

An Analysis of the South Sulawesi Seaweed Industry

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I am delighted to share our preliminary findings from the Partnership for Australia-Indonesia Research (PAIR).

PAIR is a development initiative that brings together researchers, policymakers, business and community groups to find solutions to real problems. We do this in an integrated, collaborative and evidence-based way.

We anchor our research on a segment of Indonesia’s ambitious Trans-Sulawesi railway network – the new 145-kilometre railway line connecting two major port cities: Makassar and Parepare.

The railway line will provide much-needed transport for people and goods. It also stands to stimulate the local economy, boost commodities and transform communities. Yet, experience shows that investments in connectivity do not necessarily benefit local communities if they are not ‘people-centric’ - that is sustainable, affordable and accessible. Businesses are unable to realise the new railway line’s potential without good planning and design of infrastructure. Poor intermodal connectivity, scheduling and intervention are unlikely to encourage use. Moreover, people are likely to remain disadvantaged if they lack the knowledge needed to take advantage of opportunities, and if they lack access to resources, or the skills required to thrive and enterprise.

Our research explores four areas: commodities; transport, logistics and supply chain; young people, health and wellbeing; and young people and development. We investigate what the railway lines mean for local communities, how they respond to change, and how they can take advantage of emerging opportunities.

Warm regards,



Dr Eugene Sebastian
PAIR Program Director
The Australia-Indonesia Centre

EXECUTIVE SUMMARY

The Indonesian seaweed industry has expanded rapidly over the last 20 years and now supports the livelihoods of more than 35,000 coastal households in South Sulawesi (BPS 2020).

The Government of Indonesia has prioritised the industry's development, recognising the vital role it plays in reducing poverty in coastal communities.

But it is not all good news. The industry suffers from poor coordination between farmers, traders and processors, limiting farmer incomes and creating quality issues for processors. And in common with most other industries, it has been affected by the COVID-19 pandemic.

This pilot project takes a four-stage approach to gain a better understanding of the industry.

Firstly, it reviews the global trends in the Indonesian seaweed industry. It outlines how growing global demand for hydrocolloids (often used as gelling agents in food processing) has driven the expansion of cultivation of a narrow range of seaweed species across the Indonesian archipelago, enabled by the unique characteristics of coastal farming households.

Secondly, it outlines the value chain of the industry, exploring how the phyconomic characteristics of seaweed production shape its cultivation and the livelihoods it supports, and how these in turn interact with domestic marketing systems, the processing sector, and global value chains.

Thirdly, it takes a closer look at seaweed livelihoods, using a livelihoods analysis of the industry to identify the key needs of farmers.

Finally, it considers techniques for researching the industry during COVID-19 and shows how satellite data can provide insights into the industry and how it has changed during the global pandemic.

These four sections provide insights into the industry which support the development and implementation of the Commodities Research Group's proposed Strategic Integrated Project (SIP) for 2021-2022.

1.0. INTRODUCTION

Since the year 2000, seaweed farming has expanded rapidly across coastal Indonesia. Although many species of seaweed are commercially cultivated, just seven represent over 95 per cent of the value of global aquatic plants (FAO 2020). Of these, four are high-value food products grown primarily in China, Korea and Japan. The remaining three – species of *Gracilaria*, *Eucheuma* and *Kappaphycus* – are used to produce carrageenan and agar, which are hydrocolloids used as gelling agents in a range of applications. Indonesia produces 66 per cent of the global supply of these hydrocolloid seaweeds (Figure 2).

Hydrocolloid seaweeds are much lower in value than food seaweeds, so Indonesian seaweed production is undertaken mainly by low-income smallholder farmers, primarily in Eastern Indonesia. They can work around seasonal and tidal changes and have limited other income generation opportunities (Langford et al. 2020a; 2020b; 2021).

Seaweed farming is an important income source for more than 267,000 rural households in Indonesia (Presidential Decree 33-2019, p.17), who earn profits of around US\$2,000 annually (Presidential Decree 33-2019, p.16). Farmers frequently perceive seaweed farming as more lucrative than more established industries such as copra, cocoa and other marine industries (Arsyad et al. 2014; Aslan et al. 2018; Mariño et al. 2019; Steenbergen et al. 2017).

Farmers also report a range of other benefits from seaweed farming, such as an increased ability to manage their income and save for large purchases (Mariño et al. 2019; Steenbergen et al. 2017). These sit alongside a variety of other environmental and social changes associated with the

industry (Valderrama et al. 2013; Neish 2013; Salayo et al. 2012; Suyo et al. 2020) and varying benefits to different community and household members (eg De la Torre-Castro et al. 2017; Henríquez-Antipa & Cárcamo 2019; Larson et al. 2020).

Recognising the increasingly important role of seaweed in coastal livelihoods, the Indonesian government has prioritised industry development, most recently in Presidential Decree 33-2019 (Peraturan Presiden Republik Indonesia Nomor 33 Tahun 2019 tentang Peta Panduan Pengembangan Industri Rumput Laut Nasional Tahun 2018-2021). This provides a road map for the development of the seaweed industry from 2018 to 2021 and outlines opportunities for increased seaweed production and increased domestic value-adding processing. Efforts to improve value adding have targeted food products, animal feed products, fertilisers, cosmetics and bioethanol (eg Aji et al. 2019; Mantri et al. 2017; Munandar et al. 2019; Nurjana et al 2016; Rasyid 2017; Sulfahri et al. 2020a; 2020b; Tarman et al. 2020; Yusuf et al. 2020).

Attempts to improve production focus on growth rates and quality improvements but the industry faces multiple issues, such as high transportation and logistics costs and a lack of infrastructure development (Presidential Decree 33-2019 p. 30).

The needs of farmers, traders and processors are poorly understood – limiting the design of effective policy. More informed data is needed.

South Sulawesi is Indonesia's largest seaweed-producing province, producing over a third of the nation's seaweed, and more than 20 per cent of the global supply of carrageenan seaweeds. This pilot project seeks to provide insights into the seaweed industry

which will support the development and implementation of the SIP.

The results of this pilot project are organised in four parts:

- **Section 1.4.1.** reviews the global trends in the Indonesian seaweed industry and outlines how growing global demand for hydrocolloids has driven the expansion of seaweed cultivation across the Indonesian archipelago. This is important for understanding the current patterns of production and processing, as well as for identifying future opportunities and risks in the industry.
- **Section 1.4.2.** undertakes an initial characterisation of the seaweed value chain, looking at phyconomy, cultivation and livelihoods, domestic marketing, processing, global value chains, and policies and institutions.
- **Section 1.4.3.** is a livelihoods analysis of seaweed farming and introduces an initial household budget for use in characterising seaweed farming households.
- **Section 1.4.4.** introduces initial work using satellite data for researching the industry during COVID-19.

2.0. METHODOLOGY

Due to the restrictions on travel and fieldwork created by the COVID-19 pandemic, this research relies substantially on secondary data and review of literature.

Secondary data was sought from both publicly available and non-publicly available sources (such as government departments).

This included customs data disaggregated at a level beyond that which is publicly available, quarterly seaweed production estimates from the South Sulawesi Fisheries department, global and national production estimates, rainfall records and price information. We also used remote interviews with farmers and industry stakeholders to interpret and supplement this data.

Remote sensing data has been used to monitor seaweed production patterns. Satellite data provides an extremely useful, low-cost tool for monitoring the industry. It is typically low resolution and not suitable for identifying seaweed culture sites (Hossain et al. 2016). However, they are clearly visible on high-resolution (~3m) satellite imagery (Figure 1) such as that available on Google Earth. High-resolution, high-frequency satellite data has only recently become available but provides a potentially very useful, up-to-date insight into the seaweed industry.

Basemaps are mosaics of images taken across the month and pieced together to account for cloud cover. Available monthly from PlanetLabs, they make immediate analysis of changes in the industry possible. We used them to identify plots of farmed seaweed in Pangkep Regency. Shapefiles were created in ArcGIS Pro using rectangles to represent each seaweed plot, and maps were generated to show the area under seaweed production in each month. The area of these rectangles was aggregated to calculate the total area under seaweed production in each month. This satellite data was triangulated with rainfall data (obtained from the Badan Meteorologi, Klimatologi, dan Geofisika (BMKG), online data service records from the Stasiun Klimatologi Maros), price data (obtained from JaSuDa, an industry information portal managed by Coordinating Ministry for Economic Affairs/ Kemenko Ekonomi), and informal interview data.

As such, we have proposed developing this methodology in the SIP. We have also shared initial results from this study with the South Sulawesi DKP, who have expressed interest in accessing an expanded version of this dataset, and in working with us to interpret this data and refine systems for collecting production data.

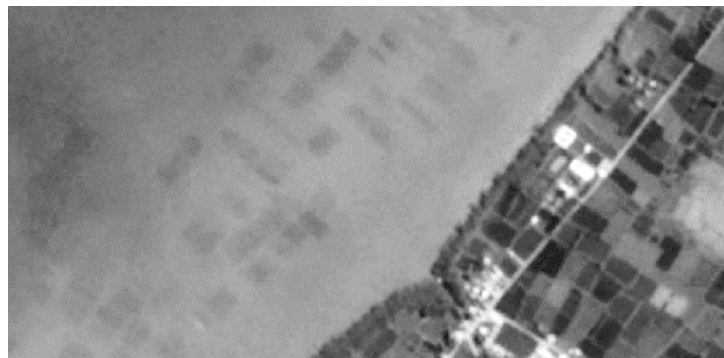


Figure 1 Seaweed plots visible on PlanetLabs basemap for May 2020. 119.5683687°E 4.5996097°S

3.0. ANALYSIS AND RESULTS

This pilot project involved four key study areas, the results of which are presented below.

3.1. SEAWEED INDUSTRY TRENDS

Seaweed is rich in nutrients¹ and has been used as a food source for centuries. Increasingly, seaweeds are used to produce hydrocolloids – gelling agents widely used in food manufacturing as well as cosmetics and the pharmaceutical industry.

Global seaweed production

In 2017, just six countries produced 96 per cent of the world’s aquatic plants (mostly seaweed). China and Indonesia are the largest producers, producing 54 per cent and 30 per cent of the world’s supply respectively (Figure 2).

Seaweeds are classified into three groups – red, brown and green. There are 221 species of commercially produced seaweed, but just seven of these (Table 1) comprise 95 per cent of the global value of aquatic plants (Figure 3). Of these species, four are primarily consumed as food products, while three are used primarily to produce the hydrocolloids carrageenan and agar. Indonesia, China and the Philippines produce most of the world’s hydrocolloid seaweeds, while China, North Korea, South Korea and Japan produce the world’s entire supply of edible seaweeds.

Food seaweeds

The food species *Saccharina japonica*, *Undaria pinnatifida*, *Sargassum fusiforme* and *Porphyra spp* are produced exclusively by China, Japan, North Korea and South Korea. Some 62 per cent of this is Chinese-produced *Saccharina Japonica*. *Saccharina Japonica* is also used to produce the hydrocolloid alginate, but alginate production competes with the higher-value use of *Saccharina Japonica* for direct consumption and so is minimally viable.

