Blue Economy Impact Investment East Asia

BUSINESS MODEL & FINANCIAL PLAN

SEAWEED FARMING PRODUCTIVITY AND
VALUE CHAIN IMPROVEMENT

# Impact Investment for a Business Venture for Community-Based Seaweed Farming in Northern Palawan, Philippines

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## Blue Economy Impact Investment for East Asia

# BUSINESS MODEL & FINANCIAL PLAN

## SEAWEED FARMING PRODUCTIVITY AND VALUE CHAIN IMPROVEMENT

## IMPACT INVESTMENT FOR A BUSINESS VENTURE FOR COMMUNITY-BASED SEAWEED FARMING IN NORTHERN PALAWAN, PHILIPPINES

This concept study has been developed and compiled by Blueyou Consulting LTD in Switzerland within the framework of a contract agreement between PEMSEA and BLUEYOU CONSULTING LTD. © Blueyou Consulting LTD | Zürich | Switzerland | August 2016

1 EXECUTIVE SUMMARY .......... 4

2 INTRODUCTION .......... 6

2.1 Seaweeds and its uses .......... 6
  2.1.1 Food .......... 6
  2.1.2 Hydrocolloids .......... 7
  2.1.3 Fertilizers .......... 8
  2.1.4 Additives .......... 8
  2.1.5 Cosmetics .......... 8
  2.1.6 Water waste management .......... 8

2.2 Seaweed production history .......... 9

3 SEAWEED PRODUCTION AND INDUSTRY IN THE PHILIPPINES .......... 10

3.1 Eligible seaweed species .......... 11

3.2 Reproductive cycle & vegetative growth .......... 11

3.3 Sites, volumes and seasonality .......... 12

3.4 Farming methods .......... 14

3.5 Trade, processing & export .......... 17

4 FEASIBILITY AND SCOPE FOR IMPACT INVESTMENT IN SEAWEED FARMING .......... 19

4.1 Criteria for community-based Seaweed Farming .......... 19

4.2 Scope for impact investment .... 20

4.3 The model site: Green Island, Roxas Palawan .... 21
4.3.1 Farming area .... 22
4.3.2 Human capacity and farming history .... 22

5 BUSINESS STRATEGY AND CONCEPT .... 22

5.1 Investment model & investable entity .... 23
5.1.1 Farm Units .... 24
5.1.2 Cooperative .... 24
5.1.3 Seaweed tissue culture lab & nurseries .... 25

5.2 Marketing and sales .... 25
5.2.1 Pricing .... 25
5.2.2 Projected outputs .... 25

5.3 Status quo vs. proposed model (Green Island) .... 26

6 FINANCIAL PROJECTION GREEN ISLAND .... 27

6.1 Assumptions .... 27
6.1.1 Cooperative .... 27
6.1.2 Farm units .... 28

6.2 CAPEX .... 29

6.3 EBIT Farms .... 30

6.4 EBIT Cooperative .... 31

7 FINANCIAL PROJECTION TISSUE CULTURE LAB .... 31

7.1 Assumptions .... 31

7.2 Processes, setup and cost of the lab .... 33

7.3 CAPEX .... 35

7.4 EBIT .... 35

8 EXPECTED IMPACTS .... 36

8.1 Environmental impact .... 36

8.2 Social impact on communities .... 36

8.3 Socio-economic impact .... 37

9 SCALE-UP TO MULTIPLE FARMING COMMUNITIES (NORTHERN PALAWAN) .... 38

9.1 Community profiles for the scale-up plan (Roxas, Dumaran, Taytay) .... 40
9.1.1 Bohol .... 40
9.1.2 Danleg .... 40
9.1.3 Calauag .... 40

9.1.4 Pamantulon ..... 40

**9.2 Synthesis: combined investment case for tissue culture lab and 5 farming sites ..... 40**

10 PROJECT IMPLEMENTATION ..... 42

**10.1 Project Management ..... 42**

**10.2 Implementation procedure and timeline ..... 43**

11 RISKS AND MITIGATION ..... 44

**11.1 Competitor analysis ..... 44**

**11.2 Social and environmental impact risks ..... 44**

**11.3 SWOT analysis ..... 44**

**11.4 Factors for success ..... 45**

**11.5 Risk & Mitigation ..... 46**
11.5.1 Farming community ..... 46
11.5.2 Seaweed culture lab ..... 46

12 ANNEX ..... 47

13 REFERENCES ..... 47

# 1 Executive summary

The seaweed industry has substantially grown in the past 50 years. While seaweeds were originally only harvested from wild sources, nowadays 96% of traded seaweeds originate from farmed sources. Traditionally, the main use of seaweeds has been for food, primarily from brown seaweeds such as kelp (Laminariaceae) or wakamae (Undariaceae), or the red seaweed Porphyra, known as nori. These are typically temperate water seaweeds where the cost of farming is relatively high because the operation must run through the full reproductive cycle of these plants (the farmed plant is the Tetrasporophyte), but these costs can be covered if the seaweed is sold as food. Other uses for brown temperate water seaweeds include the extraction of alginate or use of its extracts as fertilizer. Most red seaweeds farmed are nowadays used for the extraction of agar agar or carrageenan, gelling agents that have versatile applications in the food industry (e.g. ice creams, drinks, candies, patés, sausages, pet foods, etc.) or the cosmetic industry (creams, toothpaste, etc.), with new applications being developed (e.g. substitute for concrete, paint or paper) and the demand for carrageenan growing. Farming seaweeds for agar agar and carrageenan has been proven uneconomic in developed countries, but farming of such seaweeds has developed in SE Asia over the past 50 years. The main warm -water species for agar agar is *Gracilaria*, while for carrageenan it is mainly *Kappaphycus* and *Eucheuma* species.

In the Philippines, carrageenan seaweeds yield the most attractive market values, as there is no established end market for agar agar seaweeds. The major brown or red seaweeds (kelp, wakame, nori) used for direct consumption don't grow in the warm waters of the Philippines. The best option for seaweed farmers therefore are the *Kappaphycus* and *Eucheuma* species, red algae for carrageenan extraction. The farming cycle typically lasts for about 6-8 weeks. The seaweed is subsequently dried and the Raw Dried Seaweed (RDS) is then sold to a processor, who extracts the carrageenan as a white powder. The Philippines was the first country where carrageenan seaweeds were successfully farmed and it was the most important producer of carrageenan seaweeds for decades. It was overtaken by Indonesia in 2008, according to official data. Seaweed farmers in the Philippines therefore compete with farmers from Indonesia, which is produced at a lower cost. This competition has led to a drop in Philippine farm gate seaweed prices in recent years, but the pricing between the Philippines and Indonesia is similar nowadays.

Despite its history and importance in the Philippines, seaweed production could still be optimized in most sites and there is scope to increase productivity and economic performance. Seaweeds are usually produced by communities. However, most communities are not organized to trade the seaweeds, and farmers deal individually with traders that consolidate volumes and ship them to processors. The communities would have a much stronger position to negotiate with traders or directly with processors if they were organized in cooperatives, and if they had some working capital to store the raw material to bounce price volatility and consolidate sufficient volumes to facilitate logistics (e.g. direct shipment of large volumes to processor), which would ultimately positively impact the farm gate price they receive. Productivity can be optimized by training of best practices to seaweed farmers, for instance, how to organize their farming area and the planting in rotational harvesting cycles. Farming installations are usually made of low-cost handicraft materials and are accordingly short-lived. Long term economic performance would be improved with higher cost, but more robust, installations and more infrastructure for drying and storing seaweeds, which would have an impact on quality and price. Finally, provision of good quality seedlings (growth rate and disease resistance) is a common problem of seaweed farmers, which could be overcome by a seaweed tissue culture lab producing seaweed seedlings as an independent business case.

The community-based investment opportunity is presented here for the model case of Green Island in Roxas, Palawan in the Philippines. The community on Green Island has some history in seaweed farming, and human capacities and suitable farming sites are present, but productivity is limited due to the following restrictions:

i) organizational and management structures,
ii) proper training on best aquaculture practices,
iii) infrastructure for farming, drying and storage of dried seaweed to balance price volatility, and
iv) provision of good quality seedlings.

These shortcomings are covered by this impact investment plan to increase farming and supply chain productivity and efficiency. The first step is the formation of a cooperative, which is the investable entity in this case. The cooperative establishes contract agreements with 100 farm units, each about 1 ha in size, to transfer the capital investment. Assuming a basic farmer's salary of 10'000 PHP/month, the farmers sell the dried seaweed to the cooperative at a price with a limited margin at first (e.g. for 20 PHP/kg) in addition to their baseline salary. The cooperative in turn sells the seaweed at improved pricing relative to the status quo, due to better quality, more direct supply chains and optimized timing and logistics of sales. In this way, the EBIT will accumulate on the level of the cooperative to pay back the investment. For the model case (Green Island), a CAPEX investment of around 667 k USD is necessary, resulting in a revenue of over 1.013 million USD per year for the community with 67% cost of goods, 7% operational costs (including implementation of the plan and training and monitoring), 1% depreciation and 26% EBIT. The 100 farming units (100 ha total in Green Island) would produce an annual output of 1'587 t RDS. The cooperative will sell this produce at a value of 47.6 million PHP (1.013 million USD), while the 100 farm units obtain a revenue of 675 k USD. The farm units can reach an EBIT of >5% if they perform very well, i.e. if they produce more than the projected 3.2 t RDS per farming cycle. By the same token, they could generate a negative EBIT if they produce less than 3.0 t RDS per farming cycle, which would reduce their baseline salary.

Furthermore, investing in a commercially run tissue culture lab providing farmers with better quality seedlings would have substantial impact on the productivity of seaweed farming communities, resulting in better growth performance and disease resistance. A seaweed culture lab is proposed for Puerto Princesa, Palawan to produce 10'000 plantlets a day, which are brought to nurseries in the farming sites. By default, the lab employs nursery farmers in each site to raise the plantlets to seedling size, and the cooperative farmers are obliged to buy up the entire production of the respective nurseries based on previously agreed prices. The tissue culture lab requires an investment of around 6.13 million USD, employs 7 people in the lab and 7 in the nurseries, and will make revenue of 90 k USD with an EBIT of 24%. The major production cost would be labour and supervision (58%). Better growth performance and disease resistance of these cultured seedlings is expected to result in a better performance of the seaweed farmed than under the conservative assumptions used in the financial projections. The 100-200g seedlings are sold at 17 PHP/kg. Alternatively, the microplantlets of 3-5 cm could be sold (e.g. if the cooperative wants to manage the nursery) at a price resulting in similar profitability for the lab (1.44 PHP/pc).

