Indonesian Seaweed Supply Chain

Analysis and Opportunities

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1 Introduction

Seaweed is an interesting crop regarding the nutrient composition and the way of production. It can be produced in saltwater ponds or in the open sea. Increasing the commercial production of seaweed would result in a direct contribution to food security as food or food component, or indirectly by creating employment opportunities as result of extra food production. The replacement of food production into sea and/or ponds would make production space available on land.
Furthermore, the culture of seaweed offers opportunities for more sustainable food and aquaculture production. Combining seaweed with aquaculture also increases yields by improving water quality and reducing vulnerability of farmed animal species to disease. Moreover, seaweed is a high-quality protein food source that requires no costly inputs, is not dependent on limited freshwater sources, and improves water quality by removing nutrient burdens[1].

To contribute to the improvement of food security of the poor, it is important to realise that food security not only relates to increased production (availability of good quality food) but also to access, affordability and stability. This means that the whole value chain needs to be addressed.

Indonesia is the second largest producer of seaweed in the world, after China. In 2019, the production volume of seaweed in Indonesia was approximately 9.66 million metric tons, which is a decline compared to 2015 when it was even 11.32 tons. (Statista 2022[2]). Given this background, Indonesia should have the opportunity to play a leading role in the global seaweed market. However, based on the international export of seaweed, Indonesia is not even in the Top 3 exporting countries, although the country produces ten times as much seaweed as the number three of the world, the Philippines. The EU import from Indonesia was only 3.2 tons of fresh seaweed, 146 tons of agar and 2.600 tons of mucilage in 2017, which was less than 0.05% of the EU seaweed import [1]. It is however noted that in general statistics on seaweed, agar and carrageenan from Indonesia turn out to be inconsistent, leading to some reluctance.

In our research from 2019 till 2022 we found that seaweed drying, processing and export facilities in Indonesia are mainly supplied by smallholder farmers. Production can be typified as a push system in which optimization for volume is ambitioned and market information (like market requirements and market price data) is limited. An opportunity for improvement and scaling needs to be found in quality and market driven (or pull) supply chains. In these chains the right product of the right quality and quantity at the right time is produced. This leads to higher profitability thanks to access to high end markets and less rejections which again results in improved livelihood for farmers due to higher margins, less non-sales and non-payment risks thanks to a better market engagement. Additionally, and in contrast to push supply chains, market driven supply chains typically go hand in hand with investment capacity thanks to higher margins and fruitful return on investments based on expected and quantified market returns. Investment capacity is a major driver for upscaling any (agri-food) supply chain and professionalizing an entire (agri-food) sector, which is required to realize the “blue growth” to address the world hunger.

The seaweed sector is complex, since there are many varieties and multiple levels of operation: fresh seaweed, (semi)-dried seaweed, first level processing of carrageenan, agar and alginates and higher-level processing to make semi-finished compounds or even tailor-made special compounds, mostly as additive for food products. To a minor extend these compounds are also used as ingredients of pharmaceuticals and non-food end products. Supply chain actors in Indonesia struggle with how and where and for what market to optimize and invest, as hotspots for improvements are difficult to determine.

To find out why the import of Indonesian seaweed products by the EU is on such a limited scale, this report focusses on the Indonesian seaweed value chain and looks into potentially new interesting opportunities for the Indonesian processors in the high-end markets in Europe. The focus is not on seaweed supply chains

[1] https://www.seaweedeurope.com/hidden-champion/, viewed 1-5-2022
[2] https://www.statista.com/statistics/1083216/indonesia-production-volume-of-seaweed/, viewed 10-1-2022

that already export to the EU, but merely on the more common supply chains in Indonesia that involve smallholders and produce singular products like carrageenan, agar and alginates. One of investigated options is market diversification.

After this introduction chapter two describes the used methodology. In chapter three to seven of this report the authors look into seaweed products and the market, provide a value chain analysis of the Indonesian seaweed supply chain, identify interventions and transitions of the Indonesian seaweed supply chain, discuss two case studies, and give an index of the seaweed market requirements and prices. The latter is introduced to trigger stakeholders in the supply chain, to show where investments might be needed to enter or maintain certain markets. In the last chapter, chapter eight, the authors draw conclusions and discuss the findings.

2 Methodology

Understanding the Indonesian seaweed supply chain was the main focus for data collection. In the first phase the focus was especially on the current supply chain of semi-refined carrageenan (SRC), refined carrageenan (RC), agar and alginates from off-shore cultivation of seaweed and only to a limited extend on on-shore cultivation in ponds. Data was gathered on topics including production, domestic trade, first level of processing, the domestic market, the international market, the organization of the supply chain, agro-logistics, and bottlenecks and opportunities.

To understand the Indonesian seaweed supply chain, the data was collected directly from stakeholders involved in the Indonesian seaweed supply chain and from selected literature. The data collection from stakeholders took place by conducting a field visit, launching an online questionnaire and in-depth interviews with selected stakeholders, participating in a strategic conference, and by conducting two case studies. Data from literature was received via literature research and a data base study. The information from all those sources was summarized, automized, and used as data input in the report.

- Field visit

A field visit to Makassar area (South-West Sulawesi) and Bogor took place from September 2nd till September 10th, 2019. The field visit was conducted by delegates of Wageningen University and Research (WUR). During the field visit, information was gathered on topics like the organization of the supply chain actors, final products, transportation, quality and hygiene. Several universities and companies were visited including:

a. Faculty of Marine Science and Fisheries, Hasanuddin Univ Makassar (UNHAS); Politeknik Bosowa Makassar; Institut Pertanian Bogor (IPB)
b. Seatechenergy (primarily seaweed cultivation) and Royal IHC (primarily harvesting equipment), 2 Dutch companies with direct seaweed activities in the Makassar area
c. NGO's Hivos Indonesia and Rikolto (Belgian NGO active in supporting seaweed villages on Flores)
d. Kospermindo, a cooperation dealing with the whole seaweed value chain.

- Questionnaire

On September 9th, 2020, an online questionnaire was launched. The questionnaire was sent to actors involved in the Indonesian supply chain. It included Indonesian companies, multinationals, NGO's and experts involved in the Indonesian seaweed supply chain (see Table 1). Topics addressed in the questionnaire included production, sourcing and market requirements, certification and prices, export requirements, processing, challenges and research opportunities.
In total thirteen questionnaires were filled in anonymously by Indonesian actors in the seaweed supply chain, including producers, producer organizations, processors and exporters.
The data gathered in the questionnaires were analysed using Microsoft Excel and the results were processed anonymously in the report.

Table 1 Questionnaire respondents[3].

1 producer, domestic trader
1 producer, processor
5 processors
2 processors, exporters
2 organizations not directly involved in the supply of seaweed

[3] Due to confidentially reasons the names of stakeholders cannot be shared

- In depth interviews

From Mid-2020 to the end of February 2022 in-depth interviews were conducted. In total 12 stakeholders where interviewed. They represent Indonesian seaweed processors, the Dutch/EU ingredient market, international experts, delegate(s) of NGO's, and certification institutes. With many of those actors several rounds of interviews took place to gain the in depths data needed and to validate the collected data. Topics addressed in these interviews included supply chain activities, market requirements, certification, prices, hotspots, opportunities, and interventions. Information gathered in the interviews was summarized per stakeholder and the data analysed using a thematic content analysis. The results from the interviews were processed anonymously in the report.

- Strategic Conference

On January 19th 2021 the Republic Indonesia and CBI Ministry of Foreign Affairs launched a strategic conference on enhancing the export competitiveness of industrial products of the natural ingredients sector in Indonesia. From this national webinar data was gathered and used in this report.

- Case studies

In 2021 two Indonesian processing companies and their supply chains were analyzed. Many online meetings and mailed documents provided insights in their ways of doing business including options for improvement. The report reflects on the findings of the interviews in an anonymized way.

- Literature study

A literature study was conducted to gain more insights in the variety of seaweed and seaweed products as well as the Indonesian seaweed supply chain, the hotspots and the bottlenecks. Topics included the different type of actors, their activities, strengths, weaknesses, opportunities and threats. For this literature study only English literature was reviewed. Platforms used included Google Scholar and Scopus.

- Data base consultation

Seaweed processing in Indonesia is not well developed and not competitive with e.g. China, because of lower level of technology and knowledge, and tax advantage in China. Therefore, market research was carried out if other product groups than targeted by Chinese and Philippine competitors can be identified. The database of Innova Market Insights with worldwide product introductions since 2000 was studied.

3 Seaweed products and market

Seaweed has been utilized throughout the world for centuries but was considered only as a food source for coastal communities in the earliest times. Apart from its wide-ranging use in many industries, seaweed contributes greatly to the nutritional status of communities due to its rich composition of macronutrients.

3.1 Products

In the seaweed sector there are many different species (8000 to 10000) of which quite some play an important role in the market [2]. Green seaweeds are used as vegetables for fresh consumption, whereas the other species are processed into value-added products. Three levels can be considered with respect to processing: there are pure products like SRC, RC, agar and alginates. Next, there are general compounds (semi-finished products) that can be applied as additives in food, pharmaceuticals and other non-food and the highest level of processing is being able to create tailor-made compounds, which requires a high level of technology and expertise.
Another classification is in three colour groups: red, brown and green. The varieties are indicated by their Latin names mostly, and the most important ones are listed in Table 2:

Table 2 List of most marketed species of seaweed worldwide.

Farm species	Algae type	Water	Purpose
Laminaria japonica	Brown	temperate	
Saccharina lattisima	brown	temperate	
Porphyra	red	temperate	
Kappaphycus alvarezii	red	tropical	hydrocolloid production (mainly carrageenan)
Eucheuma	red	tropical	hydrocolloid production (agar, carrageenan)
Gracilaria spp	red	tropical	food, agar
Caulerpa spp	green	tropical	food
Sargassum spp.	brown	tropical	food, alginate

Temperate regions where seaweeds are farmed are China, Japan and North and South Korea, whereas tropical waters where seaweed culture takes place are in Indonesia, Philippines, Malaysia and Vietnam. A more general classification with more types is taken from [2]:

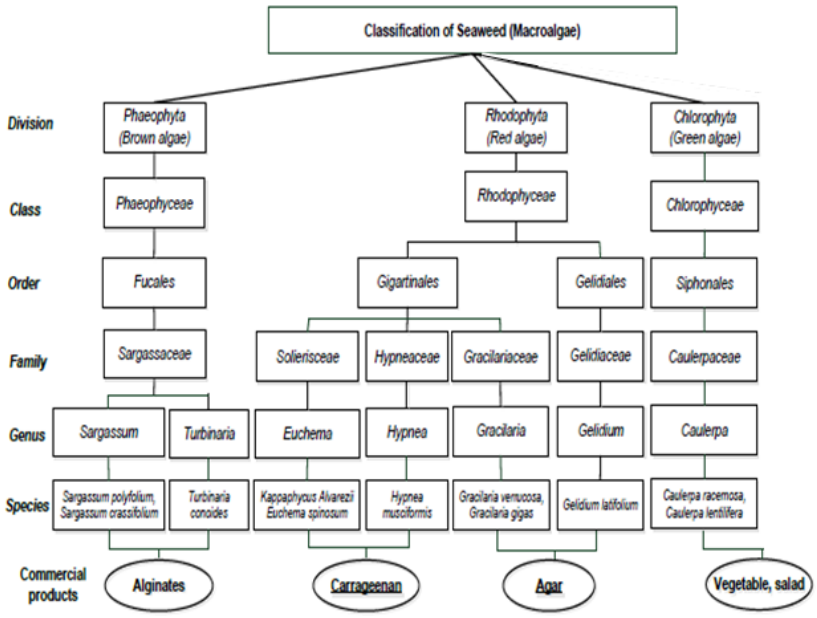

Figure 1 Classification of seaweed at various levels, including first level processing

Remark: *Kappaphycus alvarezii* is also known as *Euchema cottonii*.

The production of seaweed is difficult to estimate, since various sources provide different data, and also the definition of what is measured is often unclear (wet, semi-dry or dried seaweed). According to a presentation from Neish in 2021[4] the following volumes are produced:

Table 3 Production of dried seaweed in Indonesia in 2020.

Seaweed product (dried)	Production (tons)/month	Production (tons)/year
Kappaphycus (for Carrageenan)	12,000-15,000	144,000-180,000
Euchema (for Carrageenan and Agar)	2,000-3,000	24,000-36,000
Gracilaria (for Agar)	10,000-12,000	120,000-144,000
Total	**24,000-30,000**	**288,000-360,000**

Remark: FishstatJ from the FAO shows a production weight of about 9.3 million tons (wet seaweed), corresponding by 10% of dried seaweed: 930,000 tons. This is much higher than the data from ***Table 3***. Also the split up in species is totally different.