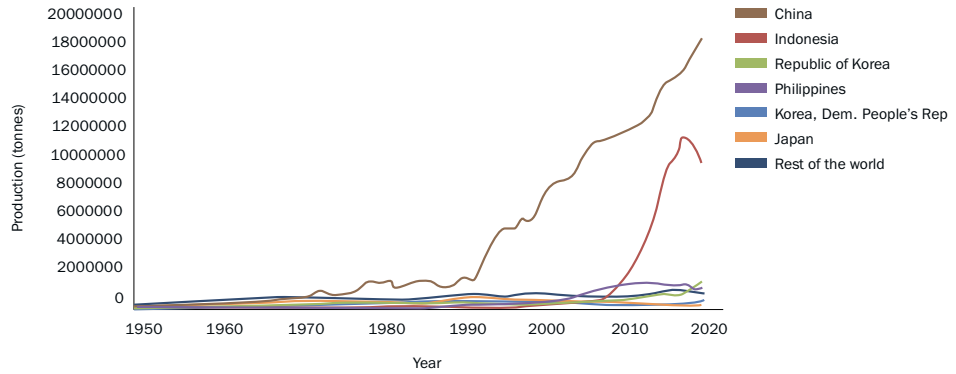


Figure 2 Global aquatic plant production by country (Source: FAO stats)

Type	Species	Main Products	USD/kg	Main producers
Brown	<i>Saccharina japonica</i> ⁴	Food – kombu, alginate	\$373	China, South Korea, North Korea
	<i>Undaria pinnatifida</i> ⁵	Food – wakame	\$667	China, South Korea, Japan
	<i>Sargassum fusiforme</i> ⁶	Food – hiziki	\$759	China, South Korea
Red	<i>Porphyra spp.</i> ⁷	Food – nori	\$905	China, Japan, South Korea
	<i>Euचेuma spp.</i> ⁸	Carrageenan	\$108	Indonesia, Philippines
	<i>Kappaphycus alvarezii</i> ⁹	Carrageenan	\$110	Indonesia, Philippines
	<i>Gracilaria spp.</i> ¹⁰	Agar	\$420	Indonesia, China

Table 1 Intensively cultivated commercial seaweed

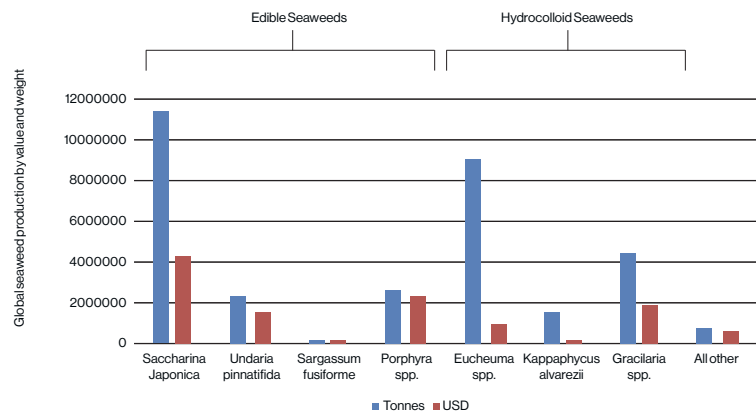


Figure 3 Global aquatic plant production by species¹¹ (Source: FAO Stats)

1. Including macronutrients such as sodium, calcium, magnesium, potassium, chlorine, sulphur and phosphorus, micronutrients such as iodine, iron, zinc, copper, selenium, molybdenum, fluoride, manganese, boron, nickel and cobalt, and vitamins such as B12, A, and K (Ferdouse et al. 2018: 1). 2. 97 per cent of the world supply of *Kappaphycus alvarezii*, *Gracilaria spp* and *Euचेuma spp*. 3. Based on FAO reported 2017 value and weight for each species 4. *Saccharina Japonica* (Japanese kelp). Formerly known as *Laminaria japonica* 5. *Undaria pinnatifida* (wakame) 6. *Sargassum fusiforme* (*Fusiform sargassum*) 7. *Porphyra spp* includes *Porphyra tenera* (*Laver (Nori)*), *Porphyra spp (Nori Nei)* Does not include *Porphyra columbina* as there is no production of this 8. *Euचेuma spp* – includes *Euचेuma spp (Euचेuma spp Nnei)* and *Euचेuma denticulatum* (spiny *Euचेuma*) formerly known as *Euचेuma spinosum* 9. *Kappaphycus alvarezii* (Elkhorn sea moss) formerly known as *Euचेuma cottoni* 10. *Gracilaria spp* includes *Gracilaria verrucosa* (warty *Gracilaria*), *Gracilaria gracilis* (slender wart weed), *Gracilaria spp (Gracilaria seaweeds)* 11. *Euचेuma spp* and *Kappaphycus alvarezii* are included in the category of carrageenan seaweeds. *Kappaphycus alvarezii* was previously known as *Euचेuma cottoni* and appears to be included under *Euचेuma spp* for some country’s datasets, including Indonesia.



Carrageenan seaweeds

The carrageenan seaweeds *Eucheuma denticulatum* (formerly known as *Eucheuma spinosum*) and *Kappaphycus alvarezii* (formerly known as *Eucheuma cottonii*) are produced primarily in Indonesia and the Philippines, which contribute 82 per cent and 14 per cent of global supply respectively (Figure 4). These carrageenan seaweeds are significantly lower value than other species (Table 1, Figure 3).

Demand for carrageenan has risen with demand for processed foods. In the late 1960s, it was discovered that *Eucheuma* seaweeds in the Philippines could produce high-quality carrageenan. The first *Eucheuma* seaweed farm there was established in 1969, and thrived due to low labour costs. Efforts to establish plantation-style farms in the Philippines failed: smallholders fared better due to the low-cost barriers to entry and the need for a highly flexible workforce that could work according to moon and tide times. Carrageenan seaweeds were soon introduced to Indonesia, which is now the world's largest producer. (Figure 4).

Agar seaweeds

Gracilaria spp are widely used to produce agar, another important colloid in food manufacturing. Together, China and Indonesia produce virtually all of the world's *Gracilaria* (72 per cent and 28 per cent of global supply respectively) (Figure 5). The *Gracilaria spp* group, native to China, includes over 100 species. Commercial cultivation of *Gracilaria* began in China in the late 1950s, and in the 1980s cultivation on suspended lines was developed. Production expanded rapidly in the early 2000s, mostly with *Gracilaria verrucosa*. *Gracilaria* production is now highly concentrated in Indonesia and China, and demand continues to increase with demand for processed foods.

Indonesian seaweed production

Indonesia produces primarily carrageenan seaweeds (87 per cent of national production), but also the agar-producing variety *Gracilaria verrucosa* (12 per cent of national production) and small amounts of other red seaweed species (Figures 6 & 7).

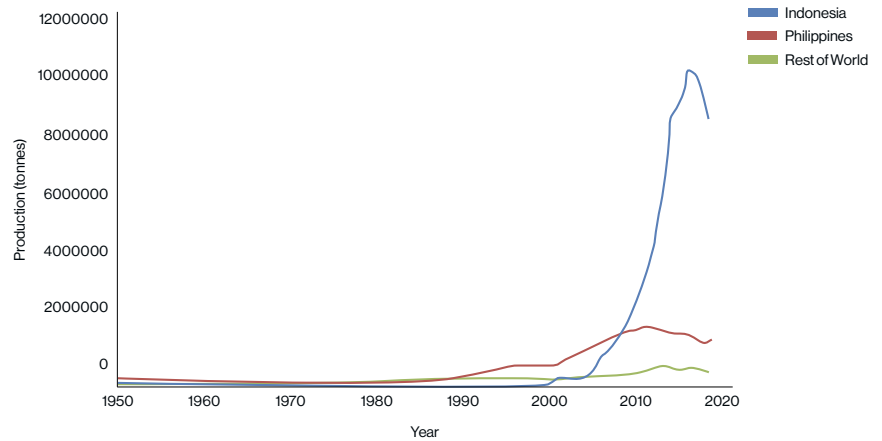


Figure 4 Global carrageenan seaweed production (Source: FAO Stats)

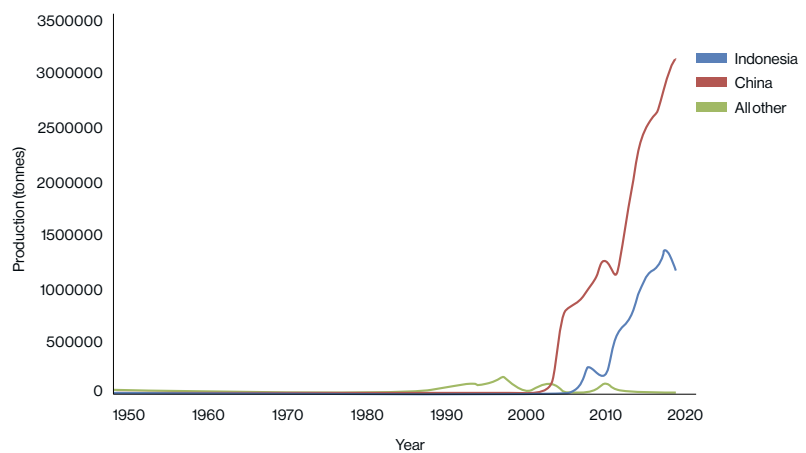


Figure 5 Global *Gracilaria spp* seaweed production (Source: FAO stats)

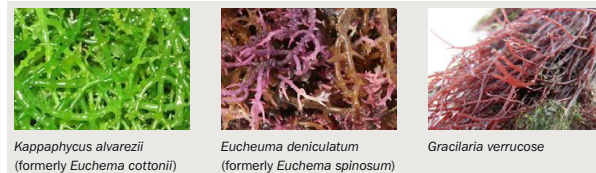


Figure 6 Widely cultivated Indonesian species

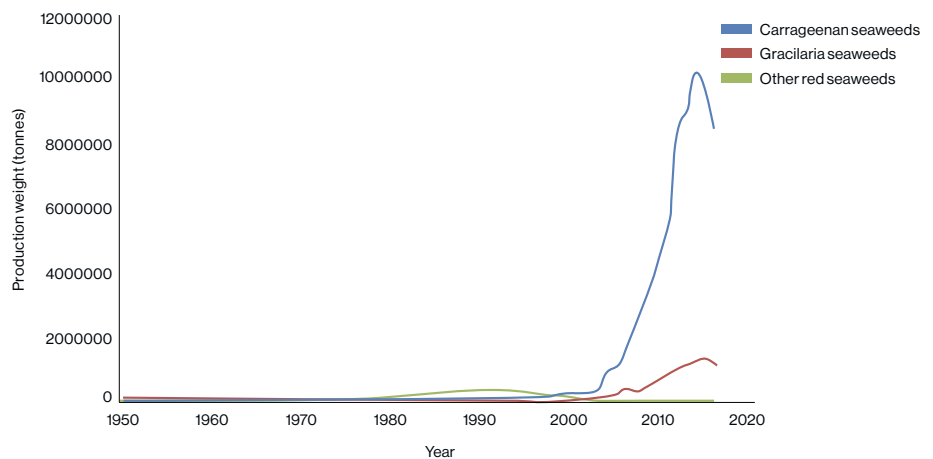


Figure 7 Indonesian seaweed production by species (Source: FAO stats)

Production is concentrated in Eastern Indonesia, particularly in Sulawesi, NTB and NTT (Figure 8). South Sulawesi alone produces 3.66 million tonnes of seaweed a year – over a third of Indonesia’s total seaweed supply and 11 per cent of global supply. South Sulawesi has been named a priority region for seaweed farming expansion, with up to 250,000 ha of farms possible (Presidential Decree 33-2019). Seaweed production in South Sulawesi is concentrated along the South Eastern coastlines, although Pangkep district has more than doubled production in the last five years (Figure 9).

These factors show how global demand for hydrocolloids has fuelled the development of what has become a highly significant industry.

3.2. A VALUE CHAIN ANALYSIS OF THE SEAWEED INDUSTRY

Value chain analyses can generate a range of insights into the seaweed industry to support development of stronger policy (see Neish 2013b; 2015; Mulyati 2015; Mulyati & Geldermann 2017; Teniwut et al. 2017; Teniwut 2019; Suadi & Kusano 2019; Ramirez, Narvaz & Santos-Ramirez 2010; Puspita & Azis 2019; Cuaton 2019; Nor et al. 2019). In this section we examine the value chain in six parts: phyconomy, cultivation and livelihoods; domestic marketing and processing; international marketing and policies and institutions (see Figure 10).

3.2.1. PHYCONOMY

Phyconomy is the commercial farming of marine algae (Hurtado, Neish & Critchley 2019). Three main species of seaweed are grown in Indonesia. Two are used to produce carrageenan (*Euचेuma deniculatum*, formerly known as *Euचेuma spinosum*, and *Kappaphycus alvarezii*, formerly known as *Euचेuma cottonii*), while one is used to produce agar (*Gracilaria spp.*).

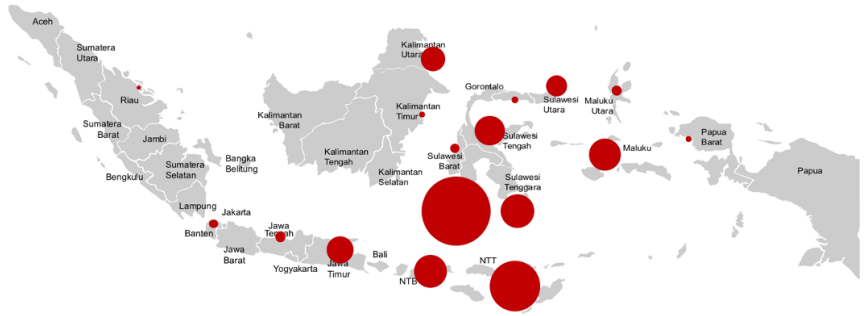


Figure 8 2017 Seaweed Production Distribution in Indonesia by weight

Source – 2017 production data

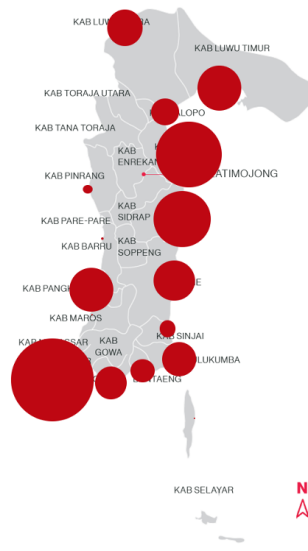


Figure 9 Seaweed production in South Sulawesi

Source – 2017 production data

Significant advances have been made in farming techniques (Hurtado et al. 2013; Hurtado, Neish & Critchley 2015). Numerous factors affect seaweed growth rate, including water temperature, irradiance, salinity, nutrients, pH, seed size and genetic material, sedimentation levels, water oxygen levels, fish grazing, epiphyte growth and disease infection (Ateweberhan, Rougier & Rakotomahazo 2015; Azanza & Ask 2017).