The expected impact of this investment plan for farming operations will be higher revenue for the community (cooperative), especially for farmers with good performance. The farmers' income from the beginning of the project would be substantially higher than under the status quo, and even higher once the investment has been paid back. No significant environmental impacts are expected.

For implementation, the first step is the formation of the cooperative, the setup of the farming units, contracts, and an agreement of a marketing strategy with a buyer, only after which can an investment be placed. A major risk is that the farmers don't cooperate according to the rules of the cooperative and prefer to continue to individually deal their seaweed with traders, with whom they maintain personal relationships. The formation of a cooperative and selection of trusted leadership is therefore crucial to avoid the farmers switching back to individual trading. It is crucial that the cooperative disposes of sufficient available operational capital (about 6 million PHP) to be able to buy the Raw Dried Seaweed (RDS) from the farmers, even though the cooperative might not be selling RDS for several weeks (e.g. if it appears better to wait for better market prices and store it meanwhile). This working capital is built in as a CAPEX component in this proposal.

Since most other communities suffer from the same challenges and inefficiencies preventing them from being more productive, the same investment plan can be scaled up to at least 4 other communities in northern Palawan. The figures changing with the scaled plan is mainly the size of the community, i.e. the number of farm units, with each cooperative representing an investable entity. The investment case for the 4 communities combined comes to 1.53 million USD, with a similar EBIT structure as Green Island (25% EBIT on a total revenue of 2.44 million USD). The culture lab could provide all these sites with good quality seedlings, throughout the year.

# 2 Introduction

## 2.1 Seaweeds and its uses

Seaweeds can be classified into three broad groups based on pigmentation, which define their division in taxonomy: brown (Phaeophyceae), red (Rhodophyceae), and green (Chlorophyceae). Brown seaweeds are usually large, and range from the giant kelp that is often 20 m long, to thick, leather-like seaweeds from 2-4 m long, to smaller species 30-60 cm long. Red seaweeds are usually smaller, generally ranging from a few centimetres to about a metre in length; however, red seaweeds are not always red: they are sometimes purple, even brownish red, but they are still classified by botanists as Rhodophyceae because of other characteristics. Green seaweeds are also small, with a similar size range to the red seaweeds. Seaweed is a versatile product that can be used for direct human consumption or processed into food additives, pet food, feeds, fertilizers, biofuel, cosmetics, and medicines, among others (McHugh 2003).

Kelp, wakame and nori are mainly produced for food and represent the major bulk of farmed seaweed production (42%, Fig. 1). *Kappaphycus* and *Eucheuma* species serve the carrageenan industry (33%) and *Gracilaria* serve the agar industry (11%).

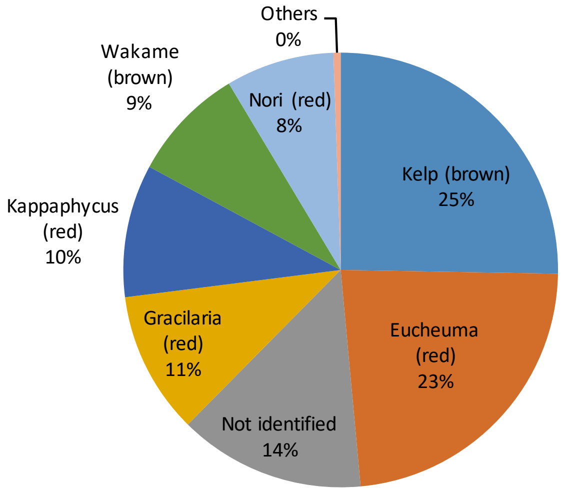


**Figure 1**: Breakdown of 27 million wet tons of farmed seaweed by seaweed types according to its uses, averaged over the years 2011-2013, from FAO (2015).

### 2.1.1 Food

The use of seaweed as food has been driven by Japan and China for 15 centuries. China, Japan and Korea are the most important consumers of seaweed as food, and as nationals from these countries emigrated, they have brought this demand to other countries.

#### 2.1.1.1 Brown seaweeds

The main uses of brown seaweeds are as foods and as the raw material for the extraction of the hydrocolloid, alginate. The more useful brown seaweeds grow in cold waters in both the Northern and Southern Hemispheres. They thrive best in waters up to about 20ºC. Brown seaweeds are found in warmer waters, but these are less suitable for alginate production and rarely used as food.

Food from brown seaweeds comes mostly from the genera *Laminaria*, *Undaria* and *Hizikia* (McHugh 2003). Originally, harvests of wild seaweeds were the only source, but since the mid twentieth century demand has gradually outstripped the supply from natural resources and methods for cultivation have been developed. Today, seaweed for food comes mainly from farming rather than natural sources.

#### 2.1.1.2 Red seaweeds

*Pyropia (=Porphyra)* species are the largest source of food from red seaweeds. *Pyropia*, known by the more common names of nori and laver, is dried and processed into thin purplish-black sheets. One of its common uses is in Japanese sushi. *Pyropia* has been cultivated in Japan and the Republic of Korea since the seventeenth century; there were natural stocks, but even at that time they were insufficient to meet demand. Cultivation was developed intuitively, by observing the seasonal appearance of spores, but *Pyropia* has a complex life cycle that was not understood until the 1950s. Since then, cultivation has flourished, and today the supply is virtually all from cultivation, which is conducted on a large scale in Japan, China and the Republic of Korea. In 1999, the combined production from these three countries was just over 1 million wet tonnes. It has the highest value of any cultivated seaweed, about 1'200 USD/t wet (16 USD/kg dry). For comparison, the brown seaweeds used as food are valued at 610 USD/t wet (3 USD/kg dry) for *Laminaria* and 530 USD/t wet (7 USD/kg dry) for *Undaria*.

### 2.1.2 Hydrocolloids

Various red and brown seaweeds are used to produce three hydrocolloids: agar, alginate and carrageenan. Alginate, agar and carrageenan are water-soluble carbohydrates that are used to thicken (increase the viscosity of) aqueous solutions, to form gels (jellies) of varying degrees of firmness, to form water soluble films, and to stabilize some products, such as ice cream (inhibiting the formation of large ice crystals so that the ice cream can retain a smooth texture).

#### 2.1.2.1 Brown seaweeds

Alginate is extracted from brown seaweeds, all of which are harvested from the wild; cultivation of brown seaweeds is too expensive to provide raw material for industrial uses. Alginate-containing brown seaweeds are nearly all harvested from natural resources. A wide variety of species are used, harvested in both the Northern and Southern Hemispheres. Countries include Argentina, Australia, Canada, Chile, Ireland, Norway, Mexico, South Africa, United Kingdom (Scotland and Northern Ireland) and United States of America. Cultivation of brown seaweeds such as *Laminaria, Saccharina* and *Undaria* go through the sexual reproduction cycle, a time consuming and labour intensive process that is expensive, even in low-labour-cost countries. Cultivated raw material is normally too expensive for alginate production.

#### 2.1.2.2 Red seaweeds

The main uses of red seaweeds are as food and as sources of two hydrocolloids: agar and carrageenan. Useful red seaweeds are found in cold waters such as Nova Scotia (Canada) and southern Chile; in more temperate waters, such as the coasts of Morocco and Portugal; and in tropical waters, such as Indonesia and the Philippines (Table 1).

- Agar production is principally from two types of red seaweed, *Gelidium* spp. and *Graciliaria* spp. *Gracilaria* has been cultivated since the 1960–70s, but on a much larger scale since 1990, allowing the expansion of the agar industry. About 90% of the agar produced is for food applications, the remaining 10% for bacteriological and other biotechnology uses (McHugh 2003).
- Two genera, *Gelidium* and *Gracilaria*, account for most of the raw material used for the extraction of agar. Extraction of *Gelidium* species gives the higher quality agar (as measured by the gel strength: the strength of a jelly formed by a 1.5 percent solution). All *Gelidium* used for commercial agar extraction comes from natural resources, principally from France, Indonesia, the Republic of Korea, Mexico, Morocco, Portugal and Spain. *Gelidium* is a small, slow growing plant, and while efforts to cultivate it in tanks/ponds have been biologically successful, it has generally proved to be uneconomical.
- *Gracilaria* species can be grown in both cold and warm waters and can thus be economically farmed. Nowadays Gracilaria is mainly cultivated commercially in Indonesia, Chile, China, Vietnam and South Africa. Since production of *Gelidium* depends largely on the wild, and the natural population is dwindling, the cultivation of *Gracilaria* was imperative. Some supply of *Gracilaria* still comes from the wild, with the degree of cultivation depending on price fluctuations.
- Carrageenan production was originally dependent on wild seaweeds, especially Irish Moss, a small seaweed growing in cold waters, with a limited resource base. However, since the early 1970s the industry has expanded rapidly because of the availability of other carrageenan-containing seaweeds that have been successfully cultivated in warm-water countries with low labour costs. Today, most of the seaweed used for carrageenan production comes mainly from cultivation in the Philippines, Indonesia, Tanzania and Malaysia although there is still some demand for Irish Moss and some other wild species from South America.
- The two species originally cultivated in the Philippines were named *Eucheuma cottonii* and *Eucheuma spinosum*, and the industry shortened these so they are often referred to as "cottonii" and "spinosum". However, botanists have since renamed both species, so that *Eucheuma cottonii* is now *Kappaphycus alvarezii*, while *Eucheuma spinosum* is now *Eucheuma denticulatum*. As an alternative to *K. alvarezii* the variety *K. striatum* is used, which is said to be more disease resistant but slow growing.

### 2.1.3 Fertilizers

Fertilizer uses of seaweed date back at least to the nineteenth century. Early usage was by coastal dwellers, who collected storm-cast seaweed, usually large brown seaweeds, and dug it into local soils. The high fibre content of the seaweed acts as a soil conditioner and assists moisture retention, while the mineral content is a useful fertilizer and source of trace elements. The growth area in seaweed fertilizers is in the production of liquid seaweed extracts. These can be produced in concentrated form for dilution by the user. Several can be applied directly onto plants or they can be watered in and around the root areas.

