Sustainable seaweed farming and its contribution to livelihoods in Eastern Indonesia

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Abstract. Seaweed farming has been used as a tool for livelihood strategy of coastal communities in Eastern Indonesia. This study aimed to analyse the characteristics of seaweed farming activity, analyse the constraints and opportunities of seaweed farming, and analyze the marketing channel of seaweed farming. This study were used structured and semi-structured questionnaires as qualitative approach, and interviews were conducted with 294 in total respondents in South Sulawesi and West Nusa Tenggara Provinces. The data were analyzed used descriptive statistics, supply chain analysis, and SWOT. The finding shows that seaweed farming plays as a primary source of household support in small-scale level (2-4 plots in each). Some constraints hinder the development of this activity, such as disease, post-harvest difficulties, farm ownership, shifts in the monsoon season, marketing constraints, quality of seaweed seeds, farm ownership, and imperfections in post-harvest methods. The supply chain of seaweed with has provided benefits (price margin: IDR 1000/kg), such as speedily supplying investment and daily operational funds, without interest through the efforts of middlemen with an exclusive relationship. As a conclusion, traditional seaweed farming method can be as key driven for sustainable seaweed farming and livelihoods for local coastal community.

1. Introduction

Seaweed farming in Indonesia has contributed to changes in the socio-economics structure coastal communities. The various factors including the availability of socio, technology and public polichave contribute to seaweed industry. Seaweed farming is also a sustainable form of aquaculture that has particularly benefited women and has contributed to government-sponsored poverty alleviation programs [1], beneficial effect on ecology and climate change, and seaweed farming is crucial to the implementation of a system of sustainable ecosystem management [2].

The development of a viable seaweed industry can support the national program for job creation, reducing unemployment and contributing to national economic growth. Fishermen usually borrow money from the family, relatives, friends and even brokers (middlemen) in the village. The patron-client relationship within seaweed farming scheme is often referred to as middlemen – seaweed farmer system. In this study, patron can be defined the person who provides the capital and lending to fishermen/seaweed farmers plant seaweed, and called middlemen. Meanwhile, client is a person/fisher planting the seaweed, and called seaweed farmer.

The main issue in developing seaweed farming is associated with supply of seeds is highly depending on seasons. Seed supply problems caused big fluctuation of K. alvarezi production in Lombok in the last six years. As consequence, the production has decreased significantly due to seed supply problem. Based on experiences of Purnomo et al. [7] and Zamroni and Yamao [8], there were

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several problems in post-harvest process still exist in both places (Gerupuk and Serewe). These problems are including; 1) Lack of financial capacity for investing in drying and processing equipment and facilities such as “para-para”. 2) Poor awareness of quality control. 3) Lack of freshwater and power or electricity. 4) Poor information of markets and prices. Many of those involved were originally corn processors (making tortilla-style crackers) and have increasingly utilized seaweed extracts as the seaweed farming industry has expanded in Lombok.

Community involvement in livelihood activities in Eastern Indonesia particularly some coastal areas of South Sulawesi and West Nusa Tenggara, Indonesia provides an overview as to how important economic improvement is in the framework of community development in the local setting. Therefore, this study proposed to analyse the characteristics of fishermen and method in seaweed farming activity, identify the constraints and opportunities of seaweed farming development in sustaining livelihood activity, and analyze the marketing channel of seaweed farming in sustaining local seaweed cultivation activities in small scale fishery community.

2. Material and methods
2.1. Duration and study area
The study were conducted during 2010 in South Sulawesi and during 2015 in West Nusa Tenggara Province. In case of South Sulawesi, the study sites were located in Laikang Village, Takalar District, South Sulawesi Province, Indonesia. Laikang Village is one of the 12 villages of Mangarabombang Sub-District, which is an area of 19.6 km² or about 19.57% of Mangarabombang Sub-District area. The population is approximately 4,139, with a population density of about 211 people/km². Most of the people work in fisheries, and some work in the agricultural sector. Laikang Village is rich in natural resources like fisheries, agriculture and tourism sectors which contribute to the economic development of the village.