Salinity appears particularly significant. The optimal salinity for growth of *Kappaphycus spp.* and *Kappaphycus alvarezii* is 30-33 and 25-35 psu respectively (Azanza & Ask 2017). Seawater has a salinity of 35 psu, so reduced salinity due to rainfall in certain seasons can significantly increase seaweed production. The growth rate and carrageenan production of seaweeds are related, so seasonal differences in both are significant (Wakibia et al. 2006; de Góes & Reis 2012; Hayashi et al. 2007; 2011; 2017).



Figure 10 Seaweed industry value chain



South Sulawesi alone produces 3.66 million tonnes of seaweed a year – over a third of Indonesia's total seaweed supply and 11 per cent of global supply. It's been named a priority region for seaweed farming expansion, with up to 250,000 ha of farms possible.

Nitrogen fertiliser run off from rainfall on land is another factor. Nutrient levels affect seaweed growth rate and it appears that nitrogen insufficiency may limit growth rates (Li, Li & Wu 1990) or lead to substantial increases (Nursidi et al. 2017; Forero 2017).

Acidic seawater conditions (Zitta et al. 2012) and planting distances (Febriyanti et al. 2019) also affect growth rates. Understanding more about the factors affecting seaweed growth rates and carrageenan production could increase productivity, and may also help with planning seaweed farming sites (Teniwut, Marimin & Djatna 2018; Utama & Handayani 2018).

Seaweed is clonally propagated using cuttings and due to the short season and reuse of seedlings, genetic material quality has declined rapidly, leading to lower yields and quality and more disease (Hurtado, Magdugo & Critchley 2020). Some projects have sought to improve seaweed cultivation through distributing improved genetic material (eg. Galon 2019; Halling et al. 2013). Maintaining and improving the quality of genetic material is a major challenge for the industry (Hurtado, Magdugo & Critchley 2020).

The environmental sustainability of the industry affects productivity locally, as well as having broader impacts. Seaweed farming can alter fish assemblages and ecological processes in surrounding areas (Chacin et al. 2020) and negatively affect biodiversity of native species (Tano et al. 2015). The environmental impacts vary significantly with location (Castelar et al. 2015). In addition, pests and disease are a major challenge (Pang et al. 2015). And while climate change apparently increases the area suitable for carrageenan seaweed farming, it also creates higher surface seawater temperatures and may have negative effects on seaweed

reproduction (Msuya & Porter 2014; Largo et al. 2017).

This all indicates a need for further applied studies of seaweed growth rates, carrageenan yields and environmental impacts. These studies should be grounded in particular geographical contexts, such as South Sulawesi, and mapped against farmer responses to changing environments to understand the interplay of biological, social and economic processes.

3.2.2. CULTIVATION AND LIVELIHOODS

Farmers typically purchase seeds from other farmers or from government, and then tie the seaweed propagules onto ropes which are hung in the ocean for around 40 days. They then harvest and dry the seaweed before selling to traders.

In South Sulawesi, seaweed farmers typically also produce other products (Aslan et al. 2015). Coastal people often report earning higher incomes from seaweed farming than other activities (Aslan et al. 2018; Poeloengasih et al. 2014; Sitompul & Matasik 2019; Sunadji & Lusiana 2019), although the profitability of different systems varies significantly (FAO 2013; Valderrama et al. 2015; Dos Santos et al. 2018).

Several studies discuss the benefits of income diversification through seaweed farming (eg FAO 2013; Salayo et al. 2012; Yarish et al. 2014; Shanmugam et al. 2017), but many farmers continue to live under the poverty line (Aslan et al. 2018). Often low uptake of new technologies limits productivity and income generation (eg Yusuf, Arsyad & Nuddin 2018). Farmers can lack access to information about technologies and marketing opportunities (Nuryadi et al. 2019). Capital costs are low, but pay

back times are still an important consideration – one study in the Philippines suggested six to nine months was typical (Samonte 2017).

The economic benefits from seaweed farming may be prioritised over environmental concerns (Akrim, Dirawan & Rauf 2019), and rapid livelihood transitions can be unsustainable (eg Steenbergen, Marlessy & Holle 2017). In addition, transition to seaweed farming can generate social changes (Rahim 2019; Mariño et al. 2019; Mirera et al. 2020). In seaweed farming villages, internal support mechanisms (such as family) are extremely important (Suyo et al. 2020).

Women dominate seaweed farming in some areas (Mirera et al. 2020); it can be an important income source for rural women (Periyasamy, Anantharaman & Balasubramanian 2014; Cuaton 2019). It appears common for women to be involved in all stages of preparation, on-farm, processing and marketing activities (Msuya & Hurtado 2017; Ramirez, Narvaez & Santos-Ramirez 2020). However, women may have reduced access to external support (Suyo et al. 2020).

The comparatively high but variable income earned from seaweed farming, reliance on capital inputs and access to sea areas, different labour requirements and different income return patterns all shape the daily activities and social relations of those in the industry. For example, farmers often use the frequent small amounts they earn from fishing to meet daily needs, and the larger, infrequent payments from seaweed to fund items such as children's school fees (Aslan et al. 2018). Close attention to how engaging in this cash crop shapes social relations is needed.

3.2.3. DOMESTIC MARKETING

Traders are important in the seaweed industry (Mulyati 2015; Sutinah et al. 2018) but their profitability varies (Sutinah et al. 2018). Some are local-level traders who sell to larger traders or processors; others operate regionally to repack seaweed and resell it to exporters or processors. Often multiple marketing channels exist with different proportions of profits going to farmers, small-scale traders and regional traders (Tumiwa et al. 2017; Sutinah et al. 2018). At the village level, traders are often the only source of marketing information for farmers (Nor 2016) and can set the local price because they provide other services such as informal credit and transportation (Nor 2016). Farmer cooperatives may be beneficial (Nor et al. 2016; 2017), and seaweed information centres and extension programs may provide crucial support to farmers (Teniwut 2019).

The poor quality of raw dried seaweed (RDS) is a major challenge for traders. Drying is a particular issue: it affects quality for traders (Katili, Dali & Yusuf 2019; Vairappan et al. 2014), while farmers often struggle to dry their seaweed in the wet season. Seaweed is dried by either hanging or lying on tarpaulins or on the ground for up to a week to reduce the moisture content to an optimal 35 per cent. The drying method affects the moisture content, as well as the presence of contaminants such as salt, dirt and sand. RDS with high moisture, sand and salt content is cheaper for traders, since the RDS may shrink (as it dries further in transit) or be cleaned by purchasers. The drying of seaweed is therefore key to improving the value chain. The use of solar 'greenhouse' drying is an important development (Hurtado et al. 2013; Pangan, Ampo & Barredo 2020) although it is yet to be widely adopted and is subject to weather fluctuations.

Makassar handles seaweed from South Sulawesi and around eastern Indonesia (Sutinah et al. 2018). There is a need to map the work of local traders and profit margins across the value chain, and target seaweed drying issues.

3.2.4. PROCESSING

Indonesia's seaweed processing industry is primarily focused on creating carrageenan products, used in food processing (see Pereira 2016; Loureiro et al. 2017). Global carrageenan prices typically follow those in Indonesia since Indonesia dominates world supply (Campbell & Hotchkiss 2017), while demand for processed foods and the operations of the major Chinese carrageenan processor BLG affect prices significantly. However, relatively little of Indonesia's RDS is processed into value-added products such as carrageenan, and the domestic processing industry has generally struggled to compete with Chinese processors, partly because processing relies on chemical imports from China (Centre for the Promotion of Imports from Developing Countries, 2019). The 2019 Presidential Decree emphasised the importance of developing new value-added products from seaweed such as food, animal feed, fertilisers, cosmetics and bioethanol. Many research projects are now targeting these goals (eg Aji et al. 2019; Mantri et al. 2017; Munandar et al. 2019; Nurjana et al. 2016; Rasyid 2017; Sulfahri et al. 2020a; 2020b; Tarman et al. 2020; Yusuf et al. 2020).

Attempts are being made to expand the range of products from seaweed (Álvarez et al. 2019) and to reduce waste (Ortiz-Tena, Schieder & Sieber 2017). Efforts to develop macroalgae-based biofuels have been promising (Meinita et al 2015; Gao 2020, and see PAIR outputs Sulfahri et al. 2020a; 2020b).

Indonesian red seaweeds show promise for developing cosmetic or pharmaceutical products (Khatulistiani et al. 2020; Puspita et al. 2020). Research into food products is popular, but there are concerns about heavy metal contamination (Afiah, Supartono & Suwondo 2019).

Realistically, the industry is likely to remain centered around carrageenan production for some time. European markets increasingly demand high-quality carrageenan blends with particular attributes (Centre for the Promotion of Imports from Developing Countries 2019). Multiple factors, determined earlier in the supply chain, affect quality. As such, better integration between seaweed farmers and processors could significantly improve the quality of the inputs into the processing industry, to mutual benefit.

Waste streams from carrageenan production represent a major environmental hazard (Mulyati 2015). This is a priority area for future research.

The Multi-Stream Zero Effluent (MUZE) process is promising (Neish 2013 a; 2013b; 2015; Neish & Suryanarayan 2017) – it aims to increase the range of seaweed products and improving efficiency by skipping drying and using raw seaweed juice as an input. However, the need for quick transport of the perishable juice would require reorganisation of supply chains. That may not be feasible in some locations.

3.2.5. INTERNATIONAL TRADE

We used Revealed Comparative Advantage (RCA) and input-output analysis to analyse the importance of Indonesian seaweed in the global market.

Seaweed production in Indonesia increased from 6.5 million tons in 2012 to 10.5 million tons in 2017, and accounted for on average 69 per cent of total aquaculture in Indonesia from 2012-2017 (KKP Statistics 2019). More than 139,500 households were involved in seaweed aquaculture in Indonesia in 2016 and Indonesian seaweed exports increased from US\$134 million in 2012 to US\$219 million in 2019 (UN Comtrade 2020). Using average RCA scores to examine export competitiveness from 2012 to 2019, it was found that Indonesia was ranked second after the Republic of Korea as seaweed exporters to the global market for “seaweeds and other algae; fit for human consumption” (HS code: 121221) and second after Chile for “seaweeds and other algae; not fit for human consumption” (HS code: 121229). Our input-output analysis undertaken using the IO database in 2010 found that 61 per cent of Indonesian seaweed production went into input/intermediate demand for other sectors of production, while only 39 per cent went to final demand, such as household consumption and exports. Furthermore, by comparing to other aquatic products such as fish, shrimp, other crustaceans and other aquatic biota, seaweed had the highest performance in total forward linkages at 1.775, compared to fish for example at 1.630, reflecting the substantial value adding that occurs. For output and income, seaweed produced multipliers at 1.167 and 0.123 respectively in 2010. Based on our initial results, we conclude that the seaweed sector is becoming more important to the Indonesian economy.

Indonesia is seeking ways to move global value chains up toward the “driving points” of the chains where more value can be accrued. As discussed above (1.4.2.4), this is especially through further processing to semi-refined seaweeds and final products within Indonesia, including South Sulawesi. This places high

demands on capital, technology and management capacities. One approach to this is through foreign investment in Indonesia, notably the development of a major processing facility by the Chinese carrageenan producer BLG. Indonesian policymakers and industry must develop a feasible strategy on the most beneficial place for Indonesia and South Sulawesi in the global seaweed value chain, which can be accompanied by appropriate policy and technological measures.

3.2.6. POLICIES AND INSTITUTIONS

International trade policy has an important impact on the competitiveness of seaweed value chains (Tombolotutu et al. 2019) and Value Added Tax exemptions are designed to support the industry (Anugrahayu, Darwanto, & Jamhari 2017). More strategic distribution of collection and processing activities could reduce risks in supply chains (Mulyati 2015; Mulyati & Geldermann 2017). Studies of the organisation of seaweed farming support coastal zone management planning (Rameshkumar & Rajaram 2018), while developing appropriate biosecurity legislation is a challenge (Campbell et al. 2019; Kambey et al. 2020 Mateo 2020). The impact of Indonesia’s public institutions on the seaweed industry vary, and research to support close integration between policymakers, industry stakeholders and farmers could improve outcomes.

These challenges can be approached through strategic, targeted interdisciplinary research, as outlined in Section 4.2.

3.3. SEAWEED LIVELIHOODS

A sustainable livelihoods approach to researching the seaweed industry

considers the interaction between seaweed farmers capital assets, vulnerability context, policies and institutions, livelihood strategies and livelihood outcomes (Figure 3.3.1). This framework will be used to conceptualise and conduct research in the SIP.