3.2 Market

Most of the seaweed sold for food today is sold dry. Various red and brown seaweed species are used to produce hydrocolloids such as alginates, agar and carrageenans, which are the primary commercial seaweed extracts. Hydrocolloids are polysaccharides, generally of high molecular weight that can be dissolved in water and provide viscosity or jellifying properties. These components are used as a thickening, gelling, emulsifying and stabilising agents and as food additives. The growth of the seaweed hydrocolloid market has slowed in the last decades but continues to rise at a rate of 2-3% per year [3]. The main raw-material providers at the global level are Asian-Pacific countries. Indonesia is the largest producer of seaweed species supplying agar and carrageenan extracts while China leads the hydrocolloid-processing sector.

The seaweed sector is very complex in the sense that there are, as described in the previous paragraph, various levels to consider seaweed products, leading to a large variety of supply chains and corresponding variety of challenges.
Currently, Indonesia is not able to participate in the market of second and third level of processing of dried seaweed. The production of general or tailor-made compounds is not taking place. According to [1] European players perceive Indonesian suppliers and processors to lack proper food safety and quality management and a lack of knowledge on differences between seaweeds, quality aspects of seaweed extracts and their applications, which result often in inconsistent quality. High investments are required to upgrade the processing level. This report focusses mainly on the Indonesian seaweed supply chains that currently produce, export dried seaweed and process seaweed into pure products including SRC, RC, agar and alginates. This first level of processing is already present on a large scale in Indonesia.

Fresh (domestic) market
In Indonesia, Caulerpa (see ***Figure 1***) is generally consumed fresh in the form of salads, besides seaweed can be processed into pickles and sweets and in Maluku, especially in the Kei Islands, Caulerpa is consumed fresh in the form of urap or eaten with colo-colo (traditional sauce). As a species that grows naturally, sea grape population is quite abundant in the waters of its habitat but its use is still very limited to consumption as fresh vegetables [4]. Data about fresh consumption were not found.

Dried seaweed for domestic processing
Domestic processing is mainly for carrageenan and agar. In 2015 18,780 ton carrageenan was produced in Indonesia as shown in ***Table 4*** [5].

[3] https://www.phyconomy.org, Neish, I.A. (2021) Ten seaweed industry development lessons from Indonesia to the world. Presentation prepared for the first workshop of the Tropical Phyconomy Coalition Development, July 7 & 8, 2021.

Table 4 Carrageenan production in Indonesia in MT (2015).

Company	Metric tons	Company	Metric tons
PT Algalindo Perdana	1,000	PT Hydrocolloid Indonesia	1,200
PT Amarta Carragenan Indonesia	1,800	PT Indonusa Algaemas Prima	3,000
PT Bantimurung Indah	1,200	CV. Karaginan Indonesia	1,000
PT Cahaya Cemerlang	1,800	PT. Sansiwita	500
PT Centram	1,000	PT Phoenix Mas	180
PT Galic Arthabahari	2,000	PT Seamatec	1,000
PT Giwang Citra Laut	1,000	PT Wahyu Putra Bimasakti	600
PT Gumindo Perkasa Indistri	1,500	**Total**	**18,780**

From the production in ***Table 3*** the Kappaphycus production (dried) was between 144-180 kton, and knowing that the conversion factor to carrageenan is about 10:1, this implies that almost the total Kappaphycus production was processed in Indonesia. This contradicts the fact that large amounts of dried seaweed are exported (see later on in this paragraph)

The margins for agar and carrageenan processors are small. Producing agar cost between $10.5 and $12 per kg. They sell agar between $11.6 and $14 per kg. For carrageenan the production price for Kappa (not Iota) is between $7.1 and $7.2 per kilogram and they sell for around $8 per kg. Processors can directly export, or sell to middlemen or exporters in Indonesia (interviews 2020).

Dried seaweed (export)

The export of dried seaweed that can be used for human consumption[5] from Indonesia to the world in 2020 was 168,364 tons of which about 83% went to China, and if South Korea and Vietnam are included over 91% is covered. The dried seaweed unfit for human consumption is much lower 13,160 tons of which 86% of the Chinese import is sourced from Indonesia. Also, more than 91% of dried seaweed for human consumption in China was sourced from Indonesia.

Problems in the domestic market include seasonal demands and competition from imports. The price for Gracilaria (for Agar) is rather stable, but the price for cottonii (trade name for Kappaphycus) fluctuates and can range between 5,000 rupiah/kg till 25,000 rupiah/kg. This makes sense, because there is much more demand from China for Kappaphycus. Price fluctuations are high, and the prices can change weekly. The price fluctuations are based on the price offered by buyers in China, which again relates to the monthly demand. The import graph from China shows these fluctuations in ***Figure 2***. Overall, the prices at the international market are more attractive compared with the domestic market. Also, the payment terms are seen as more attractive, due to direct cash, pre-payment and working capital [1].

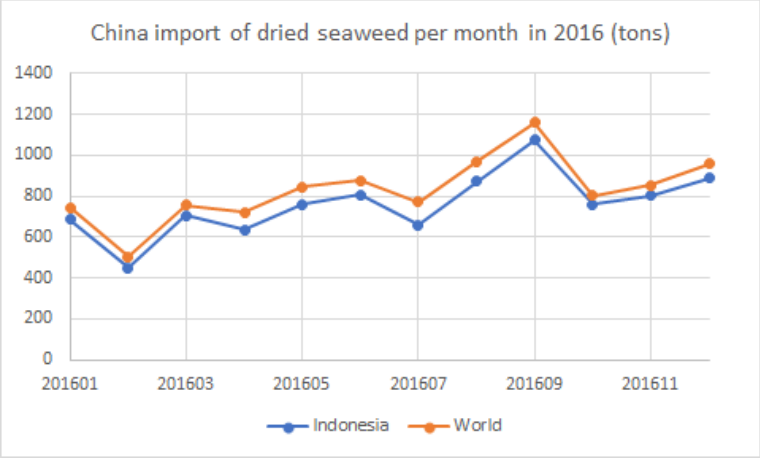

Figure 2 Seasonal dried seaweed import in China from world and Indonesia (2016) (UN Comtrade)

[4] UNComtrade: HS code 121221: Seaweeds and other algae; fit for human consumption, fresh, chilled, frozen or dried, whether or not ground

Remark: Note that based on ***Figure 2*** the total import of dried seaweed in China in 2016 is about 12 x 800 = 9,600 tons. This is far below what is mentioned earlier for 2020, where 83% of 168,364 = 139,742 tons is indicated. This again proofs the inconsistency of data. Another issue with the data is that in UN Comtrade the code 121221 that is used for data extraction is defined as 'Seaweeds and other algae; fit for human consumption, fresh, chilled, frozen or dried, whether or not ground', which does not refer clearly to dried Kappaphycus.

Carrageenan and agar export

An estimated 85% of the production of carrageenan is exported and the other 15% sold in the domestic market. According to ***Table 4*** this equals about 16,000 tons. This is more or less in line with data from UNComtrade from 2019, where the main export countries import about 12,000 tons in 2019.

Table 5 Indonesian export in tons of Carrageenan (UNComtrade).

Rank	Country	2017	2018	2019
1	China	682	4524	7110
2	USA	711	1476	1642
3	Netherlands	670	606	643
4	United Kingdom	562	591	621
5	Timor-Leste	561	276	524
6	Japan	490	482	470
7	Australia	315	402	360
8	Philippines	759	253	248
9	Spain	80	353	245
10	Germany	413	412	236

Indonesian carrageenan is exported mainly to China and the US (Table 5). Note that for carrageenan China has similar tariff cuts for Indonesia as for seaweed. Here again it is expected that Indonesian exports are mainly extracts rather than compounds, and China is processing these extracts to high-value end-products like tailor made food additives.

Statistics from FAO however claim an export weight of 5,503 tons for carrageenan and 946 tons for agar [6]. Once again the reliability of statistics seems to be low.

For agar, the local market is much more important than exports market. As a consequence of the poor image of Indonesia with respect to processing, the EU import from Indonesia for carrageenan and agar are both below 0.03% [1].

Market situation for high level processing

There is already an established industry producing high value, processed seaweed products that are used mostly in the food industry, albeit as functional ingredients rather than as a nutrient source. However, the protein, fat, and minerals in the seaweeds from which the hydrocolloids are extracted, which represent 70–92% of the raw dried seaweed used, are mostly wasted, and hence an economic opportunity is lost.

Agar is extracted from red seaweeds that include the European-occurring genera Gelidium sp. and *Gracilaria* sp. In the 1980s, Portugal and Spain were among the leading global producers of agar, but they have considerably decreased their production since. European agar production represented 6% of total production in 2015. This seaweed extract is used as microbiological and electrophoresis solid media, as a thickener and stabiliser in the food-processing industry, as a dietary product, and as an alternative to animal gelatine.

Carrageenans are widely used as emulsifier, gelling and stabilisation components in the food-processing, pharmaceutical, cosmetics and nutraceutical industries, and for aquaculture applications. They are extracted from red seaweeds such as the European-occurring species.

An overview of the applications of the main commercial products is shown in ***Table 6***:

Table 6 End products using the commercial seaweed products.

Refined and Semi-refined carrageenan	**Agar**
Desserts and ice cream	Confection (water gels)
Dairy	Baking
Processed fish, meat and egg	Retail (gel powder)
Meals and meal centers	Meat
Bakery	Other (dairy products)
Snacks	Bacto/pharmacy/agarose

There is a large gap between Indonesia and the EU seaweed market. To compete on the EU market (China, Philippines, Italy, Spain) on general and tailor-made compounds is not realistic on the short-term. Indonesia is behind in technology, quality consistency and knowledge, and moreover suffers from severe price competition. Other strategies need to be investigated to grow.

Policy and market

There is no national seaweed management in Indonesia. In Morocco the government decided that 80% of the seaweed needs to be processed in the country. Since there are only two processors in Morocco, the farmers have to compete on quality. In Chili there is a round table with government, processor and farmers, where they agree for a time period of 1 year on quantities, quality and price. In Indonesia there is no concrete policy that supports the processors to increase their competitiveness and make investments worthwhile, although high level programs are announced to support the sector[6].

[6] Discussed by Anggadirdja in his contribution to congress https://www.phyconomy.org

4 Value chain analysis of the Indonesian seaweed supply chain

This chapter gives a high-level overview of the agro-logistic design and associated challenges of the seaweed supply chain in Indonesia. It also discusses for each supply chain actor the role in the supply chain, strengths, weaknesses, opportunities and threats and addresses the hotspots for improvement.
Two standard supply chain types are discussed next to each other. The first type consists of producers, local collectors, district traders, and an exporting processor in Indonesia. The second type consists of producers, local collectors, district traders, and an exporting trader who occasionally also delivers seaweed to processors in Indonesia. The first three actors in those two type of chains are identical. The main differences of those two types of chains lay in a) the value-adding activities of the processor and the trader and b) their market orientation.
The main focus is on seaweed produced by smallholder farmers off-shore, distributed via the local collectors and district traders to the processor in Indonesia and then exported.

4.1 The Indonesian seaweed supply chain

Indonesia consists of many islands, and long coastlines suitable for seaweed production [7]. Much of Indonesian's seaweed production takes place on remote islands and is run by individual smallholder farmers. However, the majorities of the factories are based on East Java where little seaweed is produced. Therefore, as can be seen in the below Figure 3 and Figure 4, the logistic chains from the producers to the factories are very long, time consuming, inefficient, and hence very costly. Several aggregation points are needed before the seaweed arrives at its destination. The logistic connectivity between the islands is not optimal.

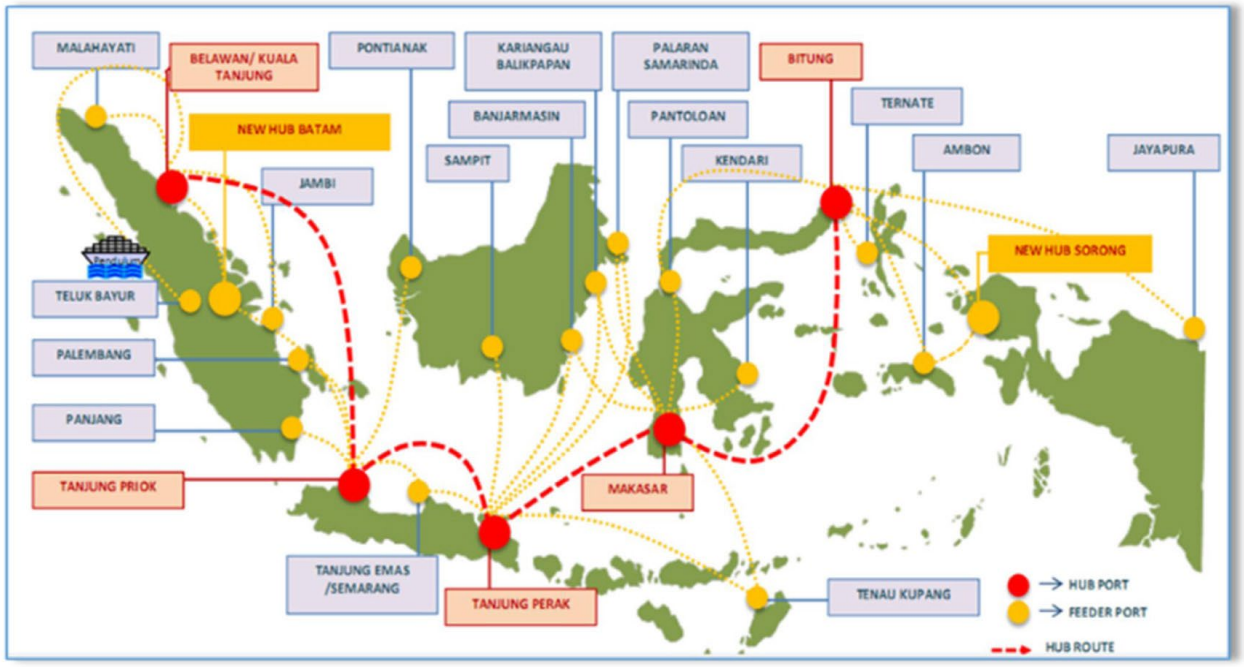

Figure 3 Inter-island transport [8]

Next to the challenging inter-island logistic lines, also the transport from the production sites to the ports of the islands is not optimal (Figure 4). To fill just one bigger truck, it needs seaweed from hundreds of farmers, several small- and medium- and district collectors which takes approximately one month.