Takalar District and Jeneponto District are located on the south side of South Sulawesi Province. It is about 42 km south of Makassar City. Interviews and data collection were conducted in Laikang Village, in Mangarabombang Sub-district in Takalar District, 16 km from the central district and 63 km from Makassar City. Jeneponto District consists of 9 sub-districts and 105 villages. Similar to other coastal areas, it has two dominant fishing activities namely capture fisheries and aquaculture including seaweed farming.

![Figure 1. Research locations in South Sulawesi and West Nusa Tenggara](image-url)
produces as much as 657,757 tonnes, thus there is 54.46% of seaweed potential area remaining untapped in West Nusa Tenggara. Mariculture area in Central Lombok Tengah is around 2,620 hectare, which located in several sub districts namely Praya Timur, Praya Barat, Praya Barat Daya and Pujut. These locations are utilized for seaweed farming, pearl farming, sea cucumbar farming and fish farming. Total area of mariculture in Pujut Sub District, Praya Barat Sub District and Praya Timur Sub District are 163.3 Ha, and 6.57% utilized for seaweed farming. The number of aquaculture facilities are 7,542 units with an area of 5,224,340 million m², aquaculture using longline, stakes and rafts system. Ownership of areas measure between 2,500 m² - 17,500 m², with an average size of 5000 to 10,000 m². Seaweed mariculture in the Pemongkong Village is located in sub-village (Dusun) Ujung. Seaweed mariculture in Batu Nampar is located in Batu Nampar Sub Village. Seaweed mariculture in Sekaroh Village is located in Sub Village of Ujung and Ketangga. Seaweed mariculture in Serewe Village is located in Semerang Sub Village, Kaliantan and Serewe.

2.2. Data collection
The investigation involved surveys, direct observations and interviews. Total number of respondents were 294, which separated into 200 respondents in Takalar and Jeneponto while East Lombok and Central Lombok were 94 in total respondents selected by the appropriate sampling method with data obtained through direct interview and focus group discussion. A structured questionnaire was prepared and used for direct interview, while semi structured questionnaires were used as guides in the focus group discussion. The structured questionnaire covered socio-economic information of seaweed farmers. Fishermen have various livelihood activities consist of fishing, seaweed farming, combination of these two activities or combination with a non-fishing activity.

2.3. Data analysis
Main respondents were seaweed farmers, while key informants were selected purposively including middlemen, staff or researchers from government offices, research centers, universities, local government officers, community leaders (tokoh masyarakat), heads of the villages (Kepala Desa), religious leaders, who understand well the social and economic conditions of the village. Secondary data were obtained mainly from statistical data and scientific journals. Descriptive analysis focused on socio economic conditions of respondents and the research areas, small-scale entrepreneurs and market characteristics, which includes input suppliers, producers, processors and buyers; and opportunities-threats matrix.

3. Result and discussion
3.1. Describe the characteristics of seaweed farming activity
The finding shows that almost all seaweed farmers in Laikang Village are 26 – 40 years old. They have 2 to 5 family members in each family. They are mostly poor education level that graduated only from elementary school. The income of respondents was from fishing artisanal fishery and seaweed farming. About 70.5% respondents have income of less than IDR 1 million per month. Approximately 10 years ago, people were mainly engaged in fishing by using simple technologies, such as nets and fishing rods. Their boats were 5-15 Horse Power (HP) engine or without an engine. The operations area were limited to 1-3 nautical miles from the shore with operation time limited to only one day fishing. Fishermen usually went to fishing in the afternoon at about 4 PM to 5 PM to set up their fishing nets in the fishing ground, then they returned to the sea at 4 AM and 5 AM for retrieve the nets. Depending on the volume of catch, they sold to markets or consume at home. The valuable species of fish would be sold either to a local trader or collector or in a traditional market, while others would be retained for domestic consumption. The size of one unit of seaweed farm as 100 m long and 30 m wide developed at water depths of less than 10 m. Seaweed farmers assisted by their wives and other family members prepare the seedlings to be attached on the stretch of rope (Figure 2). The empty bottles of 500 ml and 1000 ml are also used as small buoy. Normally, length of seaweed growth is 45 days, but it could be shorter when affected by disease. In this case, the seaweed can still be sold but at a price lower than usual.
High productivity of seaweed occurs during December to April in Takalar side. Meanwhile, highest productivity of seaweed in Jeneponto side occurs during May to November. According to these conditions, some fishermen adjusted and moved to those places following the environmental condition and productivity. During May to November, usually farming activity of some fishermen of Takalar moved to Jeneponto, and they moved to Takalar to do the same activity during December to April. However, not all the fishermen transfer their farms to highest productivity area.