Due to COVID-19, we largely focused on desktop analysis, and the development of a household seaweed budget described here. The model is primarily concerned with the economics of seaweed cultivation, including cash income and (gendered) labour use, which are central to household livelihoods, but also incorporates most dimensions identified by Serrat (2017) above.

The bio-economic model of a seaweed household is designed to simulate household seaweed production systems, so that they can be understood, quantified and improved. Improvements can include those in productivity, profitability and – importantly – labour allocation of all family members with different roles. The findings can be used directly by households or incorporated into provincial and local policy and extension systems. The structure of the model is presented below.

The model, built in Excel, is based on a representative household in Pangkep Sub-district. Model design and parameters were obtained from studies on household seaweed cultivation (see above) and cross-checked with local experts. The model extends on previous approaches in several ways. First, it has a strong seasonality dimension, based on seaweed production cycles (45-90 days). This allows examination of model results (productivity, labour use, prices and profitability) at different times of the year, which can guide household decisions and extension. Second, the model uses the performance indicator of “returns to labour” (based on income and labour use recorded in labour diaries).

Households can then make decisions about how best to use their time for seaweed cultivation (by season) and compare with other activities.

Simulations run by the model will provide recommendations for households to adjust production by season, the length of the production cycle, use their own seedlings or buy in, use fertiliser, replace or prune seaweed, conduct different post-harvest management processes, or change the time of selling to maximise prices.

The budgets will be populated in the SIP through surveys, online data collection methods (for example labour diaries, price information) and through more qualitative means (household videos and chat groups). This process aims to develop and share the economic and production management skills of the households involved in the research.

3.3.1. RESEARCHING SEAWEED DURING COVID-19

COVID-19 has created new and significant challenges for seaweed farming communities, and limited the ability of researchers to enter these communities and explore these challenges. To counter this, we used remote sensing data to monitor seaweed production (see Section 2.0). The following sections describe the results of the analysis and consider the opportunities for expanding the use of this data.

3.3.2. SPATIALLY AND TEMPORALLY DETAILED PRODUCTION ESTIMATES

Figure 1.4.4.1a shows the results of the mapping exercise for 2018. 2018 was selected as a typical year, as 2019's atypical rainfall resulted in lower production, and the pandemic affected production dynamics in 2020. The image shows the very extreme seasonality of seaweed farming, with over two-thirds of production occurring in just three months of that year (Feb-April), and 90 per cent of production occurring in the first six months of that year (Figure 11).

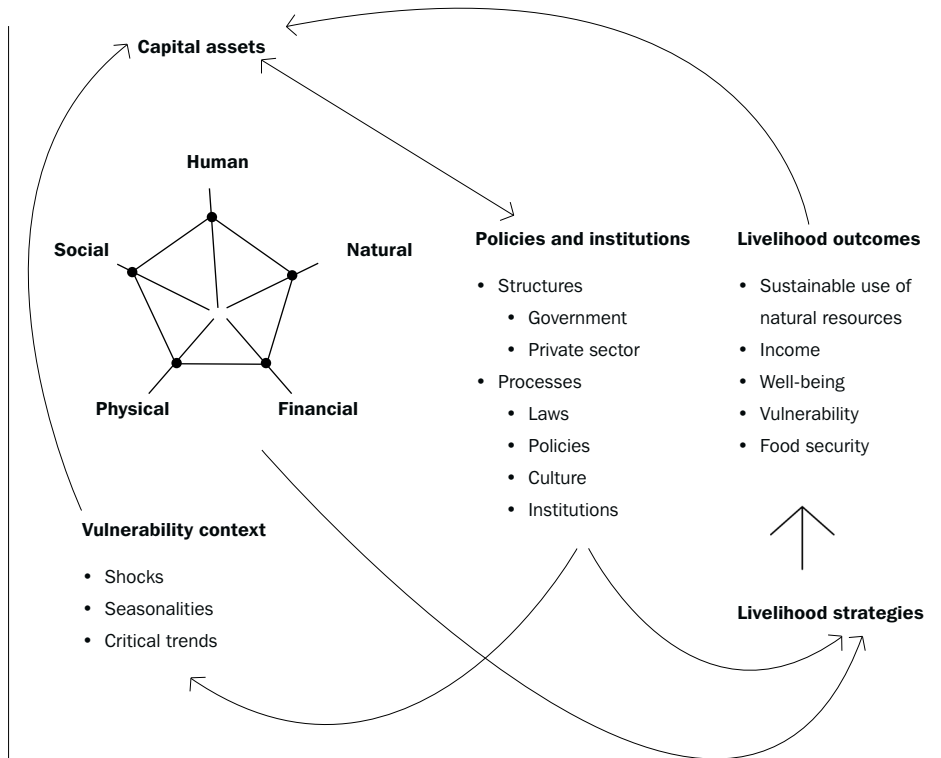


Figure 3.3.1. The Sustainable Livelihoods Approach. Reproduced from Serrat (2017)

Household seaweed production system

By production cycles

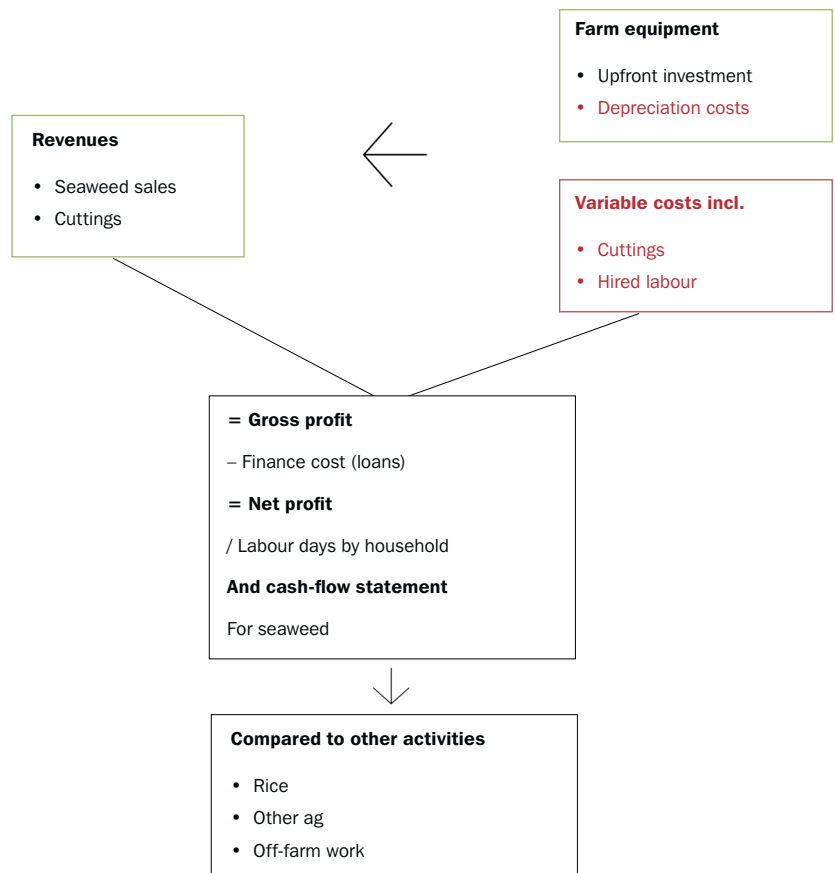


Figure 3.3.1a. Structure of a bio-economic model of a seaweed household in South Sulawesi

Mapping the area under seaweed production as viewed on satellite data against rainfall patterns yields the results shown in Figure 12. Seaweed growth rates are strongly affected by seasonal variations in salinity, light intensity and sea waves. Neish (2015) reports that growth rates at favourable times of year are as much as five times higher than in less favourable times. Seaweed growth rates are strongly affected by salinity levels in the water, which are closely linked to regional rainfall patterns (Bahiyah et al. 2019). The hydrocolloid seaweeds grown in Indonesia grow best at salinities of 29-34 ppt (Presidential Decree 33-2019, p. 22). This is slightly lower than the average seawater salinity, 35 ppt. From March to May, salinity in the Java sea off South Sulawesi is substantially lower than at other times due to high rainfall in surrounding areas (Bahiyah et al. 2019). Rainfall in South Sulawesi also increases river flows that transport nutrients to the sea (Fendi et al. 2019), although excessive rainfall may inhibit seaweed growth. During periods of favourable freshwater flows in the first half of the year, seaweed farming expands to cover offshore areas, and contracts again as river flows reduce and seawater enters the Java sea later in the year.

suggests either an increase in seaweed planting, or a decrease in seaweed harvesting. An increase in seaweed is likely due to a range of environmental, socio-economic and policy factors. Environmentally, 2020 is a La Niña year, and as a result, variations in rainfall and water temperature are expected.

In addition, the impact of the pandemic on employment across Indonesia could see increased labour availability to seaweed farming, particularly among people (especially youth) who were previously working or studying in urban areas. Furthermore, agricultural extension policy, such as the government seed distribution programs implemented in Pangkep in 2020, may make seaweed farming more favourable. Alternatively, it is possible that seaweed harvesting has decreased in response to low

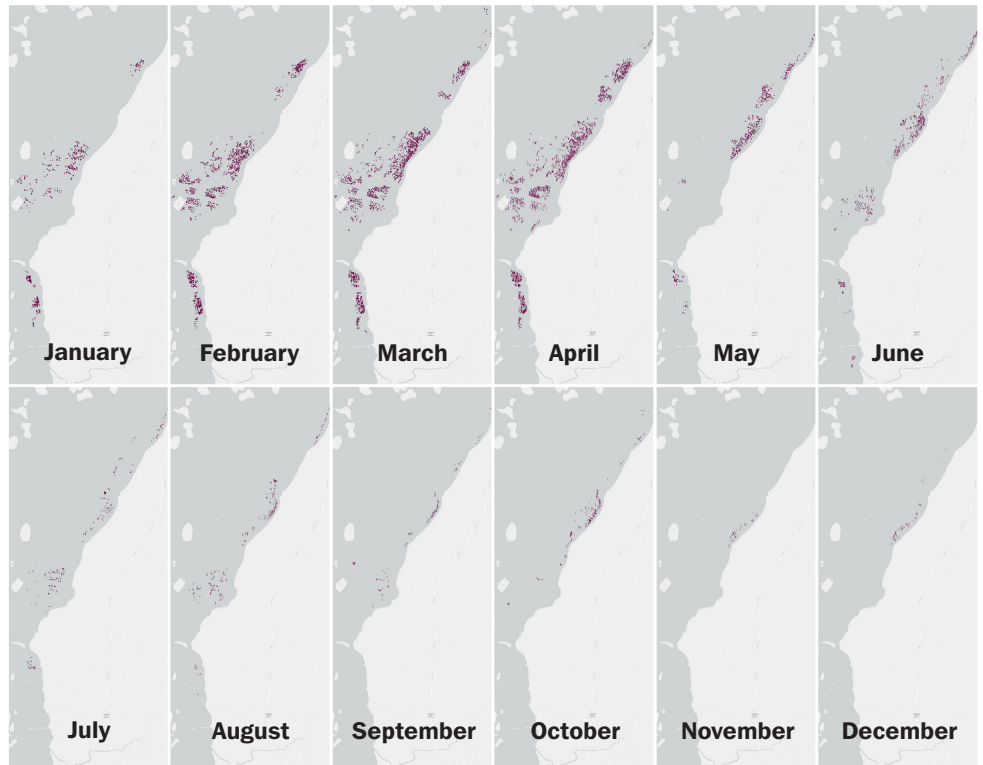


Figure 11 The area of seaweed planted along the mainland coastline of Pangkep in 2018

3.3.3. MONITORING THE SEAWEED INDUSTRY DURING COVID - 19

The travel restrictions associated with COVID-19 have limited the ability of researchers and government to explore the impacts of the pandemic. The use of satellite data offered a partial solution to this.