### 2.1.4 Additives

Seaweed meal, used as an additive to animal feed, has been produced in Norway and Ireland, where its production was pioneered in the 1960s. It is made from brown seaweeds that are collected, dried and milled. Drying is usually by oil-fired furnaces, so costs are affected by crude oil prices. Approximately 50'000 tonnes of wet seaweed are harvested annually to yield 10'000 tonnes of seaweed meal, which is sold for US$ 5 million.

### 2.1.5 Cosmetics

Cosmetic products, such as creams and lotions, sometimes show on their labels that the contents include "marine extract", "extract of alga", "seaweed extract" or similar. Usually this means that one of the hydrocolloids extracted from seaweed has been added. Alginate or carrageenan could improve the skin moisture retention properties of the product. Pastes of seaweed, made by cold grinding or freeze crushing, are used in thalassotherapy, where they are applied to the person's body and then warmed under infrared radiation. This treatment, in conjunction with seawater hydrotherapy, is said to provide relief for rheumatism and osteoporosis.

### 2.1.6 Water waste management

There are potential uses for seaweed in wastewater treatment. Some seaweeds can absorb heavy metal ions such as zinc and cadmium from polluted water. The effluent water from fish farms usually contains high levels of waste that can cause problems to other aquatic life in adjacent waters. Seaweeds can often use much of this waste material as nutrients. Trials have been undertaken to farm seaweed in areas adjacent to fish farms, offering the opportunity for Integrated Multi-Trophic Aquaculture (IMTA).

| Use | | Division | Genera | Method | Producing countries |
|---|---|---|---|---|---|
| **Food** | | Brown Alage | *Laminaria*<br>*Undaria*<br>*Hizikia* | Farmed | China, Korea, Japan |
| | | Red Algae | *Pyropia (Nori)* | Farmed | China, Korea, Japan |
| **Hydrocolloids** | Alginate | Brown Algae | *Laminaria*<br>*Undaria* | Wild | Australia, Canada, Chile, Ireland, Norway, Mexico, South Africa, UK, USA |
| | Agar agar | Red Algae | *Gelidium* | Wild | France, Indonesia, the Republic of Korea, Mexico, Morocco, Portugal, Spain |
| | | | *Gracilaria* | Wild, farmed | Wild: Chile, Canada, Argentina, Brazil, Thailand, Indonesia, Namibia<br>Farmed: China, Indonesia, Vietnam |
| | Carrageenan | Red Algae | *Chondrus*<br>*Gigartina* | Wild | France, Ireland, Portugal, Spain, Canada |
| | | | *Eucheuma*<br>*Kappaphycus* | Farmed | Indonesia, Philippines |
| **Fertilizers** | | | e.g. *Sargassum* | Wild | n.a. |

**Table 1:** Uses of seaweeds and corresponding main species (genera) and production sites.

## 2.2 Seaweed production history

Seaweed farming has largely been developed over the past five decades because supply from wild sources has not met the increasing demand. While farming was almost inexistent in the 1950s, today 96% of traded seaweed originate from farmed sources (Fig. 2).

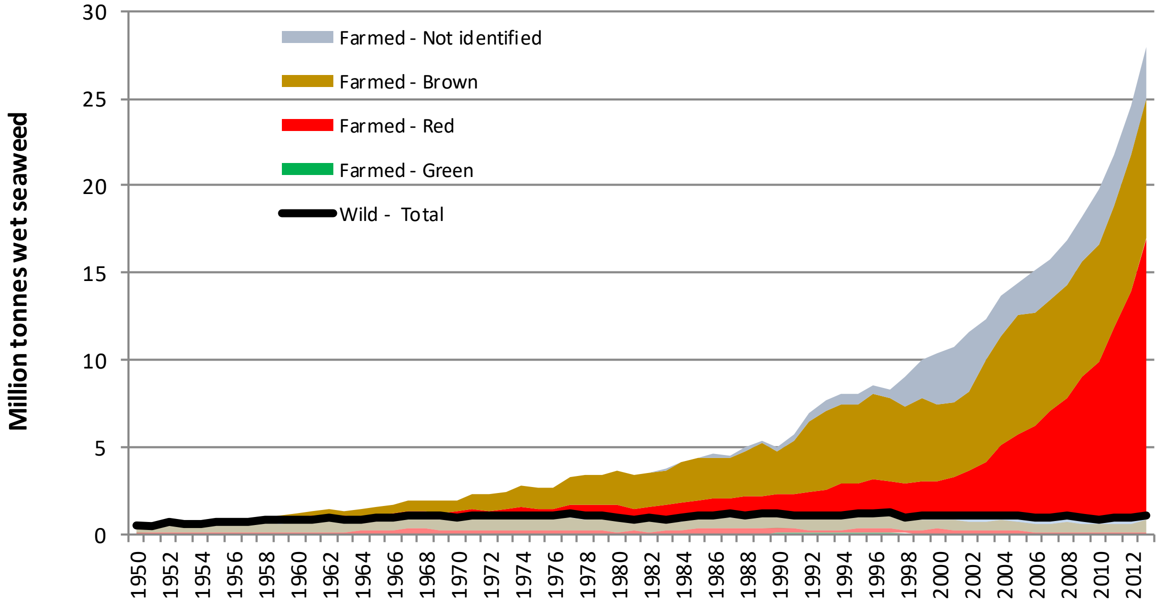


**Figure 2:** Farmed vs. wild seaweeds (brown, red, green), from FAO (2015)

Increasing demand over the last fifty years outstripped the ability to supply requirements from natural (wild) stocks. Research into the life cycles of seaweeds led to the development of cultivation industries that now produce more than 90% of the markets supply.

The market for hydrocolloids strongly developed in the past 50 years, although the properties of seaweed extracts were already previously known: In Japan gelling properties of agar were extracted with hot water from red seaweeds as early as the 17th century, extracts of carrageenan-containing Irish Moss were popular as thickening agents in the 19th century and in the 1930s alginates were produced commercially from brown seaweeds. Industrial uses of seaweed extracts expanded rapidly after the Second World War, but were sometimes limited by the availability of raw materials. Once again, research into life cycles has led to the development of cultivation industries that now supply a high proportion of the raw material for some hydrocolloids. Seaweed production since the 1990s has been dominated by a recent boost of red seaweed production used for hydrocolloid extraction (Fig. 2).

For *Gracilaria*, it was found in the 1950s that pre-treatment of the seaweed with alkali before extraction lowered the yield but provided a good quality agar (previously, it was considered unsuitable due to low agar quality). This allowed expansion of the agar industry, previously limited by the available supply of *Gelidium*, and led to the harvesting of a variety of wild species of *Gracilaria* in countries such as Argentina, Chile, Indonesia and Namibia. Chilean *Gracilaria* was especially useful, but soon there was evidence of overharvesting of the wild crop. Cultivation methods were then developed, both in ponds and in the open waters of protected bays. These methods have spread beyond Chile to other countries, such as China, the Republic of Korea, Indonesia, Namibia, the Philippines and Viet Nam, usually using species of *Gracilaria* native to each country.

Carrageenan was recognized as a substitute for agar agar during the Second World War. For almost three decades, production of carrageenan was restricted by the availability of natural stocks of *Chondrus crispus* (also known as Irish moss) from Canada, Ireland, Portugal, Spain and France and *Gigartina* from South America and Southern Europe. Carrageenan production was originally dependent on wild seaweeds, especially Irish Moss, a small seaweed growing in cold waters, with a limited resource base. However, since the early 1970s the industry has expanded rapidly due to the availability of other carrageenan-containing seaweeds that have been successfully cultivated in warm-water countries with low labour costs. The introduction of cultivated species of *Eucheuma* in the Philippines during the 1970s provided the carrageenan industry with a much-enhanced supply of raw material. A further advantage of this cultivated material was that one species contained almost exclusively one type of carrageenan (kappa-carrageenan) while a second species contained predominantly a second type (iota-carrageenan), each type having its own specific applications. Today, most of the carrageenan raw material comes from the two species originally cultivated in the Philippines, but their cultivation has now spread to some other warm-water countries, such as Indonesia and Tanzania. In 2008, Indonesia took over the Philippines as the largest carrageenan seaweeds producer with a reported 8.3 million tons of wet seaweeds in 2013 (vs. 1.5 million tons in the Philippines). These production numbers are not exactly known, but are estimated by national authorities and therefore must be taken with caution. Nevertheless, they serve as indicators.

China is the largest producer of edible seaweeds, harvesting more than 10 million wet tonnes annually (FAO 2016). The majority is for kombu (kelp), produced from hundreds of hectares of brown seaweed, *Saccharina japonica*, grown on suspended ropes in the ocean. The Republic of Korea grows about 1 million wet tonnes of three different species. About 50 percent of this is for wakame, produced from a different brown seaweed, *Undaria pinnatifida*, grown in a similar fashion to *Laminaria* in China. Japanese production is around 500'000 wet tonnes, 75% of this is for *nori*, the thin dark seaweed wrapped used for sushi.