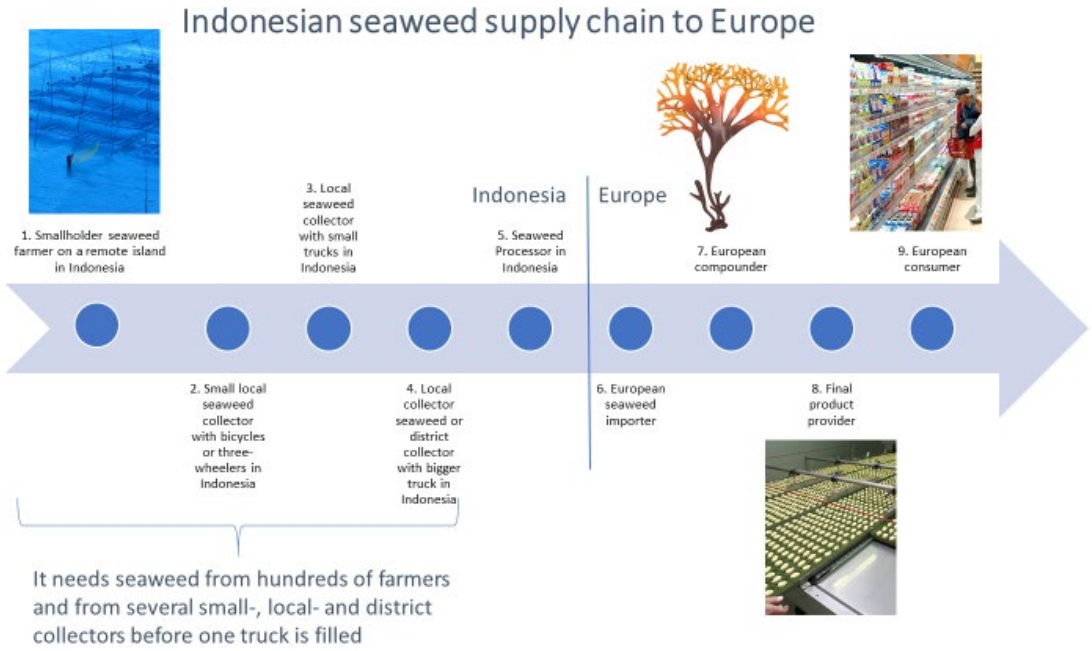

Figure 4 Indonesian Seaweed supply chain from smallholder seaweed farmers to the end consumer in Europe (based on interviews 2021).

Often the relationship between the chain actors is weak. This is due to lack of continuity in purchasing. Typically many smaller and bigger local collectors and district collectors, often middlemen, orchestrate the supply chain and bulk the volume from the smallholders to the processors or exporting traders. In individual cases, this role is also taken by the exporting traders or the Indonesian processor (interviews 2021).

4.2 Indonesian seaweed producer

Indonesia seaweed producers produce mainly three species of seaweed:

- *Kappaphycus alverzii (Euchema cottonii)*, approximately 50% of Indonesia's total seaweed production and produced offshore on ropes,
- *Eucheuma denticulatum (spinosum)*[7], approximately 20 % of Indonesian's seaweed production and produced offshore on ropes, and
- *Gracilaria verrucosa*, or *Caulerpa sertularioides*, approximately 30 % of Indonesia's seaweed production and is produced mainly in ponds (interviews 2021)

Since *cottonii* and *spinosum* are produced in seawater, the production areas are located along the coastal lines. The majority of the seaweed producers are former fishermen who could not make their living from fish catch anymore. They are smallholder farmers, rather poor and lack financial services and technical support. The majority of those smallholder farmers operates independently and sell their seaweed individually, thus are not organized in farmers' based organizations. They sell their produce to the buyer who is offering them the best price. An insignificant smaller part of the producers sell the seaweed exclusively to one stakeholder with whom they have a formal agreement ([2] and interviews 2021). This is for instance the situation in Makassar and a company in Timor. In Makassar even 60-70% of the farmers have binding relationships with local collectors or exporters. Their relation is strong with a high level of trust (Field visit 2019 [9]). The same holds for a carrageenan processor who has a very close relationship with seaweed producers on the remote islands around Timor. Producers are guided and supervised during the production and exclusively sell their

[7] Eucheuma cottonii is now Kappaphycus alvarezii, and commercially was and is called "cottonii". Eucheuma spinosum is now Eucheuma denticulatum and commercially was and is called "spinosum"; see McHugh, D.J., 2003. A guide to the seaweed industry. FAO FISHERIES TECHNICAL PAPER 441.

seaweed to them. However, such close supply chain relationships are exceptional and far from being the norm.
The producers produce, harvest and sun-dry the seaweed before selling it to a local collector or middleman [10]. For offshore production on ropes, harvesting is done after 45 days on average and includes the removal of the main ropes, bringing seaweed into the boat, and transporting the seaweed to land. The wet seaweed is sun-dried for three to four days to reach the proper moisture content, which is measured subjectively by pressing the seaweed between the fingers. After drying, the seaweed is cleaned and packed into woven bags to a total weight of 50 kilograms [2]. The 45 days of production is based on a standardized harvest cycle, without performing any measurements or gathering any underlying evidence (Field visit 2019 [9]). The on-shore seaweed production cycle is normally longer, between 40-60 days.
The initial investment for a farmer to start offshore seaweed farming is shown in ***Table 7***:

Table 7 Investments costs to start offshore seaweed production (interviews 2021).

Materials	**Qty**	**Unit**	**Unit cost (Indonesian Rupiah)**	**Amount (Indonesian Rupiah)**
Nylon rope D12mm	1	roll	1,050,000.00	1,050,000.00
Nylon rope D10mm	1	roll	750,000.00	750,000.00
Nylon rope D 5mm	5	roll	400,000.00	2,000,000.00
Spun Raffia (Tali rapia pintal)	3	Pillow (bantal)	50,000.00	150,000.00
Buoy (Pelampung bouy)	24	pcs	10,000.00	240,000.00
Bottle float (Pelampung botol)	150	pcs	1200	180,000.00
Seedlings	300	Kg	6,000.00	1,800,000.00
Total (Indonesian Rupiah)				6,170,000.00
Total (US$)				425*

* 1 US$ = 14,625.17 IDR (exchange rate XE 02/05/2022

To start with off-shore seaweed farming it needs an investment of around 425 US$ (***Table 7***). The main part of the investment goes to the buying of nylon ropes. In general the material can be used for about 3 years and then it needs to get renewed. A smallholder farmer usually has 30 ropes each of them at lengths of 30 meter long. Exceptionally a rope can also be 50 m long. 30 m long lines can produce 3.0 to 3.9 tons fresh seaweed or 350 kg to 390 kg dry seaweed per cycle (interview 2022).
After the harvest, transport can be arranged by the producer or by the local collectors. The distance between farmer and local collector depends, but is often around 30-60 kilometres [2]. Modes of transport used include bike, motor, small trucks and boats (Figure 4) (Field visit 2019 [9]), interviews 2021).
Inputs, like equipment and packaging material are purchased through local shops. Seedling production and distribution is not yet well established in Indonesia. A very limited amount of nurseries can be found in some major production areas, often run by local government agencies. However, the amount of seedlings produced there and the distribution of the seedlings is far from being sufficient to reach the smallholder farmers on the remote islands (interviews 2021). The majority of the farmers do not have access to improved seedlings. They often purchase seedlings at an early stage in the farming cycle from larger farmers [1] (interviews 2021). Thereafter farmers reuse the seeds for several cycles. This leads to a serious decrease of the quality and which again results into a significant reduction of the productivity. An expert estimated that with improved seeds the yield could increase easily with a factor 20. Productivity decrease due to poor propagating material therefor represents a real threat, especially in light of the fact that investment- and labour costs remain unchanged (interviews 2021).
Financial resources can be arranged from local collectors, family or other relatives and sometimes as well from governmental initiatives, NGO's, or international donor organizations. Generally, producers prefer to borrow money from local collectors or relatives rather than to have formal arrangements [1, 2].
Information on price and quality requirements for raw and dried seaweed is mostly not available on the producer level, especially not in remote areas [2].
In the dry and hot season the seaweed grows slowly. But the advantage is that the sanitary quality, yield and strength is higher than in the rainy season (interviews 2021).
From the questionnaire and interviews it can be concluded that all producers dry the seaweed and deliver dried seaweed to the buyer. However, the drying process is not always well controlled and done properly by

the farmers. Ideally, for quality assurance reasons during the processing, the moisture content at the farm level should be 14-20% for *Gracilaria* and 35-40% for *Euchema cottonii.*
Traditionally the drying of the seaweed is done by the producers on the ground/sand. This leads to a higher moisture content and a greater contamination with sand, mud, shelves and other material than when dried on drying installations. Proper cleaning of the seaweed when it arrives at the factory, especially during the rainy season, is then hardly possible. Companies who have a close and stable relationship with the producers train them on the drying process and motivate them to build (simple) drying areas to avoid seaweed contamination, as in Figure 8 showing drying installation (interviews 2021).

Almost all of the producers that filled in the questionnaires received guidance on how to improve their seaweed production. However, they represent the 'happy few' who are linked to organizations that provided these guidance like e.g. universities, governments (Ministry of Maritime affairs, Provincial government), cooperations (Kospermindo), Indonesian Seaweed Association (ARLI and ASTRULI), vertically integrated companies, NGO's and programs (SMART-Fish Program). Assistance was mainly given in the form of advice and training, and a very few of them also received seedlings or knowledge on new cultivation methods (questionnaires 2020, interviews 2021).

Challenges, SWOT, Conclusions
From the interviews and questionnaires conducted, a SWOT analysis has been conducted for smallholder's seaweed production (Table 8). It can be concluded that for smallholders that produce seaweed for the first level processing supply chain, challenges relate to the location, production volume, quality preservation and the market.
The main problems related to the location include the remoteness and distance to the market. Other problems mentioned were storm damages, high currents and the low water quality.
Problems related to the production and quality preservation included problems with seed and low productivity, low quality of the produce, weather and climate conditions and good drying spots. Producers faced problems in delivering enough volume continuously, since farming is still done mainly on individual level instead of collectively. Good drying spots that the actors mentioned include locations were seaweed can be dried by the hanging method were it is not exposed to water and animals ([3], interviews 2021).
Regarding the market, bottlenecks faced by producers are related to the distance, competition and lack of markets. In addition, financial problems arise due to the fluctuating prices and absence of markets that guarantee long term relationships or contracts. Quick money is often needed and therefore storing the product for a while is not an option. Traceability and certification of the produce is often not in place.

Table 8 SWOT-analysis producers offshore seaweed production (consolidated information from field visit, questionnaires, interviews and literature).

Strengths	**Weaknesses**
- Many seaweed farmers - Large seaweed production	- Problems with the quality of the produce e.g. due to use of poor genetic material, contamination with foreign material, poor drying, lack of simple objective methods for determination of product quality, lack of implementation of quality schemes - Unstable production volume - Production location far away from market - Only able to sell small quantities at once - Some unforced child labor is present - Low education level of smallholder farmers - Lack of communication between producer and buyer due to lack of mobile phone signal and land line.
Opportunities	**Threats**
- Indonesia has a large coastal line, more seaweed could be grown - Growing seaweed is relatively simple - Investment needs are limited - Harvesting and therefor earning money is possible every 45 days on average (which is a much faster cycle than other crop-cycles) - Seaweed cultivation is conducted in the sea or in former shrimp ponds therefor no new agricultural land is needed - The demand for seaweed is growing	- Insufficient production and availability of good new genetic material - Mainly spot market selling with little long-term relationships or contracts between producer and buyer - Huge price fluctuations for seaweed - Changing weather and climate conditions - Loans and payment systems making farmers dependent on buyers

Farmers should establish long-lasting relations with buyers that are willing to pay for quality, quantity and ideally provide as well loyalty incentives and work together in an integrated supply chain approach and:
- Implement good practices
- Strive for the use of the best propagation material available
- Invest in drying, storage/aggregation (knowledge, technology, capacity)
- Establish farmer based organizations to consolidate volumes
- Implement certification and traceability standards
- Apply information networks to be able to share information between producers itself and between producers and buyers and other chain actors.