In 2020, the area under seaweed production from May to August was on average more than double that in previous years (Figure 14). No increase was observed from February to April, likely because the area suitable for seaweed farming was already close to capacity in these months. The higher area under seaweed cultivation

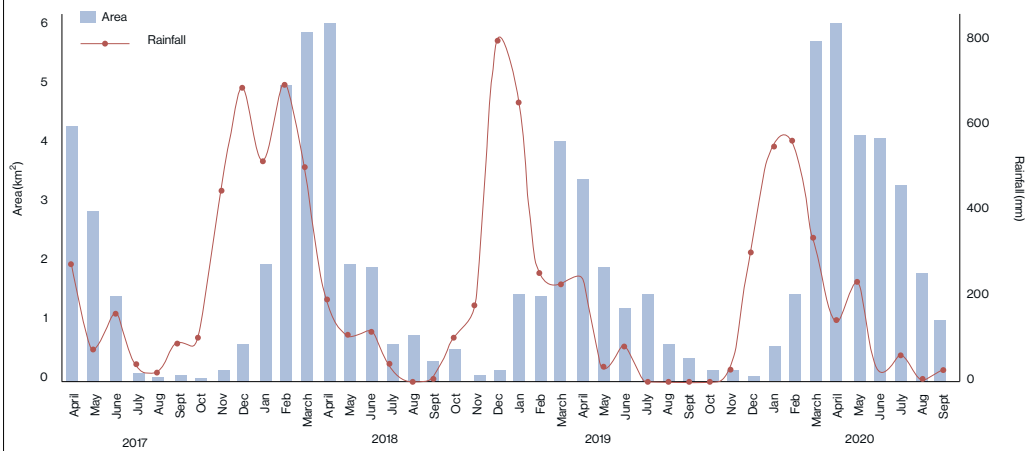


Figure 12 Area under seaweed production is highly seasonal and linked to rainfall patterns

Data Sources: BMKG (2020); Planet Team (2020)



prices, either as a storage technique or due to insufficient returns to labour. However, we have not found reports to suggest this. On the contrary, most reports suggest an increase in production during the pandemic, despite reduced government production targets (Ambari 2020).

A clear effect of COVID-19 has been a decline in seaweed prices alongside a decrease in the cost of labour. In Bali, reports suggest that many tourism operators affected by the pandemic have returned to seaweed farming, which many had left seeking better returns (BBC 2020; Pratiwi 2020). This is despite significant declines in seaweed farmgate prices (Figure 154). On average, prices have declined by 33 per cent in the South Sulawesi locations for which data is available since the start of the pandemic. This trend is reflected throughout the country, with average prices dropping from IDR 22,286 to IDR 13,961 since the pandemic began (Figure 8). As seaweed farming was already a marginally productive activity, such a decline could completely erase its profitability after accounting for input, capital depreciation, and labour costs. A report from Sulawesi suggested that in one region, prices fell from IDR 22,000 to IDR 13,000 while seed costs remained constant. This saw farmers reporting losses after accounting for seaweed seed and labour costs (Febriady 2020). Such an increase in production alongside a decrease in price is the inverse of the normal response. One explanation for this is lower input costs, in this case likely that of labour. It is suggested the decrease in seaweed prices is linked to temporary export suspensions during the pandemic, leading to a lack of storage facilities and falling prices (Kementerian Perdagangan Republik Indonesia 2020). These factors suggest significant disruption to the seaweed industry since the onset of the pandemic, with some suggesting the need for policy intervention to stabilise falling prices (Warta Ekonomi 2020).

3.3.4. INSIGHTS

The results of this analysis suggest that there is significant potential for newly available, high-resolution, high-frequency satellite data to be usefully employed in the seaweed industry to monitor production and inform policy. An accurate, spatially and temporally detailed understanding of seaweed farming patterns is important for a range of purposes, such as land and sea use planning and zoning, identifying technical issues in the industry, and improving industry integration, and for national and international statistical reporting processes.

By mapping and quantifying the area under seaweed production monthly, it has been possible to generate disaggregated production estimates that illustrate the very dramatic changes in seaweed production patterns throughout the year. This data makes possible a range of analyses with important policy implications.

Firstly, detailed production data for the province would enable analysis of the impact of various environmental factors on seaweed growth rates. Some studies

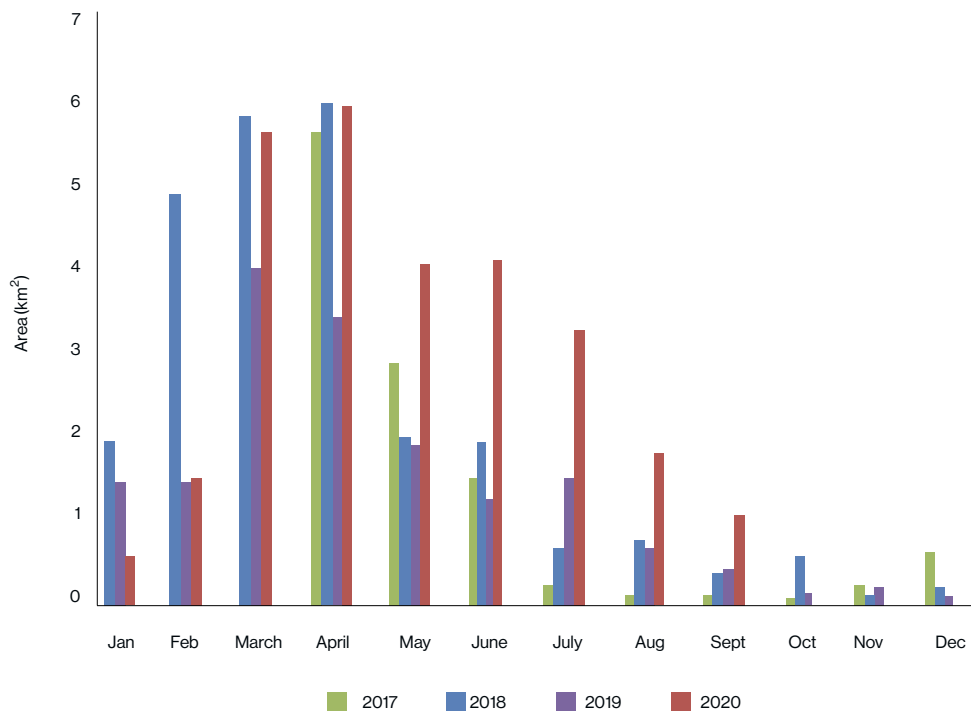


Figure 13 Area under seaweed production from May – August 2020 is significantly higher than in previous years (satellite data)

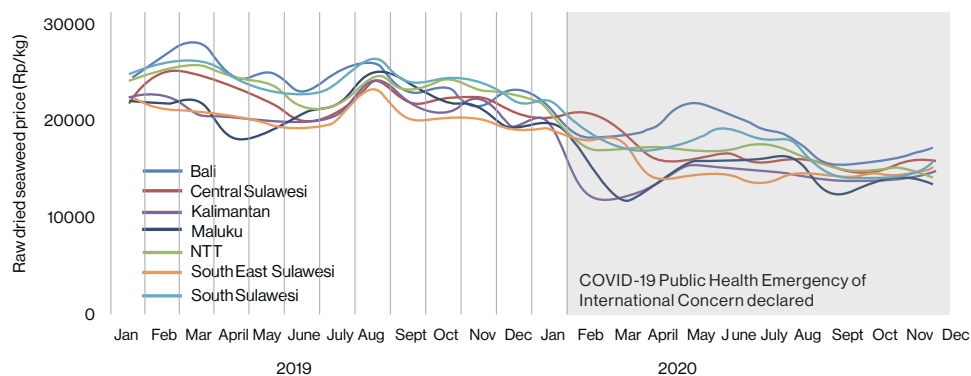


Figure 14 Purchase price for dried Cottoni (*Kappaphycus alvarezii*) across Indonesia have declined an average of 37 per cent from January to September 2020. Data Source: Average monthly price reported on JaSuDa (2020)



There is significant potential for newly available, high-resolution, high-frequency satellite data to be usefully employed in the seaweed industry to monitor production and inform policy... This data provides a very useful source of information for refining official estimate.

have attempted to assess the relative importance of these factors (Geromel de Góes & Perpetuo Reis 2012) but have been limited by constraints on the size of the study and the number of locations considered. Understanding seasonal patterns of seaweed farming across a large area – for example, if satellite data were analysed for the whole of South Sulawesi, or at a number of locations throughout Indonesia – this data could be used to generate robust models of the likely impact of a range of environmental factors on seaweed farming.

Secondly, this data could be used to undertake logistics modelling across the province, and would vastly increase the accuracy of logistics models. This would prove useful in planning policy interventions to support sustainable development of the seaweed industry.

The satellite data provided here has limitations. The accuracy of the assessment is limited by the resolution of the imagery, and the presence of cloud cover. This study used monthly basemaps that represent a range rather than a point of time. And while seaweed plots can be identified with reasonable accuracy in shallow water, this is harder in deeper water. The colour gradient in coastal waters introduces challenges for automated image processing and makes processing of imagery over large areas difficult, since plots are identified by shape more than by colour. In addition, the variable measured is area under production rather than weight produced. Since the growth rate often varies by up to five times between seasons (Neish 2015), seasonal production differences may be more or less pronounced than estimated by this data, depending on whether farmers respond to lower growth rates by reducing production (and perhaps diverting their labour to more productive activities) or increasing production (as may occur if other income-generation activities are

not available). Both the satellite data and the quarterly production estimates generate estimates of production based on area under cultivation, and do not account for losses prior to harvest or during drying or storage.

Despite these limitations, the data presented in this paper provides an additional source for mapping seaweed cultivation which is easy to generate across large areas to a high level of detail. It could be usefully employed to benchmark other government production estimates and improve their accuracy, and as a point of comparison for a range of farming locations. This data therefore provides a very useful source of information for refining official estimates, as a cross-verification of sources is expected to lead to a more accurate picture.

Finally, this data can provide very fast and up-to-date information on the impact on farmers of significant environmental and socio-economic events, such as the COVID-19 pandemic.

4.0. CONCLUSION AND RECOMMENDATIONS

4.1. CONCLUSION

This pilot project contributes new knowledge in four key areas: 1) an in-depth and comprehensive understanding of change in seaweed production worldwide, in Indonesia and South Sulawesi; 2) an in-depth and comprehensive review of seaweed value chains, including lessons from previous studies and other areas; 3) a framework and tools from which to analyse the livelihoods of seaweed farmers; and 4) an introduction to the use of remote sensing data for monitoring the seaweed industry.

Overall, this provides important insights which support the development and implementation of the SIP.

4.2. RECOMMENDATIONS

We have developed a series of recommended areas for further investigation, which underpin the design of our SIP. These are structured around the same sections as used in the value chain analysis in Section 1.4.2.

4.2.1. SUPPORT IMPROVED, SUSTAINABLE PHYCONOMIC PRACTICES

The first key area of research is to further the development of improved and sustainable phyconomic practices. This should involve, firstly, comprehensive mapping of seaweed production patterns around the province, using satellite data as described in Section 1.4.4. Secondly, characterisation of the factors affecting seaweed growth rate and carrageenan yield should

be undertaken, and these should be mapped against production patterns to develop a better understanding of the seasonality of production. Thirdly, the environmental effects of seaweed cultivation should be examined, including the effect on marine biodiversity (particularly in Marine Protected Areas off the coastline of Pangkep) and on ocean plastics.

4.2.2. SUPPORT SUSTAINABLE AND JUST LIVELIHOOD TRANSITIONS

The next key area of research is to understand the social and economic effects of transitions to seaweed farming. This should include a thorough investigation of seaweed livelihoods, including both quantitative methods (to benchmark seaweed producers against a range of other Indonesian households with different livelihood strategies) and qualitative methods (to understand the drivers and motivations of seaweed farmers and the range of social effects associated with seaweed farming). This should be supported by modelling of household budgets such as that initially developed in Section 1.4.3.

4.2.3. SUPPORT AN EQUITABLE AND EFFICIENT DOMESTIC MARKETING SYSTEM

Research is required to understand the domestic marketing system, including the role of traders of different scales operating in different locations. This should involve a range of qualitative and quantitative methods to characterise the marketing systems, the margins captured by different actors and the drivers of different benefits to different actors in different

locations. It should also involve a logistics analysis of seasonal seaweed trade flows around the province, which could be supported by satellite data as indicated in Section 1.4.4. In addition, research to improve seaweed drying practices should be undertaken, including the development of a low-cost design for constructing a dryer from local materials. Tests on the effects of changed drying practices on the domestic marketing system should be undertaken.

4.2.4. SUPPORT AN EFFICIENT AND PROFITABLE PROCESSING SECTOR

Further research to support technical innovation in processing is needed. This includes efforts to develop new products (such as food, pharmaceuticals, fertilisers and biofuels) from seaweed, as well as innovation to reduce waste streams, and develop more efficient processes such as using Multi-Stream Zero Effluent processing.

4.2.5. SUPPORT INDONESIA'S COMPETITIVENESS IN GLOBAL SUPPLY CHAINS

The fifth key research priority identified is the characterisation of global value chains. The pilot project highlighted the increasing importance of the seaweed industry to Indonesia's economy and the important role Indonesian seaweed plays in global trade flows. Further research should expand this analysis by mapping and quantifying global trade flows of seaweed products, characterising international carrageenan markets and further developing our analysis of Indonesia's competitive advantage in the global seaweed value chain.

4.2.6. SUPPORT THE SUSTAINABLE DEVELOPMENT OF THE INDUSTRY THROUGH EFFECTIVE POLICY

Finally, research from the above five agendas should be analysed to provide recommendations into industry policies, laws and institutions; to develop communication technologies and recommendations to develop industry information and technical information systems; and to provide recommendations on marine planning and zoning.