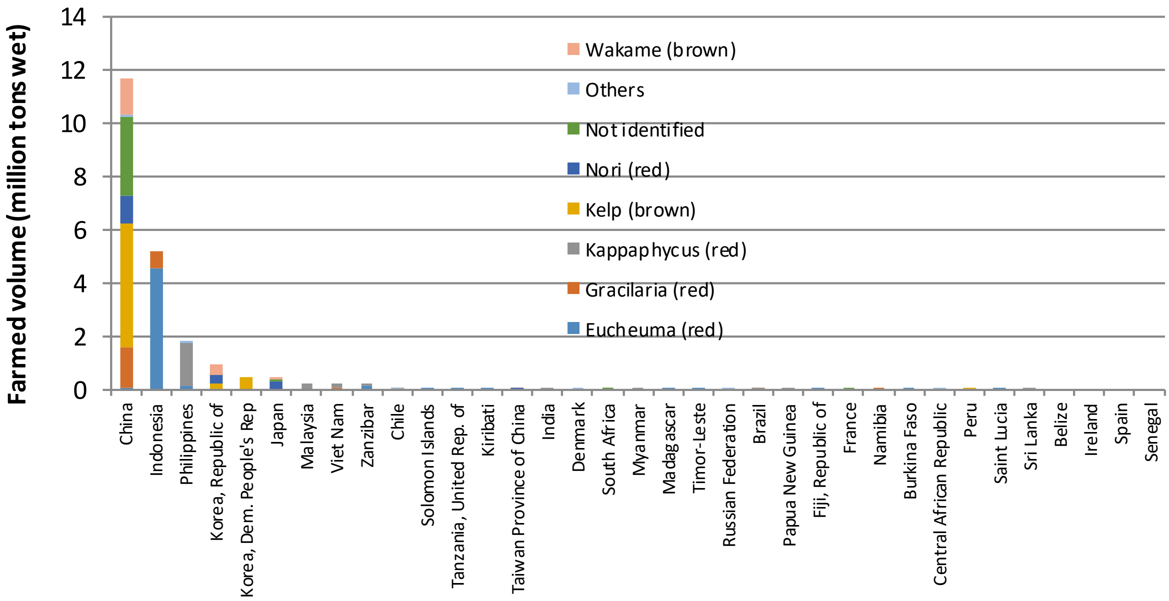


**Figure 3:** Farming of seaweed types according to its use by country, averaged over the years 2011-2013, from FAO (2015)

## 3 Seaweed production and industry in the Philippines

The history of seaweed farming in the Philippines directly relates to the demand for carrageenan. Supply from wild sources were soon not sufficient to sustain the growing demand after the Second World War and the industry was seeking alternatives. Cultivation of carrageenan seaweeds was not economically feasible in the northern hemisphere, but production of carrageenan seaweeds was first successful in the Philippines and came to be dominated by two species: *Kappaphycus alvarezii* (commonly known as cottonii) and *Eucheuma denticulatum* (known as spinosum). The Philippines remained the world's top producer of *K. alvarezii* until the late 2007, when it was surpassed by Indonesia in 2008 (Fig. 3). According to official statistics, the Philippines nowadays produces 1.5-2 million tons of seaweeds wet and Indonesia about 5-8 million tons belonging to the carrageenan-containing varieties *Kappaphycus* (*alvarezii* and *striatum*) and *Eucheuma* (*denticulatum*).

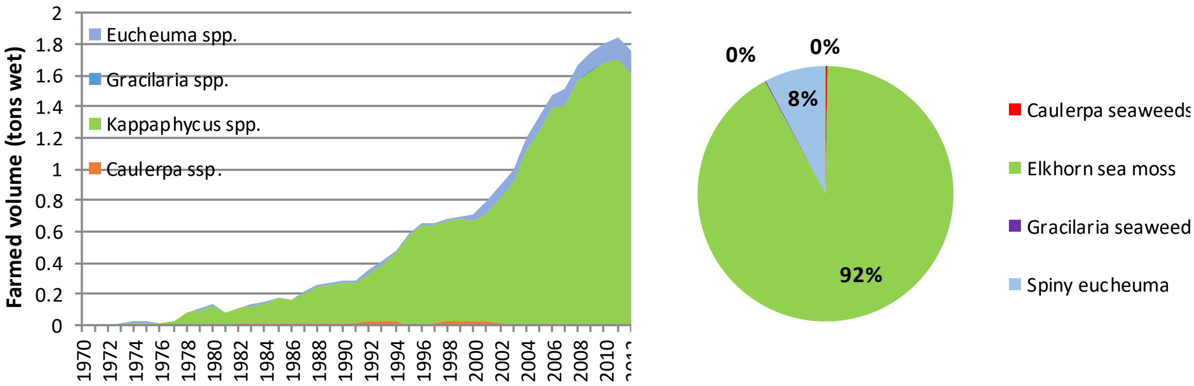


**Figure 4:** Seaweed production history (left) and breakdown by farmed species in the Philippines, from (FAO 2016)

### 3.1 Eligible seaweed species

Among various carrageenan-containing seaweeds, only warm-water *Kappaphycus* and *Eucheuma* seaweeds have been cultivated substantially and commercially. For cold water species, plant growth might be lower and the labour cost in the northern hemisphere are too high for commercial production to be viable. The main seaweeds under cultivation are *Kappaphycus* (primarily *K. alvarezii*) and *Eucheuma* (primarily *E. denticulatum*). *K. alvarezii* (commercially called cottonii) and *E. denticulatum* (commercially called spinosum) are raw materials for extracting kappa and iota carrageenan, respectively. Generally speaking, kappa carrageenan is stronger (thicker) and hence a more favoured gelling agent than iota. It is therefore no coincidence that commercial farms in Indonesia or the Philippines exclusively farm *Kappaphycus* or *Eucheuma* species.

*Gracilaria* would be the species of choice for agar-containing seaweed growing in warm waters. There is, however, almost no market for *Gracilaria* in the Philippines so it is economically unattractive compared to *Kappaphycus* and *Eucheuma* seaweeds: while growth is not necessarily faster, the drying yield of *Gracilaria* is lower than for *Kappaphycus* (10% vs. 14%, dry weight/wet weight) while prices for dried *Gracilaria* are lower than for *Kappaphycus* (currently about 15 PHP/kg vs. 25 PHP/kg). Furthermore, some *Gracilaria* species require brackish or seawater with salinities below 30 ppt, which limits the area of suitable habitats, while *Kappaphycus* and *Eucheuma* are purely marine algae that would grow anywhere in marine waters. From an economic point of view, it would be most interesting to produce seaweeds for direct human consumption. However, the most prominent seaweeds like *Pyropia* (nori), *Laminaria* (kelp), and *Undaria* (wakame) only grow in temperate and not in tropical waters.

### 3.2 Reproductive cycle & vegetative growth

Some seaweeds can be grown by vegetative cultivation, others only by going through a separate reproductive cycle, involving alternation of generations: for these, new plants cannot be grown by taking cuttings from mature ones. This is typical for many of the brown seaweeds, and *Laminaria* species are a good example: their life cycle involves alternation between a large sporophyte and a microscopic gametophyte – two generations with quite different forms (Fig. 5). The sporophyte is what is harvested as seaweed, and to grow a new sporophyte it is necessary to go through a sexual phase involving the gametophytes. The mature sporophyte releases spores that germinate and grow into microscopic gametophytes. The gametophytes become fertile, release sperm and eggs that join to form embryonic sporophytes. These slowly develop into the large sporophytes that we harvest. The principal difficulties in this kind of cultivation lie in the management of the transitions from spore to gametophyte to embryonic sporophyte; these transitions are usually carried out in land-based facilities with careful control of water temperature, nutrients and light. The high costs involved in this can be absorbed if the seaweed is sold as food, but the cost is normally too high for production of raw material for alginate production. Principal seaweeds used as food must be taken through the alternation of generations for their cultivation, and only for the food market the correspondingly high production costs and be covered.

For seaweeds used for the hydrocolloid industry (agar and carrageenan), the vegetative method is therefore mostly used: in vegetative cultivation, small pieces of seaweed are taken and placed in an environment that will sustain their growth. When they have grown to a suitable size they are harvested, either by removing the entire plant or by removing most of it but leaving a small piece that will grow again. When the whole plant is removed, small pieces are cut from it and used as seedstock for further cultivation.

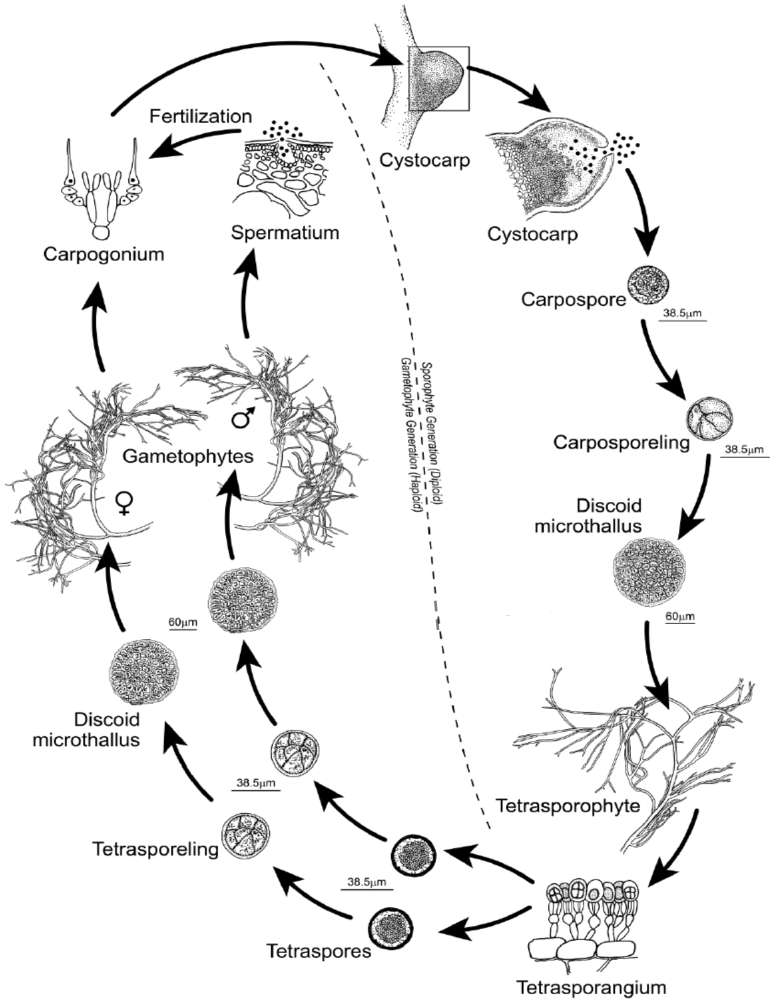


**Figure 5:** reproductive cycle of seaweeds, shown for the example of *Gracilaria* from Yarish and Redmond (2012).

Due to the high complexity and cost involved if seaweeds are farmed through their reproductive cycle, it is preferable to use seaweeds that can be grown using vegetative cultivation. *Kappaphycus* and *Eucheuma* species in the Philippines and Indonesia are grown in a vegetative manner, where the female or male haploid gametophyte is what is typically cloned within farms. According to the experience of farmers, growth of a branch will decrease after it has been cut down 2-3times. Good crop management is therefore essential for any farm using vegetative cultivation, i.e. selection of juvenile branches to be used as seedlings is essential in each farming cycle. Optimal seedlings could furthermore be produced in the lab by tissue culture. While going through the reproductive cycle is not feasible in the hydrocolloid industry, knowledge of the reproductive cycle is thus still useful for good crop management.

