry. The two villages described here have similar production methods but differ in important ways. In Laikang, seaweed farming has been established for more than two decades, and during this time, some farmers have developed very large, well-organized farming operations. In contrast, in Pitu Sunggu, seaweed farming has mostly commenced within the last 15 years, and although there are some larger farmers, they are not as large as those in Laikang. In Pitu Sunggu, there is a very strong reliance on incomes earned from commercial aquaculture of seaweed and of shrimp and fish in land-based ponds, with little crop production. Laikang, on the other hand, has significant production of food crops such as rice and corn and has a more diversified marine aquaculture sector that also includes lobster grow-out and *Caulerpa* production. In Laikang, seaweed is therefore part of a more diverse array of livelihood activities, while in Pitu Sunggu, farmers are more specialized. Despite the differences, most seaweed farmers in both locations reported that seaweed accounted for the majority of their household income. The diversity of livelihoods therefore differs between the two villages, although in both cases, seaweed farming households tend to be relatively specialized. This is important because it means that different villages have different risk exposures to changes in the seaweed industry, which need to be recognized when considering policy responses to industry changes such as price volatility.

Second, seaweed farmers are highly exposed to risks associated with weather patterns and other changes to oceanic conditions. In both villages, farmers report that they face considerable challenges managing weather-related risk and variability. Ninety-four percent of farmers in both villages reported that managing weather is a somewhat or very relevant challenge, with 78% of Pitu Sunggu farmers and 42% of Laikang farmers reporting it as “very relevant.” This makes weather patterns the most frequently reported issue reported by farmers, and as described above, farmers typically go to great lengths to manage the risks of rainfall or changes in ocean conditions. They have developed innovative ways to manage risk, such as by geographically diversifying their seaweed farming plots. They also respond to severe weather events quickly, either by bringing their seaweed in from the ocean and replanting it or by adjusting the buoyancy of their floats to sink the seaweed below the freshwater layer on the surface. Despite this, managing often unpredictable and shifting ocean conditions remains a significant challenge to farmers. Ocean conditions such as turbidity and organic matter concentration can vary greatly even across small areas. Farmers are highly exposed to changes in oceanic conditions that are often out of their control, and as a result, many of the quality attributes of the seaweed they produce are predetermined by the location of their farming plots. This makes it difficult to consistently supply higher value seaweed into value chains where specific quality attributes are demanded.

The third key point relates to the distribution of economic benefits of seaweed farming within a village. Since areas of marine space suitable for seaweed farming in both locations are widely considered to be "full," seaweed farmers with existing rights in the sea are able to benefit from rising seaweed prices, while those without are not. Other users of the sea who have not transitioned into seaweed farming, such as fishermen and crab fishermen, are negatively affected by seaweed farming since the individualization of rights to sea space effectively reduces the remaining public area in which they are allowed to fish and catch crabs. It is worth noting, however, that these effects are not clear-cut, since many fishermen are, or have at one time been, seaweed farmers. In addition, most of the current seaweed farmers were previously fishermen, and many still are. There is therefore substantial overlap in these livelihoods, and different individuals have been differently affected by the changes brought by the development of seaweed farming in coastal villages. They have been able to take advantage of the opportunities brought by seaweed farming to different extents. The extent to which seaweed farming brings economic benefits to nonseaweed farmers is not well studied (but see Langford 2024) – seaweed farmers are only a moderately sized group within a coastal village and are a small minority within a regency, and as such, although seaweed brings high incomes to these farmers, these incomes are not widely distributed at a regional scale. There is some distribution of seaweed industry income within seaweed farming villages and, in some cases, further inland, as seaweed farmers employ teams of laborers to tie seaweed propagules to ropes. The distribution of seaweed income outside of seaweed farming households was not specifically addressed in this study but is an important area for future research. The seaweed industry is widely promoted for its poverty-reducing potential; understanding the way that incomes are distributed is important for understanding the extent and limits of these benefits.

Finally, this study reveals important insights into seaweed marketing chains. Seaweed farmers sell their product into global value chains through layers of local and regional traders. We have elsewhere reported that seaweed prices do not appear to be correlated with product attributes such as moisture and dirt content (Langford et al. 2022). This survey confirms this macrolevel analysis in these two villages, where a majority of farmers reported that they did not think that the moisture and dirt content of their seaweed would significantly affect the price. This was much more common in Pitu Sunggu, where 27% of farmers did not think that a high moisture content would affect the price they received at all. Relatedly, farmers report that price was not a major factor in their choice of buyer, which is determined more by existing debt relations with particular traders. This effect was much greater in Pitu Sunggu, where 89% of farmers reported that price is not a key factor affecting their decision of where to sell their seaweed, compared to 34% in Laikang. Access to credit is therefore a major factor affecting the way that seaweed is marketed in these villages. As financial technology platforms and other microloan facilities expand in emerging markets globally, it will be interesting to see whether access to this type of credit changes the way that these seaweed marketing chains operate, and there may be a role for government extension programs or policy to support the entrance of such platforms into these areas—noting of course that the terms offered by these loans also vary in their favorability to farmers.

These four key observations highlight the need for efforts to upgrade seaweed value chains to take into account farmer diversity both within and between villages. Seaweed farmers are a diverse group, including large, innovating, and entrepreneurial farmers with access to capital who are able to expand their growing region, invest in capital improvements such as drying platforms, and negotiate good prices for their seaweed. It also includes a large number of small farmers who face considerable risks and are incorporated into seaweed value chains through relations of indebtedness that reduce the price received for their product. The seaweed value chain also has the input of large amounts of labor from nonseaweed farming households, which are essential to the harvesting and replanting process. This diverse range of farmers operating in locations with different oceanic conditions produce seaweed of vastly different product attributes and quality indicators, and these products are incorporated into value-adding processes in different ways. Efforts to improve seaweed production and quality and the livelihoods of coastal communities need to be aware of this diversity to design policy and extension programs that benefit seaweed farming communities as a whole.

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