4.3 Local collectors and district traders

The supply chain between producer and processor in Indonesia consists of many local collectors and district traders. These collectors and traders try to create volume by sourcing seaweed from several producers (Figure 4). They link the producers to the next level of collectors and traders so that their seaweed finally reaches the processor or exporter. They often play an essential role in providing market access, financial support and technical information to the producers (interviews 2021 and [3]). With reference to financial support, the collectors often purchase input material like lines and seedlings for the producers. In return, the producers have to provide the harvested seaweed to the collectors. This make farmers highly dependent on these collectors [1]. Many of the local collectors are also buyers for the Exporting Traders for the Chinese seaweed industry (paragraph 4.4 for more information). They do not only buy all available seaweed independent of the quality, they also often pay a higher price to the local producers than the buyer for the Domestic Processor in Indonesia. They can effort to do so due to the scale of the seaweed industry in China, lower production costs than in Indonesia, and the tax advantages from the Chinese government.

These traditional traders do not add much value to the value chain as a whole, and are also one of the reasons why there is little transparency in the seaweed supply chain. However, replacing them is complex. They play a key-role in bridging the logistic gap between the remote seaweed cultivation areas on the islands and the factories in East-Java (Figure 3). Also, those traders often speak the local languages and are familiar with the local cultures. In organized supply chains, sometimes also cooperatives or representatives of agar- or carrageenan processors are stepping into a part of the role of the local collectors and organize the seaweed collection from the farmers (interviews 2021).

Local collectors receive the seaweed around five days after harvesting. They often say that they buy products based on the quality like moisture content, absence of contamination like stones, sand, mud, shells, and purity. However, in fact most buyers purchase whatever is available for the cheapest price. They even lack the basic instruments to check the quality. In one vertically integrated chain some first good examples of paying for quality are observed. There, quality at the point of sales is defined, controlled and binding. The moisture content must be between 38-40 %, the amount of contamination should not exceed 2 % and they check the level purity of the seaweed.
Some of the bigger collectors bulk the products in warehouses before they send it to the next level of collectors (interviews 2021).

The district traders are located in the major port cities and can be independent or work for a processor or trader. The relationship between local collector and district trader is often strong. They exchange information about availability, quality and price. District traders also provide financial support to local traders. This strong relationship makes it difficult for new district traders to enter the market because of trust issues [2].

Activities of local collectors include buying semi-dried seaweed, bringing to warehouse, cleaning, sorting, sun drying to bring the moisture content to a percentage that is meeting the requirements of the exporters and processors, packaging and transportation to a district trader [2, 10]. District traders dry again, clean again, store the seaweed in the warehouse and transport raw dried seaweed to the Indonesian domestic processor or to the exporting trader in compressed bales of roughly 100 kg [1, 5].

Raw dried seaweed from district traders to seaweed processors or exporting traders is distributed by land and sea. A district trader will use land transportation for distribution to the same island, while using sea transportation for different domestic islands and overseas. The lead times depend much on the location.

Challenges, SWOT, Conclusions
Analysis of the strengths, weaknesses, opportunities, and threats related to the local collectors and district traders show that problems relate to aspects of the location and distance, transportation, quality, price and continuation of guidance (Table 9).

Table 9 SWOT-analysis local collectors and district traders (consolidated information from field visit, questionnaires, interviews and literature).

Strengths - Ability to bridge the logistic gap between the remote production areas and the processors/exporters - Connected to the local producers - Know the local culture/language	**Weaknesses** - Short term orientation with little long term relationships Little value adding activities: - Mainly focused on price and quantity, little incentives to pay for quality - Lack of interest in traceability and transparency of the supply chain - Lack of willingness to 'empower' producers and embedding producers in the supply chain
Opportunities - Many seaweed producers who are not connected to the market - Sufficient spot market demand for seaweed	**Threats** - Long and scattered supply chain leading to uncertain delivery and high logistic costs - High price fluctuations

Local collectors and district traders should:
- Vertically integrate or become 'the chain organizer'
- Pay producers for quality, quantity and ideally as well for loyalty
- Invest in the chain e.g. in drying and storage facilities
- Make long-term buying commitments with processor/traders and producers
- Support producers on good practices (GAP training).

4.4 Domestic processor Indonesia

In 2019 Indonesia had 32 seaweed processors. 60% of them are producing carrageenan and 40 % agar. Most processors are family owned companies producing one or two different products and are based on Java island [1, 2]. However, the difference between the processors is quite large. Their annual processing capacity varies from 250 tons up to 3,000 tons. Some of them produce basic products and others as well blends. There a few more advanced processors, a group of straggling companies, and a group of companies in between those two groups ([1] and interviews 2021). A selected group of the more advanced companies are participating in a CBI exporting promoting program. In a three year program they are guided in taking the right next steps in order to successfully enter the high-end market in Europe (interviews 2021). The average performing companies slowly develop, as they face issues in terms of access to finance, human resources, technologies and markets. The group of straggling companies has strong challenges to remain active in the seaweed supply chain.
In 2019 almost no processor in Indonesia was operating at full capacity, some even were using only 30-40% of their capacity. This was due to a lack of access to input material and/or a lack of market access ([1], interviews 2021). The biggest challenge for the Indonesian processing industry is the competition with the Chinese seaweed industry. Although the Chinese buy seaweed for a higher price from the producers than the Indonesian industry, the Chinese end product is sold for a lower price than the one from the Indonesian companies ([1], interviews 2021). This is possible due to their advanced processing technology and the scale of their seaweed industry. Next to this they benefit from tax rebates, lower energy costs, cheaper chemical inputs, and higher labour productivity ([1] and interviews 2021).

Dried seaweed is received by the processors between 14-60 days after harvesting, with an average of 37 days. Processors mainly purchased their raw material from local collectors and district traders, and only a small part from Exporting Traders. Most processors do not have a good relation with their suppliers, and also do not know exactly where their seaweed is coming from. This results on the one hand in a lack of continuity in purchasing of the raw material and on the other hand in a lack of traceability and transparency. (interviews 2020 and 2021)

Their payment to the collectors/district traders is based on the weight, moisture content and other quality aspects. Product specification which should be fulfilled before purchasing the dried seaweed include moisture content, percentage of impurities and physical conditions. Incoming seaweed is always checked by the processor on its quality. If it does not comply to the specifications of the processors it is rejected or payments are reduced. The margins for agar and carrageenan processors are small, see for more information Chapter 3.2. (interviews 2021).

Depending on the type of seaweed the processor purchase (*Eucheuma cottonii, spinosum* or *Gracilaria*), the dried seaweed is processed into RC or SRC (like kappa and iota) or agar (like agar powder). For the extraction it needs a lot of water (~ 600 l if the water is very well recycled, otherwise ~ 3,000 l of water for 1 kg of agar), chemicals in order to extract the acid and a filter aid. For the production of 1 kg agar powder it needs approximately 10 kg of dried seaweed and approximately 100 kg of fresh seaweed (interviews 2021). During the processing step, several types of losses can occur, like raw dried seaweed that is not qualified as input material and waste due to the filtration process (questionnaire 2020).

After processing, the waste streams include waste water and seaweed parts. Three processing facilities that took part in this research have an in-house waste treatment system to convert the waste streams into fertilizer. Another company sun-dries the solid waste. This waste is collected by local villagers and used as

planting medium. Other indicated options for the solid waste are: to send the waste streams to a third party that deals with the waste management, sell the side-streams for feed grade standard for a lower price, and re-sell the side streams for other applications. The liquid waste, or waste water, can also be re-used. One processor has a waste water treatment system, while another company performs a waste water treatment of which the effluent is being used by farmers as irrigation water for their plants. Also a lot of waste streams occur that are currently not used in the best possible way. For example, when filtering a press cake arises. This is now used as fertilizer for farmers, while this can be a high-value product. Another example is the side stream from semi-refined carrageenan. A lot of cellulose is present in this side stream. A next step should be to retrieve the cellulose to create new products (questionnaire 2020).

From the questionnaire it was found that processors produce their products for the Indonesian, the Asian (other than China) and South American market and a small amount for the European market. The reason to export to Asia (other than China) are the high market demand, low quality requirements of products, and little competition. High market demand and low quality requirements is also an important reason for exporting to South America. Adoption and development of new, innovative and more sustainable products is the reason for looking into export to Europe. Overall, export to Japan is easier compared to Europe, due to the time zone, vicinity, and the fact that some processors have already a close relation with Japan as they use Japanese machineries. The development of seaweed compounds has yet to get off the ground in Indonesia. The market for seaweed products like compounds is a growth market, and Europe is an important and increasing market (questionnaire 2020, interviews 2021). Literature indicates that an estimated 85% of the production of carrageenan is exported and the other 15% sold in the domestic market. For agar, the local market is much more important than the export market [1].

Requirements depend largely on the targeted market and the product. For the domestic market the main requirements are related to the moisture content, level of purity of the seaweed, and legal requirements on food safety[8]. For export to the high end international market the most stringent rules apply. Processors have to deal with many additional requirements which are strictly controlled. It needs compliance to international safety- and quality management certification schemes like FSC 22000, ISO 22000, ISO 9001:2015, BRC/IFS. But also implementation of traceability is necessary and evidence on the compliance to advanced Corporate Social Responsibility (CSR) standards related to the payment of the workers, working hours, worker's safety and general labor conditions need to be provided. In addition, depending on the targeted client, certification likes Halal, Kosher, Fair-trade and/or Organic are also required. Quality specifications that need to be fulfilled include size, moisture content, clean, color, safety including food grade standard in micro-organism and maximum limit of heavy metal and chlorate, and gel strength including stability and good viscosity. To implement these technical standards and to guarantee consistent product quality it needs highly skilled employees including R&D staff, a high-tech laboratory to control and safeguard the quality, high degree of control over raw materials production and processing, and a state-of-the-art production plant for the development and implementation of an advanced food safety management system. For the implementation of the sustainability standards, especially for the compliance to social standards, operations like labour hours, contracts etcetera often need to get adjusted. High end market supply therefor not only needs investments and scale but also a different vision of the management on the operations and the supply chain. Many of the Indonesian processors are therefore not yet able or willing to meet these requirements ([1] and interviews 2021).

Challenges, SWOT, Conclusions

Problems related to sourcing of dried seaweed consists of three aspects: price, quantity, and quality. Problems to the price are not only related to the high competition from China. There are also a high price fluctuations during the year. Next to that, the processors face a long lead time resulting in high cost for loans, difficult access to financial services and high interest rates .

Quantities that are supplied can fluctuate heavily. Especially in the raining season the quantities are low. Related to quality, the problems are related to an inconsistent quality of the supplied product. Processors do not always receive a good quality product that fulfills all quality standards. For example, sometimes the moisture content is too high or the product is still premature.

[8] Indonesia has food safety legislation. However, the enforcement of the law is difficult since the capacity of the controlling body is very limited.

Problems related to processing include problems with the phenolic content, yield, consistency of the quality and waste water treatment.

The margins are small and depend on the efficiency of the processing facility, but also on the fluctuation in price. This includes the price at farmgate and the currency exchange. Overall, between 50% and 70% of the production costs is fluctuating, and around 30% is fixed, like electricity and personnel. In case the efficiency of the processing facility is low, it is difficult to compete on the international market (interviews 2021)

Challenges in the export include competition from other hydrocolloid producing countries regarding the price, quality fluctuations, a long time to introduce new products, and a low or even a stagnant and declining demand for Indonesian products compared to the established facility outside Indonesia. Overall, Indonesian processors face competition from China that has a large processing industry and can process for lower prices than Indonesia. Competing only on price will be difficult for the Indonesian processors since the price of internal shipping between the island is high and Chinese exporters receive tax refunds. Sometimes the price for internal shipping between two islands is higher than the price for the shipping between Java and China. So far Indonesian processors could not benefit of the growing compound market in Europe. Indonesia's export to the EU was in 2017 less than 0,05 % of the EU seaweed market. Most processors do not yet comply to the EU standards, nor have the sophisticated facilities needed for compound production.

From all the above indicated challenges the top three challenges mentioned by one processor were (in order of priorities):

1. Need for new and improved seedlings via laboratories for smallholder farmers
2. Upgrading of the factory to produce products with higher value than semi-refined products
3. Need for streamlined logistic system for the seaweed sourcing from smallholder farmers.
4. Put effort in more uniformity in seaweed supply, eventually by approaching or setting up larger farms (interviews 2021).