### 3.3 Sites, volumes and seasonality

It is difficult to gather information on the total cultivation area and production of each municipality or province as government agencies do not maintain substantial records for these purposes. Nevertheless, approximate estimates can be obtained from the four key production areas in the country: ARMM, Region IV-B, Region IX, and Region VII (Fig. 6). Production estimates, e.g. the 1.8 million t of annual national wet production (Fig. 4), should be used with caution: these numbers are reported by the Bureau of Fisheries and Aquatic Resources (BFAR) and based on extrapolation assuming estimates of farmed areas and estimated growth rates, likely without taking into account seasonality, which plays a role everywhere in the Philippines.

As a general rule of thumb, the months October-May are dominated by cool northeast winds ("Amihan"), while the months of May–October are dominated by the southwest monsoon ("Habagat"), characterized by hot and humid weather and frequent rainfalls. The seasonality of a site for seaweed farming depends on the exposure of a site to these northeast or southwest trade winds. If conditions are rough, farming becomes impractical and plants might get lost by breaking off the lines. In general, weather conditions during Habagat are not optimal for seaweed farming due to rough weather conditions and rainfall that induce changes in salinity to surface water which can substantially reduce the growth of marine algae. Some farming operations therefore fully stop during Habagat, others continue at a much-reduced productivity of typically about 10-20%, mainly for the purpose of maintaining seedlings for the next season.

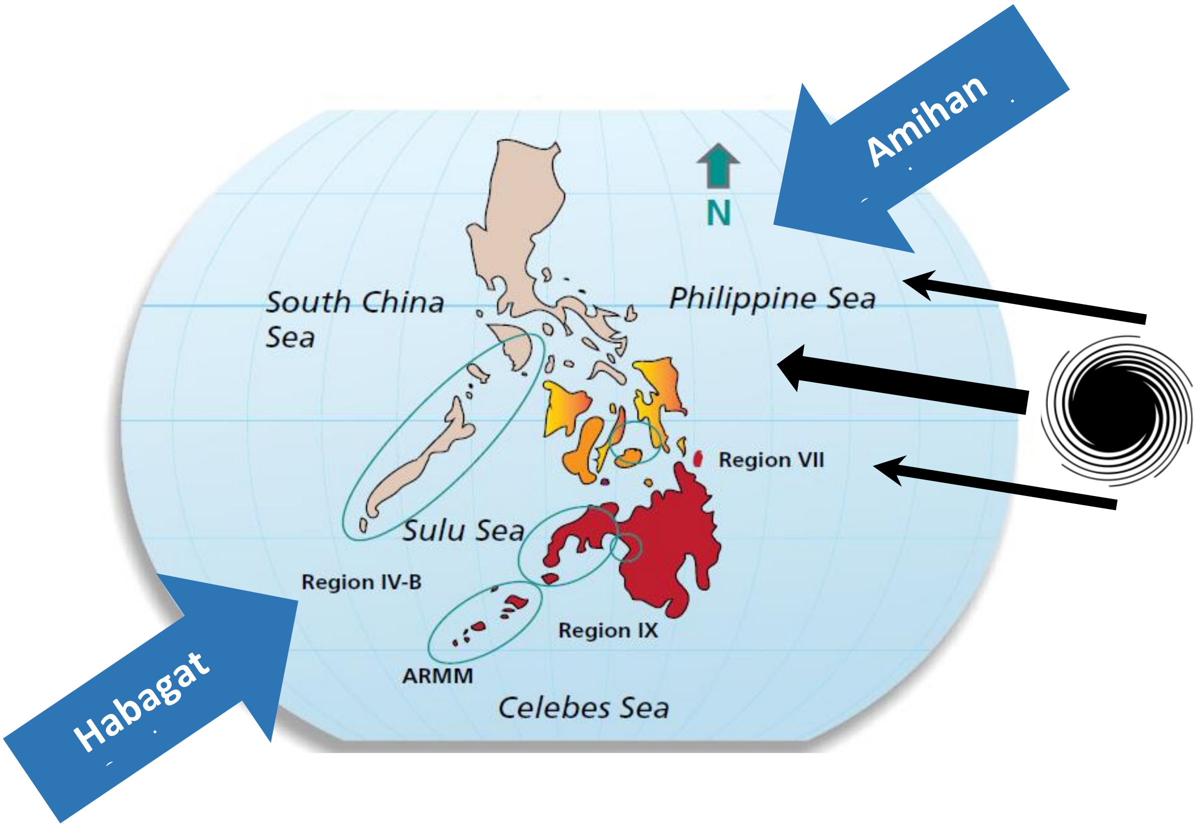


**Figure 6**. Main farming areas in the Philippines and major climatic patterns: Northeast trade winds during September to May, southwest monsoon during May to September.

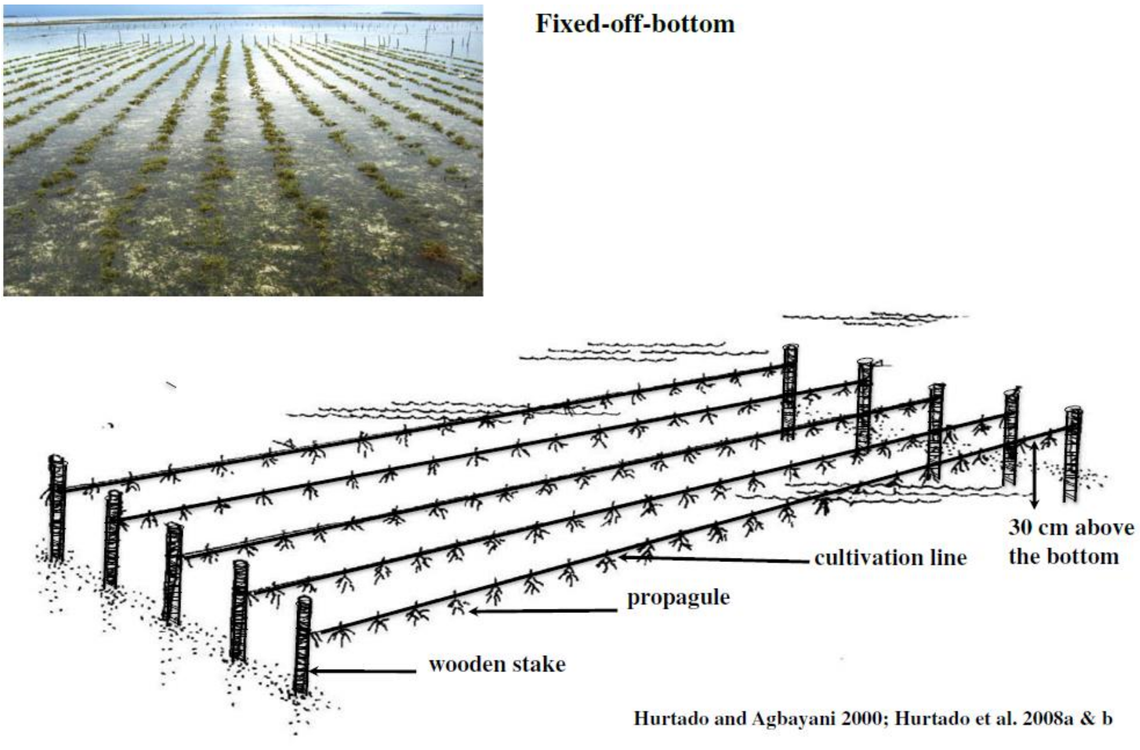
Typhoons are a major risk in seaweed farming and might wash away entire farm installations and crops. They usually occur with more intensity during Habagat and originate in the Central Pacific Ocean. The entire east coast of the Philippines is therefore most exposed to typhoons, while in Palawan (Region IV-B), Zamboanga (Region IX) and the islands around Tawi-Tawi (ARMM), no typhoons occur. It is thus no coincidence that these are the major farming areas.

A further asset for becoming a major farming site is human capacity. The main farming sites are characterized by remote areas and island archipelagos that are relatively densely populated. Environmental conditions are usually good around islands due to regular water movement. Due to the remoteness of these island societies, seaweed farming constitutes an attractive source of income. All major farming sites in the north of Palawan, Tawi-Tawi, Zamboanga, and Danajon bank are characterized by such island archipelago societies. Danajon bank has around 20'000 ha under cultivation, whereas farmers live on the bank itself or on the small islands around Bohol. It constitutes an exception with respect to its exposure to typhoons, but it has experienced no typhoon for more than 10 years now. It is estimated that ARMM, consisting mostly of Maguindanao, Lanao del Norte, Sulu and Tawi-Tawi, has about 24'000 ha under production. However, studies have revealed that, if seaweed faming were expanded to a depth of 15 m in Sitangkai, about 102'885 ha would be available for expansion (Hurtado 2013). The same would apply to other island archipelagos. For Regions IV-B and IX, no estimate is currently available, but it assumed among processors that Palawan has taken over Tawi-Tawi to be the most productive seaweed farming area.

A more reliable volume estimate of farmed seaweed might be obtained from the declared carrageenan production of seaweed processors. A typical carrageenan producer in the Philippines would have to produce about 100 t of carrageenan per month to cover its operating costs (Ricohermoso, *pers. comm.*). While the carrageenan content of dried seaweed is around 30%, the 15 producers in the Philippines all together declare to process about 60'000 t of Raw Dried Seaweed (RDS) per year, which is in line with the above figures. Since the drying ratio of seaweed is around 1:7 dry:wet weight, this volume corresponds to 420'000 t of wet seaweed, which is thus only 20-25% of the number derived by BFAR (1.8 million tons wet). It is likely, however, that processors and exporters underreport some of their production to avoid taxation. A substantial fraction of the raw material is also imported from Indonesia. The two effects might partly neutralize in their respective effect on estimated volumes produced in the Philippines. There are thus two possible explanations that both likely apply to explain the discrepancy in national production figures: 1) the extrapolation of BFAR is erroneous by assuming incorrect areas under cultivation or making wrong assumptions on productivity by area and not accounting for seasonality or by including Indonesian imports, and/or 2) the seaweed processors and carrageenan exporters underreport their annual production capacity to avoid taxation.