The number of household in Serewe Village were 375 households, which 80% of the households are seaweed farmers or 300 people. A total of 221 farmers or 73.7% have ties with collectors. About 95% of seaweed in Serewe Village was sold in dried product. Meanwhile, the problems still faced by the fishermen related to the quality of seaweed, low price from buyer. Seaweed farming is particularly prone to bottom and bust cycles given the large number of small scale price-takers in the industry [4]. Indeed, Valderrama [5] mentions that seaweed farmers, traders and processors frequently make decisions based on speculations or misinformation. Seaweed farmers in Serewe Village have 2-3 plots of seaweed farm in average, which produces 2.5 tons of wet seaweed per crop (30 days) or equal to 1.2 tons of dry seaweed. Dried seaweed were sold to collectors in sub-village level and then sold to next collector in the village level and then wholesalers in Jerowaru Sub District. The yield of each harvest is as much as 300 - 400 Kg per month (dry) at a price of IDR 7500/kg.

According to respondents (farmers), they harvested in 30 days due to three reasons; 1) weather, 2) household financial source, 3) diseases. Hurtado et al. [6] emphasize, production in “wet season” is lean, which is occurred in Indonesia during October to March. It was different with other countries i.e. Malaysia (November to March) and the Philippines (July to October). This statement is match with condition in Sereewe-East Lombok. Changes the period of monsoon seasons in Indonesia in the recent years gave influenced to planting season of seaweed as well as production pattern. The price of seaweed has been determined by collector/traders, especially for seaweed farmers that have ties with collectors. In addition, farmers also set seaweed price based on agreement between collector-traders and seaweed farmers. This is done by seaweed farmers who do not have ties with the collector.

The longline method in seaweed farming was used since 2011 though it was introduced by the DKP of East Lombok District. The longline and raft methods are generally applied to areas with the following characteristics: the depth of the waters was ≥ 3m at low tide, quite sheltered from the waves / big waves, away from areas with high sedimentation, areas of water with good visibility (≥ 2 m) and is not in a shipping line (ships or boats). The stakes method is applied to tidal regions with a minimum depth of 0.5 m at the lowest tide, has a sandy sea floor or sand mixed with corals. The longline and raft methods were most widely used in Central Lombok District (Teluk Gerupuk, Teluk Bumbang and Teluk Awang) and East Lombok District (Ekas Bay and Serewe Bay) [7].

Seaweed farming in East Lombok District was still not balanced between dried seaweed and processed products. Developing product diversifications could be as an alternatif livelihood. The role of livelihood diversification through value-added processed of seaweed has been able to lift the fishermen economy, even replacing fishing as the main source of livelihood [8]. The boat with small engine is used by fishermen to transport seaweed from the beach to farm area for daily control and cleaning of seaweed from dirty and mosses. Planting sites are located on 1-2 km from the beach due to four main reasons; 1) the location was protected from large waves, 2) rich nutrients, 3) Free from the pollution, and 4) location is not far from the beach. Several post-harvest facilities are needed to develop the seaweed in Serewe need to be improved, such as drying racks or drying floors and warehouse. Other facilities such as the ropes and buoy are still insufficient due to limited of financial capital.
3.2. The constraints and opportunities of seaweed farming activity

Changes in the monsoon season and its cycles are major problem in the development of seaweed cultivation in Laikang as well as long market channels and income distribution. A lack of financial capital is the most difficulty faced by fishermen when they begin planting. Seaweed farmers use various schemes to resolve a financial problem, such as borrow money from the family, relatives, friends and middlemen in the village. The reason is they still find a great difficulty in accessing financial capital from formal financial institutions. The quality of the seed, farm tenure, a disease and the post-harvest process is still major problem.