In the below table we give an overview of the strengths, weaknesses, opportunities, and threats related to the domestic processor.

Table 10 SWOT-analysis domestic processor Indonesia (consolidated information from field visit, questionnaires, interviews and literature).

Strengths	**Weaknesses**
- First movers with certified factories - Quality checks for raw material supply - Some recycling of waste water and solid waste streams into fertilizer, animal feed or other applications	- Inconsistent and low quality and quantity of the raw material resulting into inconstancy and low quality of processed product - Significant processing capacity available but processors do not operate at full capacity - Limited compliance to high end market requirements, little experiencing with exporting to those markets and limited buyer's network there - Little attempt and interest to get better integrated with the producers for better control of raw material supply and the chain - Limited investment space - Poor reputation on high end market in Europe
Opportunities	**Threats**
- A lot of seaweed production by producers - More seaweed could be processed - The market demand for seaweed is growing - Center for the Promotion of Imports (CBI) is supporting Indonesian processors entering the European market	- Transport between island challenging and costly - Long lead time from harvest till product reception - High price fluctuations - High competition from the Chinese buyers and Chinese factories as well as competition from other hydrocolloid producing countries and traders - Long lead time for the introduction of new products

In order to make full use Indonesia's geographic advantage local processor could introduce quality driven seaweed supply chains:

- Establish long term relationships with producers: train them, introduce improved seedlings, better drying, and other value adding activities
- Look into new market opportunities with high value products in high end markets (e.g. vegan segment, health segment, blended products) and eventually niche markets (organic)
- Look into new opportunities for the use of side- and waste streams
- Implement relevant certification for the processing and the supply chain
- Organize the logistics between the production and the factory
- Install a traceability system and distinguish with storytelling.

4.5 Exporting traders

Not all produced seaweed is going from the producers to the local collectors/district traders to the Indonesian domestic processors. Indonesia also has approximately 100 exporting traders. They export up to 80% of the produced Euchema Cottonii and 20% of the produced Gracilaria. Exporting traders primarily supply dry seaweed to foreign markets, with China as main destination, and a smaller amount to the domestic processor. Some of exporting traders are Chinese traders, and can take advantage of tax benefits from the Indonesian government.

Although the prices the exporting traders pay fluctuate a lot, they are in general considered by producers and local traders/district traders as more attractive than the prices paid for seaweed going to the domestic processors. On the one hand because they are higher. On the other hand because of the direct cash -, prepayments - and working capital given to local traders and district traders. Seaweed buying of the

exporting traders is therefore in direct competition with the seaweed buying of the domestic processing industry.

Before selling the seaweed the exporting traders dry RDS according to the requirements of the buyer. Moisture requirements are generally lower for exports than for the local market ([1] and interviews 2021).

Challenges, SWOT, Conclusions
The main problems are related to their short term commitment, and limited value adding activities beyond product consolidation.

Below we give an overview of the strengths, weaknesses, opportunities, and threats related to the exporting traders.

Table 11 SWOT-analysis exporting traders (consolidated information from field visit, questionnaires, interviews and literature).

Strengths - Pay higher prices and have better payment conditions than local processors - Consolidate production from the producers	**Weaknesses** - No long term commitment and continuity due to spot market contracts with their buyers - Unfair competition with the local processing industry Commodity trading - Little value adding activities for Indonesia - Little interest in traceability and transparency of the supply chain
Opportunities - No market linkage of the producers - Interesting market demand from China	**Threats** - Stop buying from Indonesia when other sources become more competitive or attractive - High fluctuation of prices - Market disturbance due to tax advantages

In order to overcome the weakness and threats exporting traders could:

- Vertically integrate into the supply chain, forward and backward
- Establish a processing factory.

5 Interventions and transitions of Indonesian seaweed supply chain

This chapter gives a long list with potential interventions from which to select a few for a short list and determines key opportunities for transition. It brings together the results from the questionnaires, the interviews, the strategic conference on enhancing the export competitiveness of industrial products of the natural ingredients sector in Indonesia, literature research [1] and the authors own in depth knowledge on the development of quality driven supply chains.

5.1 Interventions

Many of the interviewed parties were already involved in some kind of interventions. These included large scale cultivation of seaweed, improving productivity at farm and processing level, sourcing from new cultivation locations, and looking into the combination of seaweed production and tourism. The low-income farmers are often targeted with support program from NGO's like training on seaweed cultivation. Most of these interventions took place on an individual actor level and did not yet include the value chain as a whole or even the sector as a whole. However, the impact of the support is actually limited and unlikely to be sustainable in the long run if the end market and supply chain is not known, the agro-logistic is not organized well, and/or the quality of the propagation material is poor.

Below we provide an inventory of many possible interventions and suggest the actor which should be targeted for an effective realisation of the intervention. Interventions are listed in a random order. We distinguished interventions on three levels:

1. Hardware interventions. Those interventions relate to material equipment like for instance infrastructure, logistics, laboratories, or traceability systems.
2. Software interventions. With those interventions we mean knowledge, education, and research including training, developments of manuals and protocols.
3. Orgware interventions: Those interventions refer to the organization of the institutions and chain actors like for instance the establishment of new rules or new collaborations, and the orientation towards new markets.

The main objective of the below suggested interventions is to make the Indonesian supply more robust and competitive by delivering reliably high quality and quantity of seaweed. The scope of the interventions in the table is on the first type of the standard supply chains consisting of: Producers, Local Collectors, District Traders, and an Exporting Processor. Thus, the scope is only to a limited extend on the second type of the standard supply chains, from Producer to the Exporting Trader. The Exporting Trader operates in a commodity market, here transparency and quality is less relevant than costs. Hence, the supply chain to the Exporting Processors potentially offers more opportunities for long term commitment and therefor value added activities and structural improvement than the one to the exporting Traders.

Table 12 Improving the current seaweed supply chain: inventory of potential Hardware-, Software-, and Orgware interventions and targeted actor.

Level	Intervention	Actor
Hardware	Install close to the cultivation areas appropriate drying facilities for famers (preferably low-tech) and aggregation centres	Various options: farmer, NGO/international funder, processor
	Establish close to the production area's bigger warehouses with good drying and storing facilities and press machines	Processor
	Introduce improved packaging and design of packaging for farmers and collectors/district traders	Processor
	Optimize agro-logistic network design from farm to processor	Joint effort of: Processor, sector organization, government organisations[9], international funder, researcher
	Establish seed laboratories and an effective seed distribution network	Government organizations eventual with support of international funder, private enterprise, researcher
	Advance technology for use of waste and side streams e.g. press cake and wastewater	Processor, researcher
	Install seaweed production on industrial scale following the example of e.g China and Korea	Government organizations eventual with support of international funder, private enterprise, researcher
	Implement certification according to international standards for good practices, food safety, (social) sustainability like FFS 22000 to enable export to EU	Processor, farmer
	Install right technology for the development of value-added products like hydrocolloids, compounds, and blended products	Processor
	Implement traceability allowing for tracking and tracing and storytelling	Processor
Software	Train farmers on good seaweed cultivation- and good post-harvest practices	Processor, eventual also NGO
	Train, guide, supervise processors on exports requirements and way of doing business in new markets	Government organizations eventual collaboration with funder, sector organisation
	Train processors to adapt high-level seaweed processing options like compounds	Government organizations eventual collaboration with funder, sector organisation
	Be present at fairs in the EU to get to get to know the market and build new network	Processor, sector organisation
	Improve knowledge on side- and waste stream utilization	Researcher, Processor, government
	Improve communication between the chain actors for information sharing	Processor, eventual also government organizations and sector organisations
	Strategize research towards an integrated and market driven approach on a) production increase and quality improvement (on the level of the farmers and in the factory) b) value added products c) circularity	Government organizations, sector organisation, researcher, external funder

[9] The following three government organizations support the seaweed sector: the Ministry of Trade, the Ministry of Industry, and the Ministry of Marine Affairs and Fisheries (https://www.cbi.eu/sites/default/files/vca_seaweed_indonesia.pdf)

Orgware	Develop binding food safety regulations, national seaweed standards, and product specifications as well as effective tools and control mechanisms to guarantee compliance	Government organizations, sector organisation
	Introduce internal control systems for e.g. control of the propagation material used by the famers, control of dried seaweed	Farmers, processor
	Strategize towards export of value-added products to high end markets for human consumption	Processor
	Organize producers in Farmer Based Organizations, formal or informal	Various options: government organizations eventual with support of NGO and international funder, processor
	Look into options for vertical integration, upstream and downstream and establish long term trading commitments	Processor in collaboration with farmers and clients
	Introduce payment system to farmers and traders based on quality, quantity, loyalty	Processor with support of the government organizations, sector organization
	Establish regional value chain synergies with the Philippines under the ASEAN agreement to reduce competition	Government organizations, sector organization
	Establish/further develop Centre of Excellences with national and international collaboration	Various actors: sector organisation, private sectors, research, government organizations, international funder
	Establish joint ventures between Indonesian companies and other companies from overseas	Processor, oversea company
	Install favourable fiscal policies, e.g. reduce the tariff and non-tariff barriers, assure that current policies like e.g. regulation on wastewater treatment applies to all companies (including Chinese companies)	Government organizations
	Facilitate access to finance	Government organizations, bank
	Stabilize the internal prices by government regulation	Government organizations

The above table is a longlist. It is not the idea that all interventions are implemented in parallel. Improving the chain needs an integrated approach with a cluster of interventions. It was observed that in practice hardware- and software innovations are prioritised and often employed in isolation. However, for successful implementation its needs Hardware-, to Software-, and Orgware- interventions in parallel. The introduction of improved seeds is for instance not likely to reach its full potential if farmers are not trained properly on the cultivation and harvesting, if supervision is not in place, and if processors do not introduce a quality driven pricing system with incentives for farmers to deliver quantity, quality and be loyal.

The above inventory shows that opportunities for improvement in the seaweed chain are huge. But solving them sustainably by one individual actor via a single intervention is hardly possible. Rather than individual interventions by individual actors it needs a collaborative approach of several actors with a cluster of strategic intervention. In order to start short term the suggestion is to focus at least on a Meso-level in a collaborative approach of supply chain actors or even the whole chain, see for more information below Figure 4. Subsequently, this approach should be extended to a Macro-level approach. A Macro-level approach would allow for uplifting of the Indonesian seaweed sector as a whole and would take along beneficial policy-, regulation-, and tax frameworks, access to finance, massive transfer of knowledge and so on. However, this approach lays outside the direct cycle of influence of the chain actors and establishment would take much longer than a Meso-level approach with a cluster of interventions. It is therefore that the Meso-level approach is prioritized here as a pragmatic way to get things started.

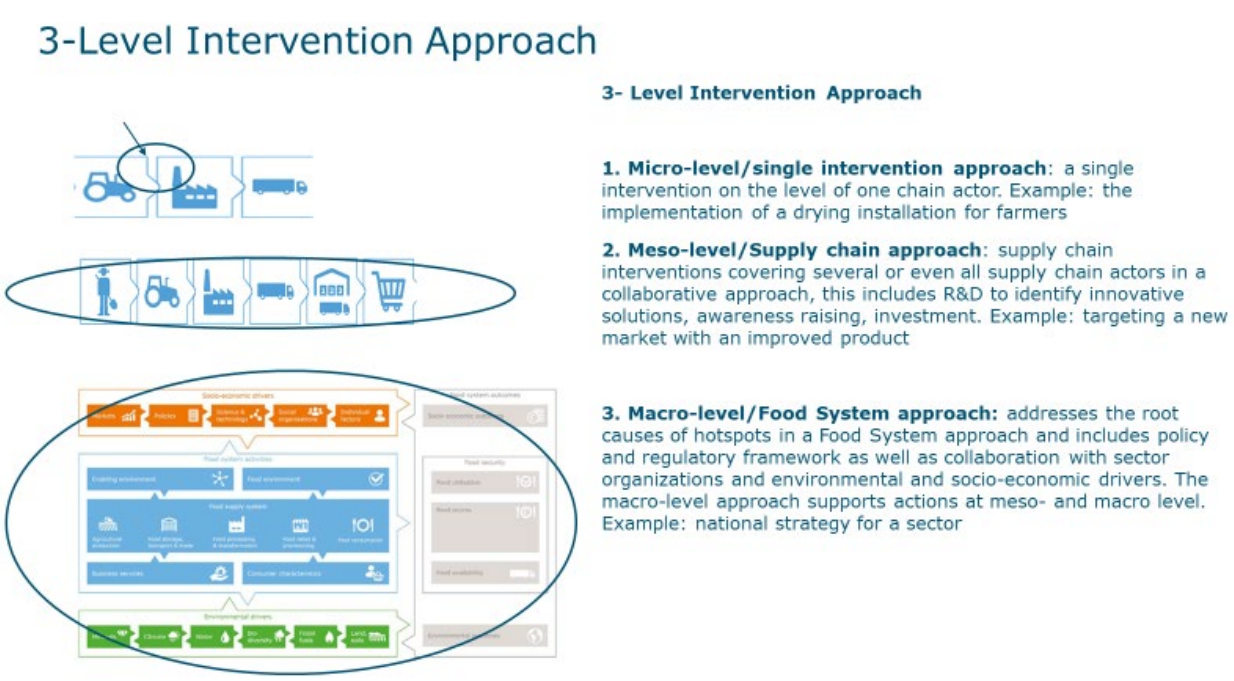

Figure 5 The 3 levels of interventions from micro- to meso- and macro-level

For this Meso-level approach, based on the above longlist, Table 13 suggests a shortlisted cluster of interventions covering the Hardware-, Software- and Orgware- Level. This cluster of interventions strives to enable exporting processors to produce high quality value-added products for high end markets like for instance the market for ingredients for bakery products, the growing market for vegan products, or the organic market. Market segments which are still in an early stage of development but are potentially interested in the added value from seaweed products out of Indonesia, like for instance storytelling. This approach looks promising since it bears the potential to overcome two key challenges of the seaweed chain:

- high competition with relative low value products in the lower-end of the market segment, and
- short term day-to day vision which is conflicting with the need for long term investments and collaboration.