4.3. REFERENCES

- Adharini, R. I., Suyono, E. A., Suadi, Jayanti, A. D., & Setyawan, A. R. (2019). A comparison of nutritional values of *Kappaphycus alvarezii*, *Kappaphycus striatum*, and *Kappaphycus spinosum* from the farming sites in Gorontalo Province, Sulawesi, Indonesia. *Journal of Applied Phycology*, 31(1), 725-730. doi:10.1007/s10811-018-1540-0
- Adnan, H., & Porse, H. (1987). Culture of *Euचेuma cottonii* and *Euचेuma spinosum* in Indonesia. *Hydrobiologia*, 151(1), 355-358. doi:10.1007/BF00046152
- Aeni, O., Aslan, L., Iba, W., Patadjai, A., Rahim, M., & Balubi, M. (2019). Effect of different seedling sources on growth and carrageenan yield of seaweed *kappaphycus alvarezii* cultivated in Marobo Waters, Muna Regency, Southeast (Se) Sulawesi, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 382, 012015. doi:10.1088/1755-1315/382/1/012015
- Afiah, R., Supartono, W., & Suwondo, E. (2019). Potential of heavy metal contamination in cultivated red seaweed (*Gracilaria* sp. and *Euचेuma cottonii*) from coastal area of Java, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 365, 012024. doi:10.1088/1755-1315/365/1/012024
- Ahmad, R., Surif, M., Ramli, N., Yahya, N., Nor, A., & Bekbayeva, L. (2011). A preliminary study on the agar content and agar gel strength of *gracilaria manilaensis* using different agar extraction processes. *World Applied Sciences Journal*, 15, 184-188.
- Aji, B.P., Prayitno, C.H. & Munasik, M. (2019). The Effect of Red Seaweed (*Gracilaria* spp.) Supplementation in Beef Cattle Feed to digestibility of dry matter and organic matter with in vitro method. *Journal of Animal Science and Technology* 1(3).
- Akrim, D., Dirawan, G., & Rauf, B. (2019). Perkembangan Budidaya Rumput Laut Dalam Meningkatkan Perekonomian Masyarakat Pesisir Di Indonesia. *UNM Environmental Journals*, 2, 52. doi:10.26858/uej.v2i2.10089
- Ali, M., Fudholi, A., Sulaiman, J., Muthuvalu, M. S., Rusland, M. H., Yasir, S., & Hurtado, A. Q. (2017). Post-Harvest Handling of *Euचेumatoid* Seaweeds. In A. Q. Hurtado, A. T. Critchley, & I. C. Neish (Eds.), *Tropical Seaweed Farming Trends, Problems and Opportunities: Focus on Kappaphycus and Euचेuma of Commerce* (pp. 131-146). *Gewerbstrasse, Switzerland: Springer*.
- Álvarez, V., Flórez Fernández, N., Torres, M. D., & Domínguez. (2019). Successful Approaches for a Red Seaweed Biorefinery. *Marine Drugs*, 17, 620. doi:10.3390/md17110620
- Ambari, M. (2020). Produksi Rumput Laut di Pusaran Pandemi COVID-19. *Mongabay: Situs Berita Lingkungan*, 22 April, available at <https://www.mongabay.co.id/2020/04/22/produksi-rumput-laut-di-pusaran-pandemi-covid-19/>
- Anugrahayu, N., Darwanto, D., & Jamhari, J. (2017). The influence of value added tax exemption towards processed seaweed exports of Indonesia Berkala Ilmiah *AGRIDEVINA*, 6. doi:10.33005/adv.v6i2.1037
- Arsyad M, Nuddin A, Zamhuri M Y and Yusuf S. (2014). The Poverty Reality of Coastal and Agriculture: How Severe the Seaweed Farmers and Cocoa Smallholders Are? *International Journal of Agricultural System*, 2 (2) :119-31
- Aslan, L., Patadjai, R., Ruslaini, Effendy, I., Sarita, A., Amina, S., . . . Armin. (2019a). Seasonal variation in growth and carrageenan yield of *Kappaphycus alvarezii* (Doty) Doty farmed using mass selection in Bungin Permai Coastal Waters, South Konawe District, Southeast (SE) Sulawesi, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 370, 012060. doi:10.1088/1755-1315/370/1/012060
- Aslan, L. O. M., Iba, W., Patadjai, A. B., Rahim, M., Febriyanti, F., Raznawati, . . . Armin, A. (2019b). Effect of Different Initial Weight on Growth and Carrageenan Yield of *Kappaphycus alvarezii* (Gigartinales, Rhodophyta) farmed using Seedlings Produced from Mass Selection Combined with Tissue-Cultured Method C3 - *IOP Conference Series: Earth and Environmental Science*. 382(1). doi:10.1088/1755-1315/382/1/012007
- Aslan, L., Supendy, R., Taridala, S., Hafid, H., Sifatu, W., Sailan, Z., & Niampe, L. (2018). Income of Seaweed Farming Households: A Case Study From Lemo of Indonesia. *IOP Conference Series: Earth and Environmental Science*, 175, 012221. doi:10.1088/1755-1315/175/1/012221
- Aslan, L., Iba, W., Bolu, L., Ingram, B., Gooley, G., & De Silva, S. (2015). Mariculture in SE Sulawesi, Indonesia: Culture practices and the socio economic aspects of the major commodities. *Ocean & Coastal Management*, 116, 44-57. doi:10.1016/j.ocecoaman.2015.06.028
- Ateweberhan, M., Rougier, A., & Rakotomahazo, C. (2015). Influence of environmental factors and farming technique on growth and health of farmed *Kappaphycus alvarezii* (cottonii) in south-west Madagascar. *Journal of Applied Phycology*, 27(2), 923-934. doi:10.1007/s10811-014-0378-3
- Azanza, R. V., & Ask, E. (2017). Reproductive Biology and Eco-physiology of Farmed *Kappaphycus* and *Euचेuma*. In A. Q. Hurtado, A. T. Critchley, & I. C. Neish (Eds.), *Tropical Seaweed Farming Trends, Problems and Opportunities: Focus on Kappaphycus and Euचेuma of Commerce* (pp. 45-54). *Gewerbstrasse, Switzerland: Springer*.
- Badan Meteorologi, Klimatologi, dan Geofisika (BMKG) (2020). <http://dataonline.bmkg.go.id/>
- Bahiyah, A., Wirasatriya, A., Marwoto, J., Handoyo, G., & Anugrah, A. (2019). Study of seasonal variation of sea surface salinity in Java Sea and its Surrounding Seas using SMAP satellite. *IOP Conference Series: Earth and Environmental Science* 246, 012043.
- BBC (2020). Covid-19: Pariwisata Bali terpuruk, rumput laut menyelamatkan warga Nusa Lembongan, *BBC News: Indonesia*, 16 September, available at <https://www.bbc.com/indonesia/majalah-54172281>
- BMKG (2020). Badan Meteorologi, Klimatologi, dan Geofisika (BMKG) online data service, available at <https://www.bmkg.go.id/>.
- Beltran-Gutierrez, M., Ferse, S. C., Kunzmann, A., Stead, S. M., Msuya, F. E., Hoffmeister, T. S., & Slater, M. J. (2016). Co-culture of sea cucumber *Holothuria scabra* and red seaweed *Kappaphycus striatum*. *Aquaculture Research*, 47(5), 1549-1559. doi:10.1111/are.12615
- Blankenhorn, S. U. (2007). Seaweed farming and artisanal fisheries in an Indonesian seagrass bed: Complementary or competitive usages? . *Alfred Wegener Institute for Polar and Marine Research*.
- Bolton, J. (2019). The problem of naming commercial seaweeds. *Journal of Applied Phycology*, 1-8. doi:10.1007/s10811-019-01928-0
- Busthanul, N., Diansari, P., Summase, I., Amiruddin, A., Lanuhu, N., Viantika, N., . . . Permadi, M. (2019). Agribusiness development economic study of seaweed. *IOP Conference Series: Earth and Environmental Science*, 343, 012110. doi:10.1088/1755-1315/343/1/012110
- Campbell, I., Kambey, C., Mateo, J., Rusekwa, S., Hurtado, A., Msuya, F., . . . Cottier-Cook, E. (2019). Biosecurity policy and legislation for the global seaweed aquaculture industry. *Journal of Applied Phycology*. doi:10.1007/s10811-019-02010-5
- Campbell, R., & Hotchkiss, S. (2017). Carrageenan Industry Market Overview. In A. Q. Hurtado, A. T. Critchley, & I. C. Neish (Eds.), *Tropical Seaweed Farming Trends, Problems and Opportunities: Focus on Kappaphycus and Euचेuma of Commerce* (pp. 193-206). *Gewerbstrasse, Switzerland: Springer*.
- Castelar, B., de Siqueira, M. F., Sánchez-Tapia, A., & Reis, R. P. (2015). Risk analysis using species distribution modeling to support public policies for the alien alga *Kappaphycus alvarezii* aquaculture in Brazil. *Aquaculture*, 446, 217-226. doi:10.1016/j.aquaculture.2015.05.012
- Centre for the Promotion of Imports from developing countries (2019). *Value Chain Analysis Indonesia Seaweed Extracts*. Retrieved from https://www.cbi.eu/sites/default/files/2019_vca_indonesia_seaweed_extracts.pdf
- Chacin, D., Stallings, C., Eggertsen, M., Åkerlund, C., Halling, C., & Berkström, C. (2020). Altered tropical seascape influence patterns of fish assemblage and ecological functions in the Western Indian Ocean. *Scientific Reports*, 10. doi:10.1038/s41598-020-68904-4
- Cottier-Cook, E., Gachon, C., Bass, D., Stentiford, G., Brodie, J., Shaxson, L., . . . al, e. (2019). The aquaculture and aliens paradox: could the reliance of the seaweed aquaculture industry on non-native species lead to its' downfall?
- Cuatón, G. (2019). A post-disaster gendered value chain analysis on seaweed farming after Super Typhoon Haiyan in the Philippines. *Journal of Enterprising Communities: People and Places in the Global Economy*, ahead-of-print. doi:10.1108/JEC-11-2018-0091
- de Góes, H. G., & Reis, R. P. (2012). Temporal variation of the growth, carrageenan yield and quality of *Kappaphycus alvarezii* (Rhodophyta, Gigartinales) cultivated at Sepetiba bay, southeastern Brazilian coast. *Journal of Applied Phycology*, 24(2), 173-180. doi:10.1007/s10811-011-9665-4
- de la Torre-Castro, M., Fröcklin, S., Börjesson, S., Okupnik, J., & Jiddawi, N. S. (2017). Gender analysis for better coastal management – Increasing our understanding of social-ecological seascapes. *Marine Policy*, 83, 62-74. doi:https://doi.org/10.1016/j.marpol.2017.05.015