The marketing problems are associated with institutional marketing, information of marketing network, and a communications gap between producers and consumers when the seaweed is not produced in accordance with (international or domestic) standards established by the processing industry and exporters. Due to such problems, the industry can buy seaweed at low prices. Despite these constraints, fishermen have the capacity to improve their livelihood through decreasing the amount of fish harvested, promoting and benefiting from seaweed cultivation as an alternative source of livelihood, tapping support from local governments and taking advantage of opportunities in the local market. These factors are of basic interest to fishermen who engage in seaweed farming as an alternative means of livelihood.

There are some opportunities for the future. First, the demand for raw material has increased year by year, in both domestic and foreign markets. Second, the policies of the national government support the development of seaweed farming. Third, the Government of Indonesia (GoI) encourages private companies and national business agencies to develop seaweed processing. The Indonesian government should encourage all stakeholders, particularly local governments, to assume greater roles in this realm. The private sector wishes to play a role in diversifying the production of seaweed. Local informal leaders can use their power to encourage local people to engage in the management of local resources.

In West Nusa Tenggara, developing seaweed farming face several constraints. This study found several constraints including; 1) lack of socialization of seaweed tissue culture technology, 2) pests and diseases that associated with site selection and mariculture development environment support capacity that is influenced by the seasons, spatial considerations, habitat, predators and other matters. Socialization the guideline of Good Aquaculture Practices and unequal Good Hatchery Practices where disease-free guarantees are required, 3) post-harvest process; harvested seaweed that is still young and farmers not drying seaweed to the required water level content. It was affect to the seaweed to deteriorate during storage and transportation, 4) prices will be determined by buyers when over-supply in production area, 5) financial capital; commercial banks do not dare to finance fisheries, 6) lack of institutional capacity of key actors and businesses, 7) the lack of instructors when compared to
the vastness of the area as the target for instruction (ideally 1 instructor 1 village) and the distribution of instructor placements that do not match the needs (there are more instructors in towns), 8) the existence of climate change that affects the activity of farming activities, 9) lack of complete aquaculture fishery databases from the related institution.

However, there are many opportunities for using superior seeds or commonly referred to as tissue culture from the *E. cotonii* type in East Lombok. The advantages of using tissue culture seedlings, among others, is that they are tougher in terms of disease resistance, do not easily become damaged in big waves and have more thallus and looks fatter compared to "conventional" seeds that have been used. Additionally, tissue culture seedlings harvest yields are greater than ordinary seeds. However, provision of tissue culture seedlings is still quite limited, has not been widely distributed to seaweed centers, especially in the area of East Lombok. Therefore, it is necessary to develop a strategy and technology for the provision of superior tissue culture seedlings as a solution for overcoming deterioration of seed quality.

In West Nusa Tenggara, East Lombok and Central Lombok are linked by the bay ecosystem, namely Ekas Bay, Bumbang Bay, Awang Bay, Serewe Bay, Jukung Bay that are characteristically similar. Therefore, the upstream-downstream economic activities based on seaweed commodity are inter-linked each other. In general, main constraints of seaweed development are faced both area have similarity. These constraints occurred in both areas are consist of; 1) Ice-ice (white spot syndrome virus) disease, 2) decline the quality of seeds, 3) lack of post-harvest management, 4) Less than optimal age at harvest (i.e. only 30 days), 5) no seaweed price differentiation according to quality, 6) the absence of zoning and carrying capacity coastal area for seaweed farming, especially the Serewe Bay. In order to encourage the development of seaweed mariculture areas; the availability of drying facilities, either seaweed drying racks, and storage facilities. Supporting infrastructure and facilities need to be strengthened, primarily in order to increase production quality and post-harvest management, to utilize the mariculture area to its full extent and for mariculture productivity. Fisheries facilities and infrastructure that can be built includes fishery business sub-systems, farming business systems, downstream/processing and marketing sub-systems.