Table 13 Shortlisted interventions to improve the current seaweed supply chain.

Level	Intervention
Hardware	Optimize agro-logistic network design from farm to processor
	Use of improved seeds by farmers
	Implement certification according to international standards for good practices, food safety, (social) sustainability like FFS 22000 to enable export to EU
	Install right technology for the development of value-added products like hydrocolloids, compounds, and blended products
	Implement traceability allowing for tracking and tracing and storytelling
Software	Train farmers on good seaweed cultivation- and good post-harvest practices
	Learn about export requirements and way of doing business in new markets
	Adapt high-level seaweed processing options like compounds
Orgware	Strategize towards export of value-added products to high end markets for human consumption
	Look into options for vertical integration, upstream and downstream and establish long term trading commitments
	Introduce payment system to farmers and traders based on quality, quantity, loyalty

The below three interventions are absolutely compulsory:

- certification according to international standards for good practices, food safety, (social) sustainability,
- right technology for the development of value-added products,
- tracking and tracing system.

Those are regular market requirements of buyers. Before being able to demonstrate compliance clients in Europe might not even be interested to talk to Indonesian processors. However, on itself and under the current circumstances, they are not necessarily more relevant than the other shortlisted interventions. As mentioned previously, one of Indonesian's challenges is its competitiveness with other origins, specifically in highly competitive markets like semi-finished products, and the carrageen - and agar market. The three most crucial hotspots in this regard are:

1. poor propagation material,
2. fragmented and costly agro-logistics supply chains, and
3. spot market sales to low end markets.

All three hotspots should be overcome to increase Indonesia's competitiveness. To give a first glance what this would mean we look in chapter 6.3 more in depth into the potential impact of:

1. increased seeding quality by improved propagation material
2. logistic optimization by improved agro-logistic network, and
3. the exploration of other markets.

6 Case Studies

Practices of two first mover seaweed processors[10] in Indonesia are described and interventions to improve the supply chain performance identified and explored.

6.1 Case study A

The first case is about an Indonesian processor that is specialized in red seaweed extracts such as agar and carrageenan, for the food as well as the pharmaceutical industry. They are the largest exporter of seaweed extracts in Indonesia, and sell to blenders in the EU as well as other regions. This case study is about the production of agar. Their supply chain is straightforward, like most of the seaweed processor chains, including a number of logistic consolidation steps, that varies per sourcing region.

Figure 6 Supply chain Case study A

Farmers
They are thousands of connected families, who cultivate Gracilaria in offshore production. The sourcing is from different islands. Sourcing from one region only is risky, because of the raining season. Farmers have no technology for drying (only sunshine). In the peak of the dry season the salinity of the pond water can increase to 40-45 gr per litre. During drying the salt is crystallized and the seaweed becomes fragile. Hence, spreading the production over different areas is necessary when growing Gracilaria in ponds. This is different if Gracilaria is produced in open sea. Then the salinity is no problem anymore, but only the drying in the rainy season.

According to this company investment in rope production is about 5000 USD[11]. The farmers are trained how to harvest the seaweed when it is 3 months old so that they get higher yield with higher quality. Obtaining seeds are the farmer's own responsibility, and very often the number of times the seaweed is reused for a new cycle is too high, leading to declining yields. The processor does not buy directly from the farmers, but from independent collectors. However, the collectors sell actually to everybody, also to the Chinese market. There is strong competition with Chinese buyers who pay directly in cash to the farmers. The processor sometimes pays farmers a significant % in advance to compete with the Chinese. Price is not only a driver to sell to the highest bidder, it also leads to changing to another product (e.g. shrimps) if the short-term profits seem higher. This short-time vision related to price fluctuation is why farmers are reluctant to invest in seaweed production.

Figure 7 Seaweed production in ponds in Indonesia (photo by Indonesian processing company)

[10] Company names are known to the authors, but hidden because of confidentiality
[11] although other sources claim that 300-375 € is sufficient, which is a huge difference

Quality is another issue in more than one way. Some farmers apply too much fertilizer. The seaweed grows fast, but has low hydrocolloid content, only skins. As long as the seaweed is not analysed this practice can continue. Uniform produce is difficult to organize, but important because of its characteristics like gel strength. The more homogeneous (less different species in 1 ton) the better their economies of scale, since less differentiation is required in processing. The alkaline process at the processing facility will change in concentration and temperature. When the seaweed is thin, you apply lower concentration of alkaline and lower temperature, otherwise the seaweed will go with the waste water. The other way around also holds for thicker species.

There are many issues at farm level, and because of the remoteness and small scale of the production areas, it is impossible to manage this from a long distance.

Logistics
The processing company mostly pays (depending on what is paid already) at the factory gate for semi-dried seaweed. Local transporters come with seaweed and go back with other things. The transport is not organized by themselves, but by their suppliers (traders). The consolidators that supply to them are asked to apply some quality control when they source the seaweed. Some margins are prescribed with respect to: moisture content, purity, age and homogeneity. It is unclear how this works in practice.
Normally the first part of the supply chain is walking or a three wheel drive (tricycle) to the nearest village, where drying and cleaning takes place. From there, a three wheel drive transports it to a little warehouse and a hydraulic pressing machine is used. When the volume is high enough the final large scale transport takes place by (boat and) truck.

Processing facility
The data for processing relate to pond production. On arrival the Gracilaria is checked on tonnage and moisture content. The moisture content should be between 15-20%, otherwise there is a complaint or a rejection. The first step is to clean the seaweed. The average composition of Gracilaria is:

Table 14 Composition of dried seaweed supply.

Seaweed components	Content
Moisture	15-20%
Salt	8-12%
Pure seaweed	45%
Mud	30-35%

The mud share is large since the seaweed is taken from the pond bottom . In the (pre)coating process with an alkaline concentration, the dirty seaweed would absorb only part of it. Some of this alkaline is in the mud and has to be cleaned with acid in the wastewater. By having less mud, the amount of alkaline and acid can be reduced. If the dried seaweed is purer (less mud and shells) the result might be a higher yield in agar powder. With a composition of ***Table 14*** the yield is about 10% (1 kg agar powder from 10 kg of dried seaweed), but this could increase to 12% if the purity was higher to start with. However, the purchasing price would also be higher. More chemicals are needed since the amount of pure seaweed is higher, but losses are less, and the net result will be better.
After the coating the product is filtrated resulting in seaweed cake that is stored for a short period. Then dewatering in membrane press, mincing, drying, milling and sieving complete the process to end up with agar powder.

Market
The processing company is selling not to the final users like food industries, but to blenders (at least 2nd level of processing). Well-known players in this compound industry are CP Kelco, FMC and Cargill. The company wants to diversify to other products, however a high price of 200-300 k€ (new product introduction) might be required to enter the EU market (novel food assessment) or the USA (US GRAS list on food safety). They sell to the EU and outside the EU and want to increase their level of technology and get commercial relationships with food processing companies in the EU.

The goal of this processing company is to get into the EU market of compounds for food industries by investing in people and technology to achieve the second and third level of seaweed processing. A potential strategy is to process certified organic seaweed. The company wants to step out of competing on price via big volumes and looks for new ideas and products. Another option is to look at the residual flows. About 90% of dried seaweed is discharged waste and the company is thinking about innovations from this flow.

6.2 Case study B

The second case study is about a processing company in Eastern Indonesia. The company produces semi-refined carrageenan (SRC) and alkali treated cottonii (ATC) together about 150-200 tons per month.

Farmers
The company sources from about 5,000 farmers who produce Kappaphycus on ropes in an archipelago in East Indonesia. The farmers are supported by the processing company with seedlings, ropes and training. In the past the propagation material was supplied by the government, but not anymore. Reusing the seeds every time decreases the genetic material significantly, and hence there is a need for increasing the lab capacity to provide more seedlings, or eventually the (local) government can help the company on this matter.
The drying used to take place in the sand near the water, leading to contamination. Nowadays the drying is on platforms as shown in 8.

Figure 8 Drying seaweed on platforms on the beach (source: company)

Farmers need to supply the dried Kappaphycus alvarezii at 38% moisture content and maximum 2% of dirt or sand. The company has a quality management system (QMS). All raw materials and the end product are subject to strict quality control.

Logistics
Farmers bring their dried seaweed to the collection center, that is related to the processing company. Contrary to most other supply chains the 'payment' to the farmers is in goods. When farmers come with their harvest the collection center registers what the farmers want to exchange for the seaweed. This can be oil, flour, clothes, pharmaceutics, etc.). This business model helped the processing company to secure raw material supply. The registration at the collection center also enables the company to have a track and trace system. Secure supply and traceability are major competitive advantages compared to many other seaweed supply chains in Indonesia. The business model also saves a lot of cost because of the reverse logistics in goods.

The company collects the seaweed from these collection centers on the islands by boat. The boat comes every week. The company does not face competition with the Chinese or other buyers, as it is very important for the isolated villagers to have long term relations with the factory to be assured of the supply of the needed goods which they exchange against dried seaweed. For farmers the most important is the continuity. Because of the high export costs per container, especially during COVID-19, logistics need to be improved. Eventually a new logistic design is needed, where optimization is carried out with respect to visit frequency, vessel size and the capacity of the collection centers. Upscaling seems one way to cope with the challenges of high logistic costs.

Processing facility
Per month about 500 tons of red dried seaweed is sourced from the islands, which is converted into 150-200 tons of carrageenan. The facility is only a few years old and has new equipment and advanced management systems (like traceability and quality control).

Market
Semi-processed products are suffering from a competitive market with relatively low prices. Besides logistic optimization and improved seed production another way to increase competitiveness is to make compounds (higher added value and margins) which is considered as an option as well. With highly qualified laboratory team with extensive experience, supported by an International Standard Laboratories, the company claims to be able to produce tailor-made innovative ingredients to meet buyer requirements. This is a potential strategy for the near future.

6.3 Intervention

Based on the interviews there are several interventions that would improve the competitiveness of the Indonesian seaweed supply chain. These are elaborated as far as possible with the available data to gain insight in the impact.

Increase seedling quality
In paragraph 4.2 investment costs for Kappaphycus alverzii were shown in ***Table 7***. The total investment is 6,170,000 IDR of which 1,800,000 IDR are spent on 300 kg of seedlings. In this example 30 ropes of 30 meter each produce 350-390 kg of RDS, let's say 370 kg on average. According to Gunarto Latama[12] the average RDS prices for the last three years were:

Table 15 Average farmer price for RDS per year.

Gracilaria (price in IDR/kg RDS)		Kappaphycus (price in IDR/kg RDS)	
2019	5,000-7,000	2019	22,000-24,000
2020	4,500-5,000	2020	13,000-16,000
2021	3,800-4,000	2021	13,000-14,500

The sales value per year for Kappaphycus in 2021 would be about 14,000 x 370 = 5,180,000 IDR. The production equipment lasts for 3 years and if the seedlings are reused no additional investment is required in three years. The profit would be (3 x 5,1800,000) – 6,170,000 =9,370,000 IDR ≈ € 570, which is € 190 per year. The average income of an agricultural worker in 2021 in Indonesia was around € 1000[13]. And the farmer has to reinvest 6,170,000 IDR for continuation (unless the seedlings are used even more often).

Earlier in this document the yield decrease in seedlings was mentioned. Farmers buy used seedlings and reuse them as well. It is not known to the authors what the price of new high-quality seed is, but the profit increase can be calculated for different scenarios.

[12] Gunarto Latama, head of dept of Fisheries, Hasanuddin Univ. Makassa; prices d.d. November 2, 2021
[13] https://www-statista-com.ezproxy.library.wur.nl/statistics/1220587/indonesia-average-daily-gross-wage-of-agricultural-workers/, viewed 25-2-2022

Table 16 Sscenario analysis when yield of seed increases.