- DKP (Dinas Kelautan dan Perikanan) SulSel 2020. Data produksi sementara komoditas unggulan perikanan budidaya.
- Dos Santos, A. A., Dorow, R., Araújo, L. A., & Hayashi, L. (2018). Socioeconomic analysis of the seaweed *Kappaphycus alvarezii* and mollusks (*Crassostrea gigas* and *perna perna*) farming in Santa Catarina state, southern Brazil. *Custos e Agronegocio*, 14(4), 443-472. Retrieved from <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85059472721&partnerID=40&md5=331f6c24d22ed2f2be595f217ba804c>
- FAO. (2013). Social and economic dimensions of carrageenan seaweed farming. Available at <http://www.fao.org/3/a-i3344e.pdf>.
- FAO (2020). Global Aquaculture Production 1950-2018. <http://www.fao.org/fishery/statistics/global-aquaculture-production/query/en>
- Febriyanti, F., Aslan, L., Iba, W., Patadjai, A., & Nurdin, A. (2019). Effect of various planting distances on growth and carrageenan yield of *Kappaphycus alvarezii* (doty) using seedlings produced from mass selection combined with tissue-cultured method. *IOP Conference Series: Earth and Environmental Science*, 278, 012027. doi:10.1088/1755-1315/278/1/012027
- Fendi, F., Lili, L., Rakhfid, A., & Rochmady, R. (2019). The growth of seaweed (*Eucheuma cottonii*) at different fertilizing doses in the waters of the village of Ghonebalano, Duruka District, Muna Regency, Indonesia. *Akuatikisile: Jurnal Akuakultur, Pesisir dan Pulau-Pulau Kecil*, 3, 17. doi:10.29239/j.akuatikisile.3.1.17-22
- Galon, F. (2019). Developing a sustainable community-based farm operation for seaweed growers of Palawan, Philippines. *The Scientific Journal of the Palawan Council for Sustainable Development* 5(1).
- Gao, G., Burgess, J., Wu, M., Wang, S., & Gao, K. (2020). Using macroalgae as biofuel: current opportunities and challenges. *Botanica Marina*. doi:10.1515/bot-2019-0065
- Geromel de Góes, H. & Perpetuo Reis, R. (2012). Temporal variation of the growth, carrageenan yield and quality of *Kappaphycus alvarezii* (Rhodophyta, Gigartinales) cultivated at Sepetiba bay, southeastern Brazilian coast, *Journal of Applied Phycology* 24: 173-180.
- Halling, C., Wikström, S. A., Lilliesköld-Sjöo, G., Mörk, E., Lundsör, E., & Zuccarello, G. C. (2013). Introduction of Asian strains and low genetic variation in farmed seaweeds: Indications for new management practices. *Journal of Applied Phycology*, 25(1), 89-95. doi:10.1007/s10811-012-9842-0
- Hayashi, L., Faria, G. S. M., Nunes, B. G., Zitta, C. S., Scariot, L. A., Rover, T., . . . Bouzon, Z. L. (2011). Effects of salinity on the growth rate, carrageenan yield, and cellular structure of *Kappaphycus alvarezii* (Rhodophyta, Gigartinales) cultured in vitro. *Journal of Applied Phycology*, 23(3), 439-447. doi:10.1007/s10811-010-9595-6
- Hayashi, L., Paula, E., & Chow, F. (2007). Growth rate and carrageenan analyses in four strains of *Kappaphycus alvarezii* (Rhodophyta, Gigartinales) farmed in the subtropical waters of São Paulo State, Brazil. *Journal of Applied Phycology*, 19(5), 393-399. doi:10.1007/s10811-006-9135-6
- Hayashi, L., Reis, R. P., dos Santos, A. A., Castelar, B., Robledo, D., de Vega, G. B., . . . Hurtado, A. Q. (2017). The Cultivation of *Kappaphycus* and *Eucheuma* in Tropical and Sub-Tropical Waters. In A. Q. Hurtado, A. T. Critchley, & I. C. Neish (Eds.), *Tropical Seaweed Farming Trends, Problems and Opportunities: Focus on Kappaphycus and Eucheuma of Commerce* (pp. 55-90). *Gewerbstrasse, Switzerland: Springer*.
- Hossain, M. S., Bujang, J. S., Zakaria, M. H., & Hashim, M. (2016). Marine and human habitat mapping for the Coral Triangle Initiative region of Sabah using Landsat and Google Earth imagery. *Marine Policy*, 72(C), 176-191. doi:10.1016/j.marpol.2016.07.003
- Hurtado, A., Neish, I., & Critchley, A. (2019). Phycomy: the extensive cultivation of seaweeds, their sustainability and economic value, with particular reference to important lessons to be learned and transferred from the practice of eucheumatoid farming. *Phycologia*, 58, 472-483. doi:10.1080/00318884.2019.1625632
- Hurtado, A. Q., Gerung, G. S., Yasir, S., & Critchley, A. T. (2014). Cultivation of tropical red seaweeds in the BIMP-EAGA region. *Journal of Applied Phycology*, 26(2), 707-718. doi:10.1007/s10811-013-0116-2
- Hurtado, A. Q., Magdugo, R., & Critchley, A. T. (2020). Selected red seaweeds from the Philippines with emerging high-value applications. In *Advances in Botanical Research: Academic Press*.
- Hurtado, A. Q., Neish, I. C., & Critchley, A. T. (2015). Developments in production technology of *Kappaphycus* in the Philippines: more than four decades of farming. *Journal of Applied Phycology*, 27(5), 1945-1961. doi:10.1007/s10811-014-0510-4
- JaSuDa (2020). JaSuDa.net: PT. Jaringan Sumber Daya. Informasi Harga. <https://jasuda.net/infopsr.php>
- Kambey, C., Campbell, I., Sondak, C., Nor, A., Lim, P., & Cottier-Cook, E. (2020). An analysis of the current status and future of biosecurity frameworks for the Indonesian seaweed industry. *Journal of Applied Phycology*. doi:10.1007/s10811-019-02020-3
- Kamuli, S., & Amin, B. (2018). Women and Organizational Capabilities in Seaweed Production in North Gorontalo. *MIMBAR : Jurnal Sosial dan Pembangunan*, 34, 1-10. doi:10.29313/mimbar.v34i1.2764
- Katili, R. A., Dali, F. A., & Yusuf, N. (2019). Quality of dried seaweed *Kappaphycus alvarezii* with traditional drying methods from North Gorontalo C3 - IOP Conference Series: Earth and Environmental Science. 278(1). doi:10.1088/1755-1315/278/1/012039
- Kelly, E., Cannon, A., & Smith, J. (2020). Environmental impacts and implications of tropical carrageenophyte seaweed farming. *Conservation Biology*, 34. doi:10.1111/cobi.13462
- Khatulistiwa, T. S., Noviendri, D., Munifah, I., & Melanie, S. (2019). Bioactivities of red seaweed extracts from Banten, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 404, 012065. doi:10.1088/1755-1315/404/1/012065
- Kunjuraman, V., Hossin, A., & Hussin, R. (2019). Women in Malaysian Seaweed Industry: Motivations and Impacts. *Kajian Malaysia*, 37, 49-74. doi:10.21315/km2019.37.2.3
- Kunzmann, A., Beltran Gutierrez, M., Fabiani, G., Namukose, M., & Msuya, F. (2018). Integrated seaweed – sea cucumber farming in Tanzania.
- Langford, A., Waldron, S., Sulphahri, Saleh, H. (2021). Monitoring the COVID-19-affected Indonesian seaweed industry using remote sensing data. *Marine Policy* 127(104431). <https://doi.org/10.1016/j.marpol.2021.104431>
- Langford, A., Waldron, S. and Sulphahri (2020a). Seaweed farmers' flexibility makes Indonesia a major player in global markets, but there is more work to be done. *The Conversation*. <https://theconversation.com/seaweed-farmers-flexibility-makes-indonesia-a-major-player-in-global-markets-but-there-is-more-work-to-be-done-150371>
- Langford, A., Waldron, S. and Sulphahri (2020b). Fleksibilitas petani menjadikan Indonesia pemain utama di pasar rumput laut global, meski masih banyak yang harus dikerjakan *The Conversation*. <https://theconversation.com/fleksibilitas-petani-menjadikan-indonesia-pemain-utama-di-pasar-rumput-laut-global-meski-masih-banyak-yang-harus-dikerjakan-150649>
- Largo, D. B., Chung, C. S., Phang, S. M., Gerung, G. S., & Sondak, C. (2017). Impacts of Climate change on *Eucheuma-Kappaphycus* Farming. In A. Q. Hurtado, A. T. Critchley, & I. C. Neish (Eds.), *Tropical Seaweed Farming Trends, Problems and Opportunities: Focus on Kappaphycus and Eucheuma of Commerce* (pp. 121-130). *Gewerbstrasse, Switzerland: Springer*.
- Larson, S. Stoeckl, N., Fachry, M.E., Mustafa, M.D., Lapong, I., Purnomo, A.H., Rimmer, M.A. & Paul, N.A. (2020). Women's well-being and household benefits from seaweed farming in Indonesia. *Aquaculture* 530(735711).
- Li R, Li J, Wu CY (1990) Effect of ammonium on growth and carrageenan content in *Kappaphycus alvarezii* (Gigartinales, Rhodophyta). *Hydrobiologia* 204-205:499-503.
- Loureiro, R. R., Cornish, M. L., & Neish, I. C. (2017). Applications of Carrageenan: With Special Reference to Iota and Kappa Forms and Derived from the Eucheumatoid Seaweeds. In A. Q. Hurtado, A. T. Critchley, & I. C. Neish (Eds.), *Tropical Seaweed Farming Trends, Problems and Opportunities: Focus on Kappaphycus and Eucheuma of Commerce* (pp. 165-172). *Gewerbstrasse, Switzerland: Springer*.
- Mariño, M., Breckwoldt, A., Teichberg, M., Kase, A., & Reuter, H. (2019). Livelihood aspects of seaweed farming in Rote Island, Indonesia. *Marine Policy*, 107(103600). doi:10.1016/j.marpol.2019.103600
- Mateo, J., Campbell, I., Cottier-Cook, E., Luhan, M., Ferriols, V. M. E., & Hurtado, A. (2020). Analysis of biosecurity-related policies governing the seaweed industry of the Philippines. *Journal of Applied Phycology*. doi:10.1007/s10811-020-02083-7
- Meinita, M. D. N., Marhaeni, B., Jeong, G. T., & Hong, Y. K. (2015). Seaweed bioethanol production: Its potentials and challenges. *Marine Bioenergy: Trends and Developments*, 245-255. doi:10.1201/b18494
- Mendoza, W. G., Ganzon-Fortes, E. T., Villanueva, R. D., Romero, J. B., & Montaña, M. N. E. (2006). Tissue age as a factor affecting carrageenan quantity and quality