### 3.3. The marketing channel of seaweed farming in sustaining local seaweed cultivation activities

The marketing system of seaweed plays an important role for sustaining fisheries livelihood activities in coastal area of Takalar and Jeneponto Districts. In Takalar, seaweed farmers sell seaweed in dried form to middlemen at the village level. Then, they sell the product to middlemen at the district level, who, in turn, sell it to wholesalers who have warehouses in Makassar/Ujung Pandang, or to a processing company there. Wholesalers receive shipments of seaweed from traders who have become frequent partners. Wholesalers receive seaweed from the same traders who have become frequent and reliable suppliers over time thus reinforcing the strong ties between wholesalers and traders based on personal trust among them. The trust is important factor between wholesalers and traders with strong business ties. Wholesalers exist because they are able to provide a more effective and efficient distribution system than any other participants in the market [9]. Seaweed farmers have been adopted these two major market channels that showed in Figure 3 below.
Figure 3. The two major market channels of dried seaweed at South Sulawesi

In general speaking, the price of dried seaweed can be distinguished based on quality of dried seaweed. Length of market channels have also influence the price formation of dried seaweed at farm level. The price of dried seaweed in first level (farmer to middlemen) is IDR 7000 – 8000/kg, the price at second level (middlemen to wholesaler) is IDR 8000 – 9000/kg, and the price at third (wholesaler to exporter/processing company) is IDR 9000 to 10,000/kg. In the last level, pricing is depend on the buyer who is an exporter of processing company. In practice, the first market channel is the most adopted in South Sulawesi since about last two decades. This is due to the decisive role of middlemen, as has been already mentioned. Middlemen located in farming areas, and traders in some areas are members of the seaweed farmers’ group; some even serve as heads of groups. This procedure was confirmed by Gadde and Snehota [10], who argue that middlemen bridge a production-consumption gap. This study finds that some seaweed farmers are closely affiliated with particular middleman. In addition, Ju et al. [11] mentioned that intermediaries begin by choosing the best goods, then buy the goods from producers and sell them to consumers. In case of market chain type 2, company’s agents found in the marketing chain are not an employee of a processing company or an exporter, but some agents are appointed by the company to purchase raw materials. Some exporters are also engaged in seaweed processing aside from being exporters of dried seaweed.

There are two types of seaweed collector in East Lombok as well as Central Lombok. First, the independent collector, namely a collector who is free to purchase seaweed from seaweed farmers without any obligations between the two. There were 2 types of independent collectors, namely collector who have focus only to quantity and the collector who has a patron-client ties with seaweed farmers. This collector also has patron-client ties with wholesalers. Besides focusing on quantity, the seaweed collector or trader also intends to obligate farmers so that the seaweed farmers do not sell their yields to other traders in the hope of achieving their target quantities. Middleman in sub district sell dry seaweed to exporters in Surabaya and Bali without any sorting process prior to purchasing
seaweed from village collectors. In addition, wholesalers have set quality requirements to the seaweed collectors at village level. These requirements were includes; 1) the seaweed must be clean of any dirt or debris, 2) the level of dryness is with a moisture content of approximately 30-35% or often called rubber-dry, 3) according to seaweed farmers, traders are not concerned if there is any salt sticking on the seaweed thallus, 4) Minimum delivery is 5 tons. Wholesalers are usually distribute seaweed to exporters two times a month, using a Fuso truck with a capacity of 10 - 12 tons. The cost of each shipment is IDR 3,000,000 which is charged to the exporters.