Yield increase	Yield (RDS kg/year)	Profit per year* (US$)	Profit per year (kIDR)
20%	445	259	3,788
50%	555	354	5,177
100%	740	514	7,517

* 1 US$ = 14,625.17 IDR (exchange rate XE 02/05/2022

Note that if the seed is mor expensive the profit will decrease by the difference in purchase price for 300 kg of seed. Moreover, the dramatic price drop (see Table 15) has a huge impact on the seaweed business, that eventually will cause a withdrawal of many farmers in 2022.
One of the interviewees mentioned a scenario where the yield increase was much bigger than 100%. The analysis shows that if you can afford it, investing in better seed is rewarding.

Logistic optimization
Most processors do not have contracts or strong relationships with the seaweed producers. The seaweed market is very opportunistic, and supply as well as demand is volatile. Currently, COVID-19 leaves many people unemployed in the tourist sector, and many of them started seaweed production. The resulting mismatch in supply and demand caused a price drop of about 40% between 2019 and 2021. According to these uncertainties (including the seasonality of the Chinese demand), it is rather risky to invest in farmers that can switch in what they produce as well as who they sell to. This particularly holds on the main islands, where job hopping (tourism, office, shops, ...) is easier than in remote areas, where there is much less economic activity and transport on water less frequent.

Case study B is about seaweed production in remote areas in Eastern Indonesia. Kappaphycus is collected from several islands once a week, and farmers are supplied with the same boat with goods they asked for in return for their produce. Here relationships between processor and farmers are strong, and it pays to invest. The logistic structure is shown in where clients C1-C4 (e.g. USA, Japan) are supplied with different containerships.

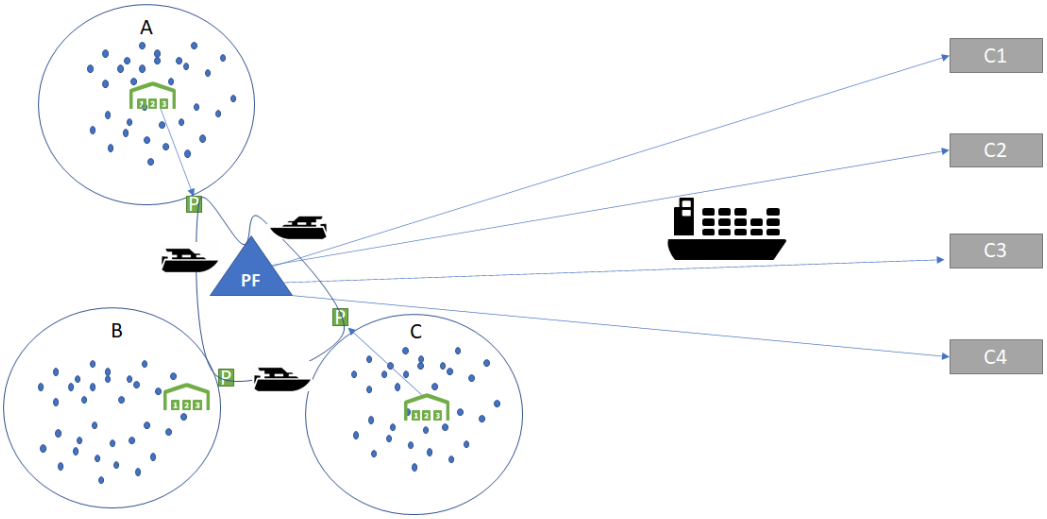

Figure 9 Logistic structure for case study B (PF=processing facility)

The conditions are suitable for logistic optimization on various levels: operational, tactical and strategic. The company wants to grow, implying more collection and transport capacity. There are various options to organize and control the operations and supply chain design, and depending on company criteria optimization can provide the best configuration, e.g. with respect to cost and/or sustainability (e.g. GHG, livelihood). In practice one could think of an extra boat, a bigger boat, higher collection frequency, where to increase production, production planning, inventory capacity, etc. on the supply side and combining loads on the distribution side. Dried seaweed is not as perishable as fruits and vegetables and carrageenan powder can be stored (and transported for a longer period of time). Hence, from the climatic control point of view the logistics are not challenged very much.

Explore other markets

For international retailers, seaweed is a new product with potential, as it is considered super healthy. Seaweed products plays an increasing role in the food industry as shown by the growth of product introductions containing carrageenan, agar or specific compounds. As an example the number of product introductions in food in the EU[14] with carrageenan as an ingredient from 2012-2019 are shown in ***Table 17***

Table 17 # product introductions in main food categories and main EU countries from 2012-2019.

Product category	France	Germany	UK	Spain	Netherlands	Italy	Belgium	%
Desserts & Ice Cream	1128	1099	824	627	614	498	379	38%
Dairy	612	536	703	300	238	284	243	21%
Meat, Fish & Eggs	294	235	140	230	110	109	95	8%
Sports Nutrition	180	293	239	61	90	56	11	8%
Soft Drinks	77	138	146	102	86	18	66	5%
Ready Meals & Side Dishes	335	78	141	126	57	18	42	5%
Bakery	238	113	163	45	86	42	42	5%
Confectionery	29	84	113	13	35	13	14	2%
Sauces & Seasonings	78	74	33	25	26	16	14	2%
Spreads	86	32	24	79	20		13	2%
Supplements	37	14	87	21	49	12	9	1%
Snacks	125	27	10	13	10	5	13	1%
Rest	69	30	60	62	18	10	15	2%
Grand Total	3288	2753	2683	1704	1439	1081	956	100%
%	18%	15%	15%	9%	8%	6%	5%	

Animal-based food categories are the most involved in seaweed type ingredients, but opportunities are present in other categories like bakery, where several countries show much less products for sale than the top 3. Both processors are ambitious and want to connect directly to the food industry, instead of first level processing supply to companies like CP Kelco and Cargill. Potential clients are the food processors in the EU with the highest number of product introduction with seaweed-based ingredients as shown in ***Table 18***:

Table 18 Food companies with the highest # PI with seaweed-products in EU.

Seaweed	# PI 2000-2019	Carrageenan	# PI 2012-2019
Nestlé	80	Unilever	1658
Lima	68	Danone	615
Rosa Maria Miras Antel	49	Nestlé	542
Pukka Herbs	41	Aela	295
Agar	**# PI 2000-2019**	Alpro	294
Alpro	88	Friesland Campina	255
Haribo	71	Mueller Dairy	226
Nature et Aliments	46	Lactalis Nestlé	219
Pastificio Rana	43	Oetker	217

Currently, both processors lack the level of technology to enter the compound market, but both consider it as a strategic goal on the short term.

[14] Al quantitative data on PI (product introductions) are taken from the Innova Market Insights database.

7 Index of seaweed market requirements and prices

One of the goals of this project is to realize an index of market requirements and prices, that will facilitate Indonesian market players in setting the right priorities, determining return on investments and realizing robust and sustainable seaweed supply chains, with a focus on export to the EU.
As one of the largest seaweed producers in the world Indonesia wants to find ways to exploit that position. Not only by selling dried seaweed to China, but also by increasing export of commercial products like agar, carrageenan and (if possible) high-end additives like compounds, preferably towards the EU. Currently, Indonesia has a weak position in the international market of these value-added products, although exports of agar and carrageenan from Indonesia to the EU are taking place nowadays. The index is meant to support decision making on supply chain level, and will only touch some overarching governmental topics.

In the previous chapter a general analysis is carried out on the low- and mid-tech processor supply chains in Indonesia, resulting in SWOTs per supply chain stakeholder. These SWOTs often are triggers for interventions, however include issues on different organizational levels. For instance, the lack of enforcement of the law with respect to food safety is a governmental problem, that cannot be solved by a supply chain. The same holds for e.g., water quality and climate-adaptive production. Many problems cannot be solved by a supply chain, and hence a distinction is made between interventions that can be solved by a supply chain and those that require third parties, as there are knowledge institutes or governmental bodies.

It can be used by supply chains to investigate how close they are on being competitive at the EU market for seaweed processed products and what interventions need to be invested in. These interventions will be supply chain specific rather than upgrading the seaweed sector as a whole. It should be considered as a business-driven instrument. The index includes market requirements, price competitiveness, knowledge level and some kind of vertical integration as elements for the analysis.

Many issues relate to the export position of a seaweed supply chain, and to improve the current status an index that relates to these issues helps to focus on what is needed to become competitive. Therefore, the most relevant criteria for export of commercial products are listed and will be integrated in the index. The approach is elaborated for carrageenan, but can be copied for agar and dried seaweed.

Relevant elements to become competitive
Based on literature and interviews with Indonesian processors and other experts, the following topics are considered relevant for the index:

a) Market requirements
b) Price
c) Knowledge level at processing
d) Vertical integration

a) *Market requirements*

To increase the market share in the EU several market requirements need to be satisfied in the area of food safety, traceability, (consistent) quality and eventually sustainability. To adopt these topics as a dichotomic variable in the index is not appropriate, since progress is not from 0 to 100% at once, but goes step by step. Therefore, these issues are split up in subtopics that can be set as goals in the development of the supply chain at hand with respect to EU market requirements.

Traceability
Traceability within value chains is very important due to legislative and buyer requirements, and the image of Indonesia in this respect is low. According to the General Food Law (GFL) traceability:

- facilitates withdrawal of faulty food/feed from the market
- provides consumers with targeted and accurate information on specific products
- covers all food and feed, all food and feed business operators, without prejudice to existing legislation on specific sectors
- affects importers who are required to be able to identify by whom the product was exported in the country of origin
- obliges businesses to be able to identify at least the immediate supplier of the product in question and the immediate subsequent recipient, with the exemption of retailers to final consumers - one step back-one step forward (unless specific provisions for further traceability exist).

More details can be found on the EU food safety website:
https://ec.europa.eu/food/sites/food/files/safety/docs/gfl_req_factsheet_traceability_2007_en.pdf

The goal of traceability is that actions can be taken when a risk is identified. For that purpose, the critical issue is the 'one step back-one step forward' documentation. In case of an Indonesian processor the information backwards in the chain may be available up to village level, because aggregation takes place there. Moreover, the documentation and the data quality probably do comply with the EU requirements, as presented in [11]. In spite of the fact that traceability is not arranged, part of the required information and processes are already in place, and this should be converted into a score between e.g., 0 and 10, resulting in an indication to how far away the necessary level of 10 is, and what needs to be done.

Food safety
Food products and ingredients are covered by an extensive body of legislation in the General Food Law[15] (GFL). The most important aspects of this law deal with food safety, which includes hygiene, pesticide residues, contaminants, microbiological criteria, permitted additives, and processes and systems to control these requirements, such as tests and Hazard Analysis and Critical Control Points (HACCP).

Of course, Indonesia has food safety legislation. The Indonesian government has promulgated several regulations on food safety such as Act 18/2012 on Food and Government Regulation No. 28 of 2004 on Food Safety, Quality and Nutrition. In addition, they adopted the Integrated Food Safety System (IFSS) to reach equivalence to the international food safety standards. To monitor and supervise the food sector the government has established the National Agency for Drug and Food Control (NADFC). However, food safety offense such as food adulteration is still easily found in almost every area in Indonesia and causing serious illnesses and economic losses. The NADFC turns out to have insufficient power to enforce the low, and hence export partners have less confidence in Indonesia as a trade partner [12]. In a study [1] where 10 seaweed companies where interviewed, all of them had HACCP certification, and all certified by the Ministry of Marine Affairs and Fisheries (MOMAF). None of these companies had external bodies for certification nor auditing involved.

To trade with EU seaweed buyers food safety management should be in place. The standard approach is to implement a HACCP system. A compact overview how to do this can be found in [13] (p.23-41). Comparing the current situation with the HACCP approach, especially with respect to hygiene and risk control, will elucidate how close the supply chain is to this standardized food safety management system. We expect this to be in order, since it is the law, but, as described earlier, the enforcement is difficult and often lacking, which leads to mistrust on the side of the foreign buyer.

With respect to contamination of carrageenan there is a list of requirements (see [11]) that can be found in the Appendix. A parameter for contamination can be calculated at processor level to check how much % of these requirements are fulfilled.
Food safety is essential in EU trade and therefore certification schemes are introduced. In the seaweed extract business common certifications are Food Safety System Certification 22000 (FSSC 22000), ISO 22000 (ISO's food safety management standards), British Retail Consortium (BRC), International Featured Standard (IFS) and Good Manufacturing Practices (GMP). Big seaweed compound exporters have multiple certificates in order to enable export in various segments, like animal products, food in general or

[15] https://ec.europa.eu/food/safety/general_food_law_en, viewed December 15, 2020

pharmaceutical products and to various markets. Certification is a necessary condition for export to the EU, and only accredited and approved inspection- and certification bodies are allowed to audit and certify compliance to the standards in question. Companies can proof their compliance to the standards via the issued scope certificate. The certificate states not only the certified products, processes and/or units and where the products are produced or processed, but also the period of validity of the certificate.