### 3.4 Farming methods

The most traditional seaweed farming method is the Fixed off-bottom (FOB) method. Stakes are fixed into the sediments, typically 1-1.5m apart and the seaweeds are attached to the line. Investment typically only involves costs for the lines and seedlings and due to the low investment it is the default method that would be applied by a community that starts to farm seaweeds along the shoreline (Hurtado et al. 2013). Plantation and harvesting is practical and can be done in the shallow water, no vessels are needed. While for more complicated installations men would typically do the technical work, the FOB method might be fully operated by females.
The suitable habitat for this method is, however, limited as it relies on subtidal flats that are not exposed during low tide but that don't exceed a certain water depth beyond which handling becomes impractical. Optimal sites are rare because in such flats along the shoreline water movement is usually limited – however, continuous water movement is crucial for growth of marine algae. Coral bank flats such as e.g. Danajon bank between Bohol and Leyte or Green Island on Palawan represent exceptions in this respect: the water is shallow but water movement is strong and continuous.



Hurtado and Agbayani 2000; Hurtado et al. 2008a & b

**Figure 7:** Fixed off-bottom method is the most traditional and lowest investment farming method, from Hurtado et al. (2013)

With more investment into installations, seaweed farming can become independent of water depth and, by using such installations, the suitable habitat becomes much larger as compared to applying only the FOB method. Since these installations would have to be anchored somehow, water depths of 2-15m (at low tide) can be considered practical.

There are many ways such installations can be constructed, the common feature being that they are fixed by anchors and provide a floating frame to which the seaweed lines can be attached an optimal distance to the water surface (50cm). Among these methods are e.g. the hanging long line (HLL, Fig. 8), the single raft longline (SRL), the multiple raft longline (MRL), and the spider web (SWB) methods (Fig. 9a-c). The hanging longline is the simplest of these, consisting of just one line that is anchored at both ends with boys, and floaters in between along the line, to maintain an optimal distance to the water surface (Fig 8).

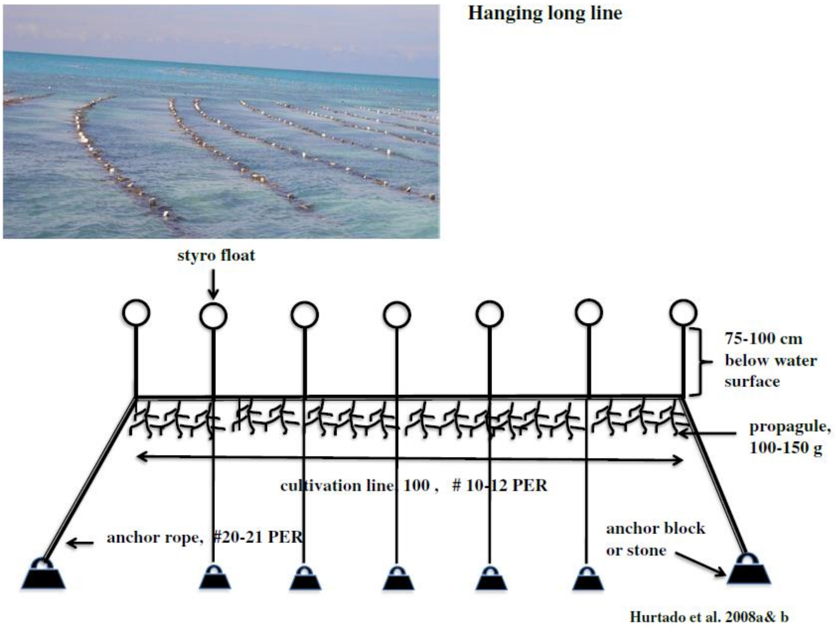
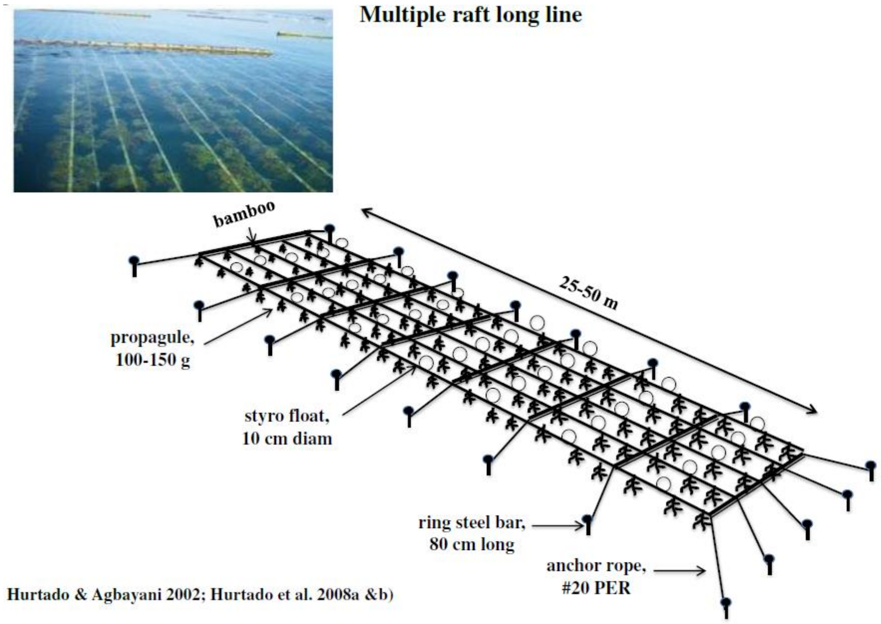


**Figure 8:** Single hanging longline method (HLL), from Hurtado et al. (2013)

In the multiple raft method, multiple hanging longlines are combined and laid over bamboo sticks e.g. every 20 meters to maintain stable buoyancy. This system can be extended to any length that appears suitable, but it is not very flexible if it must be moved e.g. due to bad weather. The single raft method consists of a wooden (bamboo) quadratic frame of up to 20m in diameter within which the seaweed lines are fixed. This has the advantage that the framed structure can be easily moved to another place if needed (Fig. 9b).

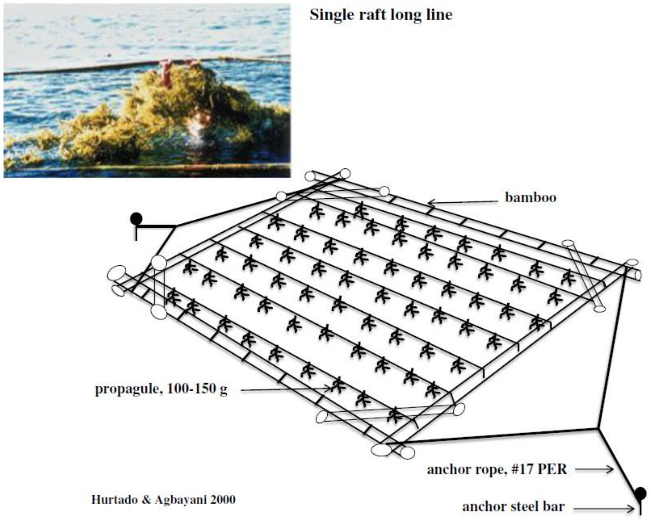
The spider web (Fig. 9c) is the most flexible method, relying only on ropes and no bamboo, and therefore comes with the highest investment cost. Units framed by ropes of 40-50m in diameter can be combined next to each other as suitable, there is no limitation in size. Spider webs are more stable and have the advantage of longer amortization times than, for example, bamboo rafts that only last for about 1 year. Despite the higher initial investment, the investment efficiency might therefore be higher for spider web than for the other methods.

The farm setup and production cycles depend on the farmers and differ from area to area. Often, the farms are operated by households that don't operate according to a fixed commercial schedule (e.g. rotational farming cycles corresponding to the growing time of the plant), but rather they plant and harvest according to their daily necessity. The farming cycles corresponding to optimal plant growth are 6-8 weeks (Ricohermoso, *pers. comm.*), capturing the maximal growth increment of the plant, which is short for an aquaculture operation. Despite the short optimal cycle, it might happen that farmers harvest prematurely after 1 month due to short-term monetary needs.



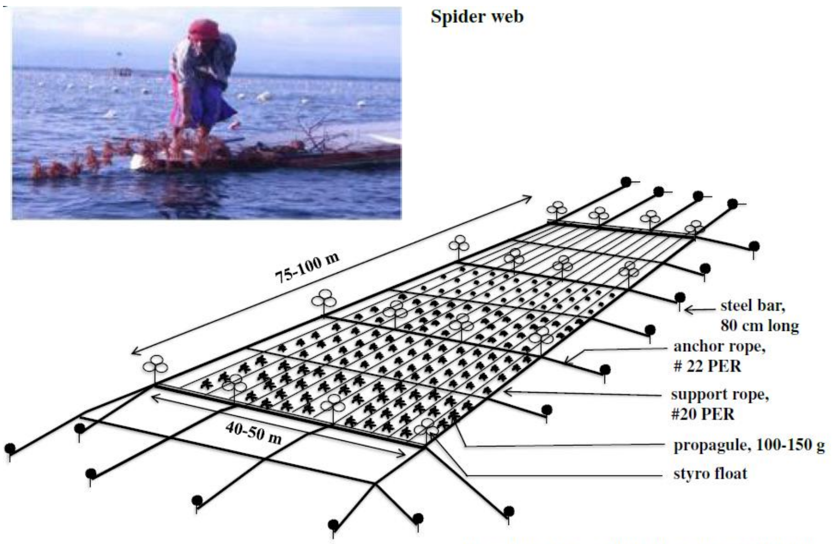
Multiple raft long line

Hurtado & Agbayani 2002; Hurtado et al. 2008a &b)