Figure 4. Marketing map of seaweed in East Lombok and Central Lombok

Marketing network of seaweed in East Lombok and Central Lombok for value-added products is needs an advanced strategy. This strategy can take advantage of the role of middlemen to reduce frictions in seaweed market [12]. Product diversification and market opportunities can open up more job opportunities. In order to maximize the seaweed for fishermen’s livelihood, Smith and Renard [13] suggests that the integration of technology, ecology, sociology and economics is one of appropriate strategy approach. Seaweed market in Serewe was still dominated by middlemen who buy dried seaweed. Seaweed farming cycles in Serewe Bay is divided into three seasons a year. In term of peak season, farmers can harvest the seaweed 4-5 times, with an average yield is 3-4 tons/harvest/unit. It was usually occurring during June to September. In low season, they harvested at least 4-5 times and usually occur during the rainy season or during January to May with average production was 1 ton/unit/crop. The season with moderate production has occurred during October-December and average yield was 1.5 ton/cycle/unit. The problem of low prices has become a "label" of seaweed from Serewe. In addition, the factors affecting to low price of seaweed are consider the following factors; 1) The age of seaweed is under 45 days or mainly during 25-30 days, 2) Drying method did not pay attention to hygiene standards, 3) The seeds quality has been slowly declined. It was indicated with the thallus is growth slowly and easily broken. 4) Low quality of post-harvest handling by seaweed farmers. Bonded system (jon) between seaweed farmers and middleman was affected to the seaweed price. The existence of bonded system is driven by farmer’s expenditure. In other words, the debts of farmers to collectors were mostly not for business matter.

The double roles that middlemen play cannot alone guarantee a sustainable business, although they are assured of the availability of dried seaweed from the farmers who borrow capital from him. This means that middlemen and seaweed farmers are implicitly "tied" to one another in a mutually beneficial relationship. Day [14] emphasizes the value of such relationship building when there are only a few valuable customers who engage in large transactions. The relationship between middlemen and fishermen/seaweed farmers is being transformed, in the long term, into a trade with an exclusive relationship at the local level. The middlemen’s financial sources are independently different from
regular institutional sources. The same “patron-client” relationship (local name called: punggawa-sawi) relationship exists in the traditional fishery system but it is different from that in the seaweed farming system. The positive impact on the relationship between seaweed farmers and middlemen can be summarized into four points; 1) seaweed farmers could get loans through quicker process, 2) there was no interest collected on loans, 3) the farmers were assured of selling their harvest and 4) the farmers got cash payment for their produce which actually represents additional debt. Middlemen may not be the best buyers, but they can provide some social benefits in the long run [15] by seeking the best market prices whose profits can sometimes be passed on to the farmers [11,16,17,4]. Indeed, middlemen have two essential roles as direct links to the external market and as provider of credit to fishermen [18].

4. Conclusion
Seaweed farming plays an important role in the socioeconomic condition of fishing communities by small scale level. The level of business only 2-4 plots per person in average and using floating longline method as a primary source of household support. However, some constraints hinder the development of this activity, such as disease, post-harvest difficulties, farm ownership, shifts in the monsoon season, and marketing constraints. In addition, the availability and quality of seaweed seeds, issues surrounding farm ownership, predatory behavior and imperfections in post-harvest methods are also constraints. However, farmers can overcome these constraints. Positive factors include the lack of restrictions on the development of coastal areas, the availability of successful farming methods and the price of dried seaweed.

In short term strategy, the marketing system with middlemen has provided benefits, such as speedily supplying investment and daily operational funds, without interest, to seaweed farmers through the efforts of middlemen. Middlemen are perceived to be very important to sustaining seaweed farming. However, this situation has created a heavy dependency on middlemen and, consequently, also created an exclusive relationship. Nevertheless, the activities of middlemen are necessary to the operation of the dried seaweed supply chain in study areas as long as the local and central governments cannot facilitate the creation of an effective alternative market chain at the local level.

Finally, seaweed farming within floating logline method could contribute for sustainable livelihood activity in suitable coastal communities in the future. However, they should consider with 9 key points to develop seaweed industry in the research areas; 1) expand the potential farm area in an optimal and environmentally friendly manner to meet the market demand for seaweed, 2) encourage seaweed farmers to improve their knowledge of business management, including aspects of finance, farming methods, post-harvesting processes, quality and market, 3) develop alternative models of farming methods to minimize risks, 4) prohibit destructive activities could reduce the quality of seaweed, 5) build public understanding and awareness of environmental protection, 6) livelihood diversification based on local product is a better choice to support the fishermen adapting from the impact of decreased resource, 7) local government should provide some assistance such as training for alternative livelihoods, capacity building for fishermen, and institutional strengthening, 8) maintain the existing marketing system (for short-term strategy), 9) encouraging farmers to organize seaweed cooperative.

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