Quality
The image of Indonesia with respect to food safety management is poor. Adulteration, is considered as a quality problem, in general, and for seaweed in particular can be found easily. This is confirmed by research as in [12]. This needs first all adequate product specification throughout the purchasing process and secondly consistent and reliable quality control of incoming- and outgoing goods. Batches need to get tested for adulteration and consistency. The earlier-mentioned certification schemes and specifically Food Safety Certification (FSSC 22000), International Food Safety (IFS), Safe Quality Food (SFQ) and British Retail Consortium (BRC) certification give concrete directions with regard to the implementation of Standard Operating Procedures (SOPs) tackling quality issues and ensuring consistency in daily operations. Buyers may require certification concerning quality standards.
Consistency is another quality issue. To have stable pricing purchased quality should behave accordingly in time. On the processing level, the perception of Indonesian performance is generally suboptimal. European players perceive Indonesian suppliers to lack proper food safety and quality management and a lack of knowledge on differences between seaweeds, quality aspects of seaweed extracts and their applications, which result often in inconsistent quality [1].
Typical quality parameters are clarity, gel strength and cleanliness (no contamination)
To include these considerations in the index food safety consists of five elements:

- How close is the processor to a HACCP system (the FAO version or the version of the Indonesian government)? (% estimate)
- How much of the contamination requirements with respect to carrageenan are satisfied? (% calculation)
- Has the processor up to date certificates, issued by an accredited certification body, for the target market and scope in question? (0 or 100%)
- Satisfying market requirements on quality: e.g. Clarity (%), Gel strength[16] (800-900[17])
- Monitoring of quality consistency

b) *Price*
Prices for seaweed are investigated for 13 cities in Indonesia in [14]. The analysis shows that price variations are huge ($\sigma/\mu \approx 0.5$) within the year, over the years and between cities. The latter can partly be explained by the high logistic costs for production in remote areas. Because of these price fluctuations, farmers are reluctant to invest money or time in one crop. So, commitment to processor or contracts are very hard to get. The same study revealed also the interesting fact that prices are not significantly related to product (quality) attributes such as moisture, sand and salt content.

The price volatility also holds for Chinese buyers, who very often pay good prices in relation to the local price, but still provide no commitment or guarantees. As a consequence, the risk for investment is high for Indonesian stakeholders. This is different for partners in the EU, that are used to contract-based business if the high market requirements are met. From this point of view, it may be concluded that the sustainability transformation of the Indonesian seaweed supply chain can only be triggered by market-driven agreements, in which case the EU seems to be the best option, although compared to China the requirements are much higher.

[16] This is application specific. An example is: semi-refined carrageenan was in the range of 388 to 512 g cm-1 and for the refined carrageenan, the values ranged from 534 to 712 g cm-1. See http://www.mspp.org.my/files/jtpp/jttpvol9/JTPP%20Vol%209%202017%20page%2014-23%20Kappaphycus%20alvarezii.pdf, viewed 1-1-2021
[17] These values are standard on the domestic Indonesian market

The EU is an interesting market for carrageenan. It is used mainly in desserts, ice cream and dairy products. France, Spain, Germany and the UK are the main importers. Export of carrageenan to the EU is dominated by the Philippines, China and India.

Table 19 Import carrageenan (HS 130239) for EU-28 in 2019 (UNComtrade).

Rank	Partner	Qty (tons)	Trade Value (kUSD)	price (USD/kg)	Qty %
1	Philippines	9290	79732	$ 8.58	29%
2	China	8981	85628	$ 9.53	28%
3	India	6065	10946	$ 1.80[18]	19%
4	Indonesia	2413	18693	$ 7.75	7%
5	Chile	1555	19727	$ 12.68	5%
6	USA	1047	18349	$ 17.52	3%
7	Peru	817	3203	$ 3.92	3%
8	Canada	731	5941	$ 8.12	2%
9	Rep. of Korea	589	6899	$ 11.71	2%
10	Pakistan	253	410	$ 1.62	1%

The export price in the top was between 7.75-9.53 USD/kg on average in 2019. This might be explained that within the code 130239 there are several products each with different added value. The export price is different from the cost price. For Indonesia the cost price of Carrageenan is 7.1-7.2 USD/kg, and they sell for 8 USD/kg, whereas China sells for 7 USD/kg[19]. The background of the low price in China lies in the tariff and tax regulations. On the one hand China has a SPT (Special Preferential Tariff) rate for imports of seaweed from Indonesia and the Philippines, which is 7.5% against 15% for all other WTO members [15]. Moreover, the export VAT for carrageenan is 17%, and the Chinese government provides a rebate of 13% on this VAT [15]. This impedes the international position of Indonesia, since China sources almost all Kappaphycus alvarrezii (=Euchema cottonii) from Indonesia and because of the governmental support Chinese importers can pay good prices for Indonesian seaweed, that are competitive to the domestic market. In addition, Chinese traders in Indonesia pay cash, contrary to very often delayed payments from Indonesian buyers [1]. Conclusion is that Indonesia will not be able to be competitive on price, since the regulations from the Chinese government prohibit a level playing field, and this kind of support is not expected from the Indonesian government. The price will be part of the index, since it is a reference value and Indonesian supply chains cannot conduct prices that are higher. The price for Indonesian carrageenan in 2019 was lower, that could be explained by the non-discriminating HS code. Carrageenan is contained in HS code 130239, but no difference is made between carrageenan extract and carrageenan compounds. Extracts like semi-refined and refined carrageenan are retrieved by relatively simple processing, whereas customised compounds are based on seaweed extracts and other hydrocolloids for the food and feed sector are used to achieve specific texturing solutions for specific products of manufacturers, often in close coordination with the client [1]. It is important to find out more details about the products behind HS code 130239 (statistics can go deeper than 6 digits[20]) to have a better understanding of the price differences. This can be done by analysing the costs in the supply chain, e.g., with Activity Based Costing. This is company/supply chain specific but will elucidate the options where cost reductions might be possible.
The investment costs of course depend on the size of the farm and can go up to 8000 USD (example from 2009) as shown in [16]. From our interviews it was noted that on average the start-up investment for seaweed production with ropes is about 5000 USD. For ponds this would be 500 USD.

Nevertheless, China will have a price advantage and, as in regular marketing, other elements than price need to be addressed by Indonesian seaweed supply chains to become more competitive (e.g., sustainability, added value like formulated carrageenan).
For now, the index will incorporate the annual Chinese price as a reference value. In the future it might also be relevant to explore seasonality, since China imports Indonesian seaweed mostly at the end of the year.

[18] The data for India are not reliable; see https://www.zauba.com/export-carrageenan-hs-code.html , where prices are close to the price of China, Philippines and Indonesia, viewed December 15, 2020
[19] Interview Stefan Kraan, the Seaweed Company d.d. October 27, 2020
[20] https://hts.usitc.gov/current, viewed 15-12-2020

Clearly, this part of the index shows that processors on Indonesian islands with bad connections to EU will be less competitive, since inter-island transport is very expensive.
The score for the price level is determined by the following table:

Table 20 Scoring table for price.

Price level Indonesia lower than China				
<3%	**3-6%**	**6-9%**	**9-12%**	**12-15%**
1	2	3	4	5

c) *Knowledge level at processing*
Especially in the high-end EU, food and beverage manufacturers increasingly need tailored texturising systems for their new products. Many of them rely on blenders to do research and develop tailored solutions (formulated products), such as low-cost seaweed compounds which retain their well-defined target properties, functionality and performance. It can exist in liquid, semisolid or powder form. This often requires the combination of various hydrocolloids. This type of R&D requires close collaboration between end users and blenders. Suppliers of seaweed compounds must be able to advise manufacturers on the application including processing characteristics. According to European buyers, this level of knowledge and market connectivity is currently not present in Indonesia [1].
The knowledge level at processing level is an important element in competitiveness and hence for the index. We introduce the following levels in this context:

i. Low-value extracts (ATC, SRC, RC)
ii. Compound processing
iii. Compound processing including R&D

The scores for these alternatives are 1,3 and 5 respectively.

Remark: Sustainability (can be added, but is a complex indicator with many dimensions). In response to the demand for certified sustainable seaweeds, the Marine Stewardship Council and the Aquaculture Stewardship Council launched a new ASC-MSC seaweed standard in 2017, setting the requirements for seaweed harvesting and farming practices. In Indonesia it is launched one year ago, and until now only 4 companies are certified, probably hindered by Covid-19[21].

d) *Vertical integration*
In the previous texts the fickleness of seaweed farmers has been demonstrated. In such a setting it is difficult to invest in the supply chain. If relations were tight training, seed supply and other services would increase the performance, strength and competitiveness of the entire supply chain. Case study B is an example how market requirements like quality control and traceability can be implemented if farmers are committed to their buyer The level of integration may vary. If the collection is done by the processor (as in Case study B) and farmers are trained, get seed etc. there is full integration. But sometimes only part of the sourcing has strong relationships (e.g. for organic production you need more control), or logistics and quality control is outsourced to traders, who again have or not have contracts with the processor.

Three levels of vertical integration are defined as input for the Index:
1. No commitment from a significant share of the farmers that supply (so suppliers will vary a lot)
2. Commitment with a significant share of the farmers and eventually traders
3. Full commitment of (almost all) farmers and the processor is service provider for these farmers. This can be seed supply, training, collection of goods, investment support,...

Here commitment is defined as 'supply according to some agreement with the processor'. This can be on amount, timing and price and agricultural practices.

[14] Interview Patricia Bianchi, Aquaculture Stewardship Council (ASC), d.d. June 8, 2020

Index
The index is a combination of these 3 elements, where market requirements consist of 3 sub-elements.

Indonesia	a) Market requirements			b) Price	c) Knowledge	d) Vertical integration
Carrageenan	Traceability	Food safety	Quality			
Supply chain X						

It is important to stress that a) Market requirements are necessary conditions, that should be complied with 100%, in order to export to the EU.
The scoring can be considered separately, since it merely shows what needs to be done per topic. Therefore, the scoring in % of the market requirements is fine; no adding up is needed.

The index can be applied with market or client-specific targets, that will alter the quality requirements, reference price, required level of knowledge and vertical integration.

8 Conclusions and Discussion

Seaweed is a great natural renewable resource. Growing it is relatively simple, with low initial capital investment. For the offshore production it only needs nylon lines seeded with spores and for the on-shore production bamboo racks. It requires no land, no fertilizer, and no fresh water to grow, and the crop can be harvest already after as little time as 6 weeks! Therefore, its cultivation potentially offers many new attractive opportunities for the poorest and specifically to the rural population in the coastal areas in developing countries. Increasing the commercial production of seaweed could potentially result in a direct contribution to food security as food or food component, or indirectly by creating employment opportunities and extra income as result of the seaweed production and processing.

Indonesia has a lot of potential for seaweed production and also has a significant seaweed processing industry. However, the Indonesian seaweed sector do not yet make use of its full potential. Per individual seaweed chain actor there are many strengths as well as opportunities. However the question is whether those can compensate for the serious weaknesses and threats observed. Many of the actors face challenges and for some actors seaweed even have become a tough business. Chain actors are not optimally interlinked and are not trading with each other in an aligned market driven supply chain approach in which products are matched to market demands and consumer preferences and all chain actors are receiving a fair share. Instead, products are marketed through fragmented supply chains characterized by many handlers, hardly any cooperation and integration and poor transparency. The focus of the actors is on short term profit and lowest prices, with little long term commitments and incentives for improvements. This leads to high supply risks and transaction costs, price inefficiencies, and finally unnecessary losses and reduced income.

The majority of the interventions noticed focused on individual micro-level interventions. Hardware- and software interventions were clearly preferred before orgware interventions. However, it needs an integrated meso- or macrolevel approach on the three levels. Some first good examples of supply chain integration are observed in the form of vertical backwards integration from the processor towards the farmer. Forward integration of the processor towards the end market was not yet observed.

Potentially, there are new interesting opportunities for the Indonesian Processor in the high-end markets in Europe with added-value seaweed products (paragraph 3.2). Possibly also side- and waste streams could offer new market opportunities. Exporting to Europe goes along with comprehensive quality assurance requirements for the end product and the processes. Also, to be competitive with e.g. Chinese products, many inefficiencies in the supply chain would need to get solved. The preparation for such new market entrances goes along with a cluster of interventions. Our assessment of three of the interventions showed that:

- Investing in high quality seed pays off, although price volatility may reduce the positive impact
- Logistics is a challenge in Indonesia when sourcing seaweed from remote farmers from various islands. Especially on tactical and strategic level a supply chain analysis with various scenarios could show improvement in logistic performance and cost reduction, in particular for growth options
- Currently, Indonesian processors are not able to compete in the global market of carrageenan and agar (first level seaweed extracts). Therefor companies should look for alternative markets, although this surely requires investment. The index might indicate the priorities in this context. This however requires more added value knowledge and technological facilities
- Quality (of product and logistics) and loyalty should pay off in the domestic supply chain, inducing stronger relationships, cooperation and market-driven production
- Traceability and audits by non-Indonesian organisations are necessary to increase trust from EU and USA.

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