- in farmed *Kappaphycus striatum* (Schmitz) Doty ex Silva. *Botanica Marina*, 49(1), 57-64. doi:10.1515/BOT.2006.007
- Ministry of Marine Affairs and Fisheries Republic of Indonesia (2019). Marine and Fisheries Figure 2018, Data Information Centre.
- Mirera, D., Kimathi, A., Ngarari, M., Magondu, E., Wainaina, M., & Ototo, A. (2020). Societal and environmental impacts of seaweed farming in relation to rural development: The case of Kibuyuni village, south coast, Kenya. *Ocean & Coastal Management*, 194, 105253. doi:10.1016/j.ocecoaman.2020.105253
- Msuya, F., & Hurtado, A. (2017). The role of women in seaweed aquaculture in the Western Indian Ocean and South-East Asia. *European Journal of Phycology*, 52, 482-494. doi:10.1080/09670262.2017.1357084
- Msuya, F. E., & Porter, M. (2014). Impact of environmental changes on farmed seaweed and farmers: the case of Songo Songo Island, Tanzania. *Journal of Applied Phycology*, 26(5), 2135-2141. doi:10.1007/s10811-014-0243-4
- Mulyati, H. (2015). Supply Chain Risk Management Study of the Indonesian Seaweed Industry. University of Göttingen, Retrieved from <https://ediss.uni-goettingen.de/handle/11858/00-1735-0000-0022-606A-8>
- Mulyati, H., & Geldermann, J. (2017). Managing risks in the Indonesian seaweed supply chain. *Clean Technologies and Environmental Policy*, 19(1), 175-189. doi:10.1007/s10098-016-1219-7
- Munandar, A., Surilayani, D., Haryati, S., Sumantri, M.H., Aditia, R.P. and Pratama, G. (2019). Characterization flour of two seaweeds (*Gracilaria* spp. And *Kappaphycus alvarezii*) for reducing consumption of wheat flour in Indonesia. IOP Conference Series: Earth and Environmental Science 383 (012009).
- Neish, I. (2015). A diagnostic analysis of seaweed value chains in Sumenep Regency, Madura Indonesia.
- Neish, I., & Suryanarayan, S. (2017). Development of Eucheumatoid Seaweed Value-Chains Through Carrageenan and Beyond. In *Developments in Applied Phycology* (pp. 173-192).
- Neish, I. C. (2013a). Feasibility Assessment for a Zanzibar MUZE Seaweed Processing Facility (ZanMUZE). Retrieved from https://open.unido.org/api/documents/4313856/download/3ADI_Feasibility%20assessment%20for%20Zanzibar.pdf
- Neish, I. C. (2013b). Seaweed Value Chain Assessment of Zanzibar: Creating value for the poor. Retrieved from https://open.unido.org/api/documents/4315887/download/3ADI_Seaweed%20value%20chain%20assessment.pdf
- Nor, A. (2016). Exploring and understanding the seaweed marketing system in Malaysia.
- Nor, A. (2017). The Effect of Seaweed Aquaculture Cooperatives on Sustainable Livelihoods in Malaysia.
- Nor, A., Gray, T., Caldwell, G., & Stead, S. (2016). Is a cooperative approach to seaweed farming effectual? An analysis of the seaweed cluster project (SCP), Malaysia. *Journal of Applied Phycology*. doi:10.1007/s10811-016-1025-y
- Nor, A. M., Gray, T. S., Caldwell, G. S., & Stead, S. M. (2019). A value chain analysis of Malaysia's seaweed industry. *Journal of Applied Phycology*. doi:10.1007/s10811-019-02004-3
- Nurjanah, Nurilmala, M., Hidayat, T. & Sudirdjo, F. (2016). Characteristics of Seaweed as Raw Materials for Cosmetics. *Aquatic Procedia* 7:177-180. doi. org/10.1016/j.aqpro.2016.07.02
- Nursidi, Ali, S. A., Anshary, H., & Tahya, A. M. (2017). Environmental parameters and specific growth of *Kappaphycus alvarezii* in Saugi Island, South Sulawesi Province, Indonesia. *AAFL Bioflux*, 10(4), 698-702. Retrieved from <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85026402999&partnerID=40&md5=d12c87ad875552bb201594326845a180>
- Nuryadi, A., Sara, L., Rianda, L., & Bafadal, A. (2019). A model for developing seaweed agribusiness in South Konawe, Southeast Sulawesi, Indonesia. *AAFL Bioflux*, 12, 1718-1725.
- Ortiz-Tena, J. G., Schieder, D., & Sieber, V. (2017). Carrageenan and More: Biorefinery Approaches with Special Reference to the Processing of *Kappaphycus*. In A. Q. Hurtado, A. T. Critchley, & I. C. Neish (Eds.), *Tropical Seaweed Farming Trends, Problems and Opportunities: Focus on Kappaphycus and Eucheuma of Commerce* (pp. 155-164). *Gewerbstrasse, Switzerland: Springer*.
- Pang, T., Liu, J., Liu, Q., Li, H., & Li, J. (2015). Observations on pests and diseases affecting a eucheumatoid farm in China. *Journal of Applied Phycology*, 27(5), 1975-1984. doi:10.1007/s10811-014-0507-z
- Pangan, R., Ampo, M., & Barredo, Y. (2020). Optimization of the floating-type seaweed dryer. *Aquacultural Engineering*, 89, 102068. doi:10.1016/j.aquaeng.2020.102068
- Periyasamy, C., Anantharaman, P., & Balasubramanian, T. (2014). Social upliftment of coastal fisher women through seaweed (*Kappaphycus alvarezii* (Doty) Doty) farming in Tamil Nadu, India. *Journal of Applied Phycology*, 26(2), 775-781. doi:10.1007/s10811-013-0228-8
- Planet Team (2020). Planet Application Program Interface: In Space for Life on Earth. San Francisco, CA. <https://api.planet.com>.
- Poeloengasih, C. D., Bardant, T. B., Rosyida, V. T., Maryana, R., & Wahono, S. K. (2014). Coastal community empowerment in processing *Kappaphycus alvarezii*: A case study in Ceningan Island, Bali, Indonesia. *Journal of Applied Phycology*, 26(3), 1539-1546. doi:10.1007/s10811-013-0153-x
- Pratiwi, F. (2020). Warga Nusa Lemongan Beralih Jadi ke Budidaya Rumput Laut. *Republika* 20 August, available at <https://republika.co.id/berita/qfddfp457/warga-nusa-lemongan-beralih-jadi-ke-budidaya-rumput-laut>
- Puspita, M., & Azis, S. (2019). Indonesian Seaweed Hydrocolloids: Challenges and perspective for future development in global value Chain.
- Puspita, M., Setyawidati, N., Stiger, V., Vandanjon, L., Widowati, I., Radjasa, o. k., . . . Bourgougnon, N. (2020). Indonesian Sargassum species bioprospecting: potential applications of bioactive compounds and challenge for sustainable development.
- Rahim, M., Aslan, L., Ruslaini, Taridala, S., Wianti, N., Nikoyan, A., . . . Hafid, H. (2019). Livelihood Features of Seaweed Farming Households: A Case study from Bungin Permai Village, South Konawe, South East (SE) Sulawesi, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 370, 012025. doi:10.1088/1755-1315/370/1/012025
- Rameshkumar, S., & Rajaram, R. (2018). Impact of Seaweed Farming on Socio-Economic Development of a Fishing Community in Palk Bay, Southeast Coast of India. *Coastal Zone Management: Global Perspectives, Regional Processes, Local Issues*, 501-513. doi:10.1016/B978-0-12-814350-6.00022-7
- Ramirez, P., Narvaez, T., & Santos-Ramirez, E. (2020). Gender-inclusive value chains: the case of seaweed farming in Zamboanga Peninsula, Philippines. *Gender, Technology and Development*, 1-21. doi:10.1080/09718524.2020.1728810
- Rasyid, A. (2017). Evaluation of Nutritional Composition of the Dried Seaweed *Ulva lactuca* from Pameungpeuk Waters, Indonesia. *Tropical Life Sciences Research* 28(2). doi. org/10.21315/tlsr2017.28.2.9
- Salayo, N. D., Perez, M. L., Garces, L. R., & Pido, M. D. (2012). Mariculture development and livelihood diversification in the Philippines. *Marine Policy*, 36(4), 867-881. doi:https://doi.org/10.1016/j.marpol.2011.12.003
- Samonte, G. P. B. (2017). Economics of *Kappaphycus* spp. Seaweed Farming with Special Reference to the Central Philippines. In A. Q. Hurtado, A. T. Critchley, & I. C. Neish (Eds.), *Tropical Seaweed Farming Trends, Problems and Opportunities: Focus on Kappaphycus and Eucheuma of Commerce* (pp. 147-154). *Gewerbstrasse, Switzerland: Springer*.
- Serrat, O. (2017). The Sustainable Livelihoods Approach. *Knowledge Solutions* 21-26.
- Shanmugam, M., Sivaram, K., Rajeev, E., Pahalawattaarachchi, V., Chandraratne, P. N., Asoka, J. M., & Seth, A. (2017). Successful establishment of commercial farming of carrageenophyte *Kappaphycus alvarezii* Doty in Sri Lanka: Economics of farming and quality of dry seaweed. *Journal of Applied Phycology*, 29(6), 3015-3027. doi:10.1007/s10811-017-1161-z
- Sitompul, F. K. T., & Matasik, D. (2019). Analysis of socio-economic conditions of seaweed farmers in Nemberala Village, West Rote district, Indonesia. *Russian Journal of Agricultural and Socio-Economic Sciences*, 91, 186-190. doi:10.18551/rjoas.2019-07.19
- Steenbergen, D. J., Marlessy, C., & Holle, E. (2017). Effects of rapid livelihood transitions: Examining local co-developed change following a seaweed farming boom. *Marine Policy*, 82, 216-223. doi:https://doi.org/10.1016/j.marpol.2017.03.026
- Suadi, & Kusano, E. (2019). Indonesian Seafood Supply Chain. In E. Kusano (Ed.), *Food Value Chain in ASEAN: Case Studies Focussing on Local Producers* (pp. 134-163). Jakarta: ERIA.

- Sulfahri, Mushlihah, S., Husain, D. R., Langford, A., & Tassakka, A. C. M. A. R. (2020). Fungal pretreatment as a sustainable and low cost option for bioethanol production from marine algae. *Journal of Cleaner Production*, 121763. doi:<https://doi.org/10.1016/j.jclepro.2020.121763>
- Sulfahri, Mushlihah, S., Langford, A., & Tassakka, A. C. M. A. R. (2020). Ozonolysis as an Effective Pretreatment Strategy for Bioethanol Production from Marine Algae. *BioEnergy Research*. doi:10.1007/s12155-020-10131-w
- Sunadji, & Lusiana, E. D. (2019). A Study on influencing factors of seaweed farmers income in rote ndao district, indonesia. *Russian Journal of Agricultural and Socio-Economic Sciences*, 94, 87-91. doi:10.18551/rjoas.2019-10.11
- Sutinah, Tahang, H., Hasani, M., & Nurmaena. (2018). Study of seaweed (*Eucheuma cottonii*) marketing in Makassar Industrial Area (PT. Kima) as seaweed marketing center in Eastern Indonesia. 2321-9009.
- Suyo, J. G. B., Le Masson, V., Shaxson, L., Luhan, M. R. J., & Hurtado, A. Q. (2020). A social network analysis of the Philippine seaweed farming industry: Unravelling the web. *Marine Policy*, 118. doi:10.1016/j.marpol.2020.104007
- Tano, S. A., Halling, C., Lind, E., Buriyo, A., & Wikström, S. A. (2015). Extensive spread of farmed seaweeds causes a shift from native to non-native haplotypes in natural seaweed beds. *Marine Biology*, 162(10), 1983-1992. doi:10.1007/s00227-015-2724-7
- Tarman, K., Ain, N., Sulistiawati, S., Hardjito, L. & Sadi, U. (2020). Biological Process to Valorise Marine Algae. *IOP Conference Series: Earth and Environmental Science*, 414(012026). doi:10.1088/1755-1315/414/1/012026
- Teniwut, W., Betaubun, K., Marimin, M., & Djatna, T. (2017). A conceptual mitigation model for asymmetric information of supply chain in seaweed cultivation. *IOP Conference Series: Earth and Environmental Science*, 89, 012022. doi:10.1088/1755-1315/89/1/012022
- Teniwut, W., Marimin, M., & Djatna, T. (2018). GIS-Based multi-criteria decision making model for site selection of seaweed farming information centre: A lesson from small islands, Indonesia. *Decision Science Letters*, 8. doi:10.5267/j.dsl.2018.8.001
- Teniwut, W., Marimin, M., & Djatna, T. (2019). Seaweed Micro-Business Enterprises' Support on Forming the Information Centre of Seaweed Farming. *Jurnal Bisnis dan Kewirausahaan*, 15, 49-57. doi:10.31940/jbk.v15i1.1250
- Teniwut, W., Teniwut, Y., Teniwut, R., & Hasyim, C. (2017). Family vs Village-Based: Intangible View on the Sustainable of Seaweed Farming. *IOP Conference Series: Earth and Environmental Science*, 89, 012021. doi:10.1088/1755-1315/89/1/012021
- Tombolotutu, A., Khaldun, R., Palampanga, A., Djirimu, M., & Tenge, E. (2019). Trade Liberalization and Export Competitiveness: A Case Study on Indonesian Seaweed In the Global Market. *IOP Conference Series: Earth and Environmental Science*, 270, 012056. doi:10.1088/1755-1315/270/1/012056
- Tumiwa, B., Renjaan, M., Somnaikubun, G., Betaubun, K., & Hungan, M. (2017). Analysis of seaweed marketing in warbal village, Southeast Maluku Regency, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 89, 012018. doi:10.1088/1755-1315/89/1/012018
- Utama, R. Z., & Handayani, T. (2018). Suitability between Oceanography and Seaweed (*Eucheuma cottonii*) Cultivation Potential in Tidung Island with Geographic Information System (GIS) C3 - E3S Web of Conferences. 73. doi:10.1051/e3sconf/20187312009
- Vairappan, C. S., Chung, C. S., & Matsunaga, S. (2014). Effect of epiphyte infection on physical and chemical properties of carrageenan produced by *Kappaphycus alvarezii* Doty (Soliericeae, Gigartinales, Rhodophyta). *Journal of Applied Phycology*, 26(2), 923-931. doi:10.1007/s10811-013-0126-0
- Vairappan, C. S., Razalie, R., Elias, U. M., & Ramachandram, T. (2014). Effects of improved post-harvest handling on the chemical constituents and quality of carrageenan in red alga, *Kappaphycus alvarezii* Doty. *Journal of Applied Phycology*, 26(2), 909-916. doi:10.1007/s10811-013-0117-1
- Valderrama, D., Cai, J., Hishamunda, N., Ridler, N., Neish, I., Hurtado, A., . . . Fraga, J. (2015). The Economics of *Kappaphycus* Seaweed Cultivation in Developing Countries: A Comparative Analysis of Farming Systems. *Aquaculture Economics & Management*, 19, 251-277. doi:10.1080/13657305.2015.1024348
- Wakibia, J. G., Bolton, J. J., Keats, D. W., & Raitt, L. M. (2006). Seasonal changes in carrageenan yield and gel properties in three commercial eucheumoids grown in southern Kenya. *Botanica Marina*, 49(3), 208-215. doi:10.1515/BOT.2006.026
- Warta Ekonomi (2020). Pariwisata Lumpuh, Pemkab Klungkung Siap Stabilkan Harga Rumput Laut di Nusa Penida. 21 September 2020, *Warta Ekonomi*, available at <https://www.wartaekonomi.co.id/read305167/pariwisata-lumpuh-pemkab-klungkung-siap-stabilkan-harga-rumput-laut-di-nusa-penida>.
- Yarish, C., Brummett, R., Hansen, S., Bjerregaard, R., Valderrama, D., Sims, N., . . . McKinnie, C. (2016). Seaweed Aquaculture for Food Security, Income Generation and Environmental Health in Tropical Developing Countries.
- Yusuf, S., Arsyad, M., & Nuddin, A. (2018). Prospect of seaweed development in South Sulawesi through a mapping study approach C3 - IOP Conference Series: Earth and Environmental Science. 157(1). doi:10.1088/1755-1315/157/1/012041
- Zamroni, A., Apriliani, T., Yusuf, R., & Kurniasari, N. (2019). Enhancing small-scale community for coastal management in Puntundo Bay, Indonesia C3 - IOP Conference Series: Earth and Environmental Science. 370(1). doi:10.1088/1755-1315/370/1/012072
- Zitta CS, Oliviera EM, Bouzon ZL, Hayashi L (2012) Ploidy determination of three *Kappaphycus alvarezii* strains (Rhodophyta, Gigartinales) by confocal fluorescence microscopy. *J Appl Phycol* 24:495–499.



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