Single raft long line

Hurtado & Agbayani 2000



Spider web

Hurtado & Agbayani 2002; Hurtado et al. 2008a&b

**Figure 9:** Multiple raft (a), single raft (b) and Spider web farming methods, from Hurtado et al. (2013)

### 3.5 Trade, processing & export

The seaweed processing sector in the Philippines is mainly based in Cebu: of the 15 processors, one is in Zamboanga, 3 are around Manila, and the remaining 11 are in Cebu. The seaweed trade is therefore determined mainly by the logistics from the farm sites to Cebu. Seaweed from islands in the northern Sulu Sea (e.g. Cuyo, Agutaya, Cagayancillo), for instance, is first collected from the farms and then consolidated in San José (Mindoro). From there it must be brought to Batangas where it can be shipped directly to Cebu. From the Palawan mainland, supply would be transported through Puerto Princesa, from the islands between Mindanao and Sabah first to Zamboanga, and be processed there or subsequently shipped to Cebu. It is therefore typical that several traders are part of the value chain between the farm and the processor, and each might add up to 5 PhP/kg to the price. It can therefore happen that a farmgate price of around 20 PhP/kg will come to 30-35 PhP/kg once landed in Cebu. It is thus in the interest of the farmers to consolidate as high volumes as possible to be able to ship as large quantities as possible with logistics that directly lead to the processor to minimize transportation and trading costs.

| | Name | Product | Year established | Address |
|---|---|---|---|---|
| 1 | ACCEL Carrageenan Corp. | SRC food grade | 1990 | People's Technology Complex<br>Carmona, Cavite 4116<br>sales@accelcarrageenan.com<br>Phone - 632-559 8206 |
| 2 | CP-Kelco | SRC<br>RC | 1997 | Abugon, Sibonga, 6020 Cebu<br>Phone:(032) 486 9800 |
| 3 | Marcel Carrageenan | SRC food grade | 1977 | 5th Flr. First Marcel Tower<br>926 Araneta Ave. Quezon City |
| 4 | Martson Food Corporation | SRC food grade | | Toril, Davao City, Philippines<br>P.O. Box 81323<br>elephone: (63-82) 2910670 |
| 5 | MCPI Corporation | PNG | 1983 | Tugbongan, Consolacion 6001<br>Tel 63-32-345-2751 x801<br>info@mcpicarrageenan.com |
| 7 | Miyoka W Hydrocolloids Inc. | SRC food grade | 2003 | 2nd Floor, W Tower, 39th St., Bonifacio<br>Global City Taguig, Metro Manila<br>Phone:(02) 856 3838 |
| 8 | Shemberg Marketing | SRC food grade<br>SRC pet food<br>RC | 1966 | SW Division<br>Jayme St., Pak-na-an, Mandaue Cebu |
| 9 | Shemberg Biotech Corporation | RC | | MCkinley Sr., Cogon West<br>Carmen, Cebu<br>Carmen, Cebu |
| 10 | TBK Manufacturing Corporation | SRC food grade | 1999 | Brgy. Hollywood, Nula-tula<br>Tacloban City, 6500 Leyte |
| 11 | Zamboanga Carrageenan Manufacturing Corp. | SRC food grade<br>SRC pet food<br>sun-dried white seaweed chips & powder | 1995 | Talon-talon Road<br>Kasangyangan, Zamboanga City |
| 12 | Cargill Philippines | RC | 1989 | Citbank Center, Paseo de Roxas<br>Makati City 1200<br>Plant, Canlubang .Laguna |
| 13 | FMC Biopolymer | SRC food grade | | Quano Compound, Looc Mandaue<br>6014 Cebu |
| 14 | Kerry Food Ingredients (Philippines) | SRC food grade | | GF/SFB #1, Mactan, Econmic Zone 1<br>Lapu-Lapu City, Cebu |
| 15 | CEAMSA Asia Inc | SRC food grade | | Pook Looban 2 Crispulo dela Cruz St.<br>Loma de Gato Marilao, Bulacan<br>Phone - 044-7201244<br>admin@ceamsaasia.com |

**Table 2:** List of registered seaweed processing companies in the Philippines.

Farmgate prices are volatile and vary with the FOB prices on the international market (here, FOB means "Freight On Board" or "Free On Board", referring to the cost of movement of goods borne by the seller). In the Philippines, the export price of dry *cottonii* (FOB Cebu City) averaged about 800 USD/t between 2003 and 2007 with relatively little fluctuation, whereas in 2007 the price was driven enormously high by strong demand from China, reaching 2'750 USD/t in 2008 (Fig. 10). Farmgate prices at that time reached 90 Php/kg of RDS. When the supply reacted swiftly to the price hike, the price was dampened and dropped to 1'300 USD/t in 2009 and then rebounded to 1'600 USD in 2010 (Hurtado 2013).

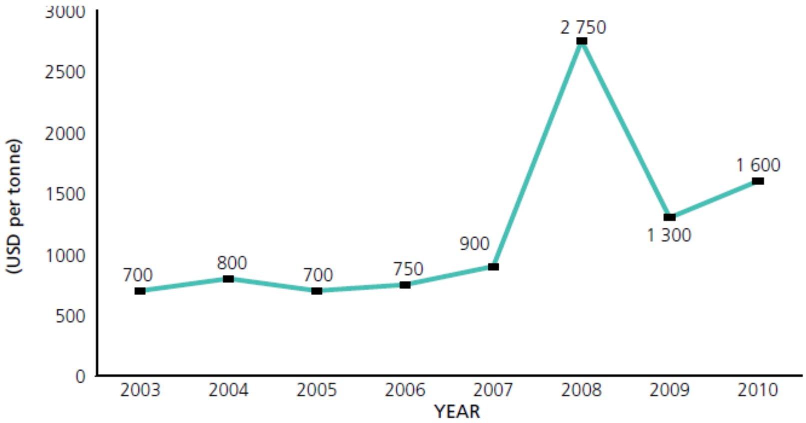


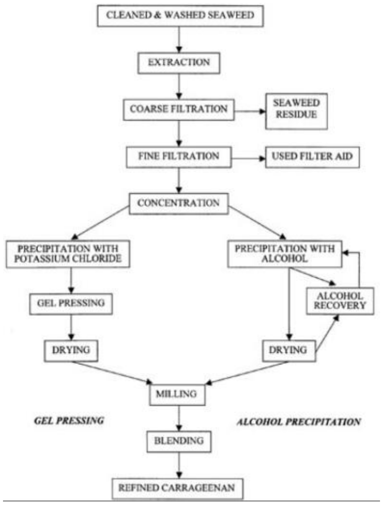
**Figure 10:** FOB prices for raw dried seaweed (RDS), which determine farmgate prices, from Hurtado (2013).

The processor pays a price depending on the moisture content: the drier the RDS is, the higher the value. The industry standard for maximum moisture content of dry cottonii is 35-40% depending on the specification of the processor.

There are two different methods of producing carrageenan, based on different principles. In the original method – the only one used until the late 1970s to early 1980s – the carrageenan is extracted from the seaweed into an aqueous solution, the seaweed residue is removed by filtration and then the carrageenan is recovered from the solution, eventually as a dry solid containing little else other than carrageenan. This recovery process is difficult and expensive relative to the costs of the second method. In the second method, the carrageenan is never actually extracted from the seaweed. Rather, the principle is to wash everything out of the seaweed that will dissolve in alkali and water, leaving the carrageenan and other insoluble matter behind. This insoluble residue, consisting largely of carrageenan and cellulose, is then dried and sold as semi-refined carrageenan (SRC). Because the carrageenan does not need to be recovered from solution, the process is much shorter and cheaper.

The carrageenan content of dried seaweed is around 30%. A production of 1'200 t of carrageenan would thus require 4'000 t of RDS or 28'000 t of wet seaweed.

**Refined carrageenan**



**Semi-refined carrageenan**

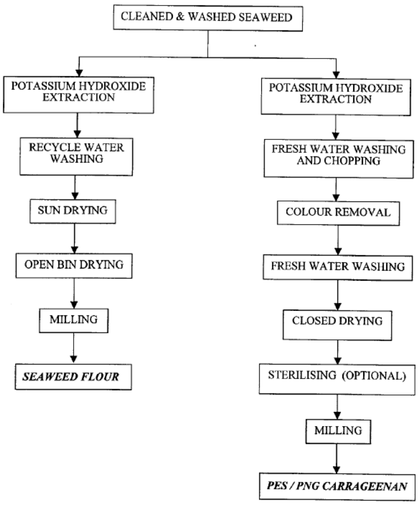


**Figure 11:** Processes for refined carrageenan (left) and semi-refined carrageenan (right).

It appears that carrageenan processing from seaweeds is a profitable business and demand can be expected to continue to grow. Europe and Northern America (mainly the United States of America) have been the main international markets for carrageenan. However, future development of the carrageenan seaweed industry faces various challenges such as inclement weather conditions, disease outbreaks, uncertain and fluctuating market conditions, competition from other sectors (e.g. fisheries, tourism and urban development), a lack of value-added products and value-adding activities in seaweed farming countries, low incomes of seaweed farmers in some countries, and occupational health hazards. New applications are currently being developed for additional uses of carrageenan, such uses in concrete and paper, etc. (Ricohermoso, *pers. comm.*).

# 4 Feasibility and scope for impact investment in seaweed farming

Certain factors must be met when planning a seaweed farming operation with communities. The environmental conditions should be suitable for seaweed farming. Furthermore, human capacity and a certain working attitude and motivation to do seaweed farming are necessary. To justify the need for investment, it must be shown that there is a potential for increasing revenues as compared to the status quo. The following sections broadly describe the conditions that should be met to venture into seaweed farming, why investments into seaweed farming make sense, and the model community (Green Island), for which the case example of the business plan will be presented.

## 4.1 Criteria for community-based Seaweed Farming

An important factor for success or failure is choosing a suitable farming site. *Kappaphycus alvarezii* is found in the upper part of the sub-littoral zone, from just below the low tide line, of reef areas on sandy-corally to rocky substrates where water flow is slow to moderate. *Eucheuma denticulatum* thrives on sandy-corally to rocky substrates in areas constantly exposed to moderate to strong water currents. If *Kappaphycus* or *Eucheuma* are growing naturally, the place is probably suitable. If not, the following criteria apply.

- Shelter from heavy wind and wave action. At strong wave action handling becomes impractical and plants might get detached from the lines.
- Reefs, well away from any freshwater sources (small rivers, etc.), have proven to be good sites. If the seawater salinity (usually 35 parts of salt per 1 000 parts of water) falls below 28 ppt, the seaweed does not grow well.
- Water temperature should be 25 – 30° C; in shallow water near the beach, water temperature may become too high during the day; a good site is between the low tide limit and the reef edge.
- The seaweed obtains its nutrients for growth from the water so water movement through the seaweed is important. Moderate water movement is preferable; this also helps to stabilize water temperature and salinity. If the current is too strong it can cause pieces of the growing plant to break off and be lost; wave action must be avoided for the same reason.
- The sea bottom type is important; a white, firm bottom with a limited amount of natural seaweed is good, too much seaweed or sea grass will compete for nutrients and $CO_2$ with the cultivated seaweed. Silt or mud on the bottom indicates possible poor water flow and if the silt is disturbed it may settle on the plants; muddy water will also reduce the light available to the seaweed.
- Plenty of sunlight is necessary for good growth; seaweed planted in shallow water (30 – 50 cm) grows well; in deeper water (more than 1 m) the light is reduced and growth is poor. Water depth is also important for farming: 0.5 – 1.0 m depth at low tide is good for the seaweed and allows the farmer to carry out maintenance more easily.
- Regular maintenance is essential. It consists of removing other seaweeds growing either on the lines or the crop itself, removing poorly growing plants, replacing lost plants, and making any necessary repairs to the stakes and lines.

There are many suitable sites in sub-littoral zones that would be available for seaweed farming, and the more areas, the more flexible the farming installation is. Since seaweed can thus be grown virtually anywhere in the sea if the right infrastructure is provided, the most important factor for feasibility of investment is human capacity and attitude. Even the best environmental conditions, best farming installation and production plan are of no use if there are no people willing or able to farm seaweeds and to perform according to the plan. If community members don't have easy access to the farming site or if there are simply no people that are motivated to do seaweed farming, a seaweed farming operation makes no sense. Like any other farming operation, seaweed farming requires work to be done without immediate returns, such that a certain work attitude is necessary. It is not advisable to expect that people will start seaweed farming out of the blue, especially not if other alternatives for earning income are possible in the area. Tourism, for instance, represents a sector where relatively high revenues can be generated on relatively short time scales. In areas where tourism develops, it therefore appears less likely that people will engage in seaweed farming. Imagine, for instance, that 10'000 PHP can be earned in a month by working 3 full days a week on seaweeds, but 1'500 PHP can be earned in a day by driving around some tourists. The remoteness of a place is therefore an indicator for the readiness of communities for seaweed farming. On remote islands, fishing and farming might just represent the only options for income, and seaweed farming can provide more regular revenue than fishing or fish farming. Hence, there is a good incentive for people to engage in seaweed farming. Island communities represent the most important community-based seaweed producers in the Philippines. Seasonality is an important factor to consider when planning a seaweed farming operation. If a site is exposed to rough weather, seaweed farming might only be feasible for about 6-8 months, typically during Amihan. This will cause an interruption to operations and farmers would have to find alternatives for income during the rest of the year. It also implies that seedlings at the start of the subsequent farming cycle might have to be purchased. In areas that are remote to the main farming areas of Zamboanga, Tawi-Tawi, Palawan, and Danajon Bank, good seedlings are not readily available.

### 4.2 Scope for impact investment

The community-based production of seaweeds is typically not optimally organized if it is not strictly organized by a processor like, for example, MCPI on Danajon bank. The productivity and generated values in most sites could therefore be substantially increased by: i) organizing the farmers in cooperatives, ii) training them on best farming practices, iii) closing infrastructure gaps, and iv) providing a solution for good quality seedlings (Table 3).

| Scope of improvement action | Rationale and expected effect on generated value |
|---|---|
| **Organizational structure & management through cooperatives** | A cooperative helps farmers to move up the value chain, negotiate prices, consolidate volumes to directly ship to processors, organize planting and harvesting events, organize the finances of seaweed farming, and hence achieve better prices and profitability per farmer. The cooperative can also help its members to manage their finances. Agreements on minimum prices and percentages to retain as investment or working capital funds help improve the long-term economic sustainability of the community and the individual farmers. |
| **Training on aquaculture best practices** | Productivity is limited due to inefficient practices, for instance, lack of planning in space and time, no proper farming cycling design, inadequate shoot selection as seedlings, etc. Farming efficiency can thus be increased by introducing rotational harvesting cycles to prolong the duration of seaweed growth at sea, spatial management of installations, sound selection of propagules, etc. Furthermore, efficiency depends on the type of installation, for instance SWB is considered more efficient than FOB, while most farmers are used to applying FOB due to short-term financial limitations and are not used to working with SWB. SEAFDEC as well as BFAR are offering workshops and on-site trainings at relatively low costs. |
| **Infrastructure** | Infrastructure investments are mainly needed for installations and in the postharvest sector. To increase the quality of RDS, it is important to have sufficient space for drying the fresh seaweed by drying racks about 1m above the floor or sea surface. A cooperative should further have its own storage building (bodega) for RDS to bounce the price volatility and ship to processors directly when minimum price requirements are met. Investments in robust installations (e.g. SWB) and outrigger boats for planting and harvesting can further increase efficiency. |
| **Provision of good quality seedlings** | Access to good quality seedlings is an issue in all farming sites. Usually, the gametophyte stage of a male or female plant is used in farming operations (Fig. 5) and raised by vegetative growth, but it won't grow indefinitely at a constant rate as the plant at some point switches to a reproductive mode. Apical meristems can then be selected as new propagules, but since vegetative growth is based on the same genetic material (cloning), it could be expected that growth rates or disease resistance might decrease at some point. One option to overcome the drawbacks of cloning is to produce new (cloned) plantlets in a tissue culture lab, or even better but costlier, mix genetic materials to produce new plantlets. Such a culture lab itself can be profitable, especially if the operation is carried to the nursery stage, where plants reach sizes that are suitable for farmers to be used as new propagules. |

**Table 3:** Investment needs and rationale for the expected increase in productivity and generated value.

The productivity of community-based farming sites is currently dictated by individual farming operations that are driven by short-term financial needs and limitations. Based on the proposed improvements (Table 3), a substantial increase in productivity and unit value can thus be expected. Productivity increases because seaweed is more efficient through better organization, planning and implementation, using better and more efficient infrastructure and tools. The unit value increases due to better quality, more efficient and direct supply chains between producer and processor, and the ability to balance short-term market fluctuations. Since the Philippines and Indonesia are by far the most important producers of seaweeds, it might be perceived that seaweed farming is well developed and the market is saturated. High production levels, however, don't indicate that the production is optimized and, furthermore, the production level might not be as high as assumed based on official statistics. As outlined in section 3.3, the true production of the Philippine carrageenan seaweeds is likely about 5 times less than officially reported. Lastly, the market is not saturated based on the demand – supply hasn't exceeded demand so far.

Productivity of farms has been decreasing since 2004, which might be related to the worsening quality and growth rate of available seed stocks, which are more and more disease prone. Therefore, the development of an effective tissue culture system will overcome the problem, leading to savings in time and cost through better growth and higher disease resistance of farmed plants. Since the importance of seaweed farming as a livelihood activity is widely acknowledged in local politics, it is not the first attempt to build a tissue culture laboratory to support farmers with a supply of seedlings. BFAR has built 13 laboratories in the Philippines. However, only three of these labs ever commenced operations and none of them produces an output on a commercial scale to satisfy farmers' needs for new seedlings. The reasons for this failure are unclear, perhaps it's mainly a management problem. BFAR is currently accepting unsolicited offers from private investors interested in running a seaweed culture lab and is willing to subsidize the operation by 350 Million PHP yearly to solve the shortage of seedlings. In Palawan, there is an opportunity to use the already existing infrastructure for a seaweed culture lab in Puerto Princesa, which is currently not operated.

Since there is currently no seaweed processing plant on Palawan, investment into a processing plant to source the seaweeds produced in Palawan more directly, might also make sense. The governor of Palawan is currently pursuing this plan in collaboration with established seaweed processors. A carrageenan processing plant in Palawan would imply more direct supply chains between the farm and the processor and should lead to better pricing. Since there is no international port on Palawan, the feasibility of the processing plant is not clear. Also, the impact for farming communities is not obvious – pricing would be the only impact that could be expected, but this will depend on the setup and behaviour of the new plant. As of September 2016, it is reported that the construction of a processing plant has started. The plant is scheduled to start its operation by early 2018 producing refined Carrageenan, while details on capacity and ownership are not yet official.

## 4.3 The model site: Green Island, Roxas Palawan

Green Island is a coral reef bank in the northern part of Palawan along the north-eastern coast line, a distance of about 10 km from Roxas, located at 10°16'4.31"N and 119°29'37.55"E (Fig. 13). It has been selected as a case example for investment in community-based seaweed farming.

**Figure 12:** Roxas, with its main farming sites of Green Island and Johnson Island.

A seaweed farmers association has been founded and accredited at the site by the municipal government. However, there is no real organizational structure yet and the purpose of the mentioned association is not well defined. Green Island is also a project site for the Philippine Rural Development Project (PRDP), which recently applied for a grant of 4.2 million PHP.

### 4.3.1 Farming area

Green Island is the most important farming site around Roxas, Palawan, with a total available farm area of about 800 ha. The bank has a sandy substrate with patches of *Zostera* and *Cymodocea* seagrass, but no consistent seagrass meadows as in the bay of Roxas, and occasional corals. The depth at the lowest low tide is 1-2 meters, such that substantial water movement can be expected on the bank at any time. The sandy bottom and the good water movement and low depths constitute an optimal environment for seaweed farming. In the shallower areas, FOB techniques are applied. The southern coast of Palawan has exceptional climatic conditions: typhoons have never reached Palawan, and this side of the Island is more sheltered from Habagat (southwest monsoon) than the other side facing the south China sea. Furthermore, the area is known for good water quality.

### 4.3.2 Human capacity and farming history

There are about 3,000 inhabitants on Green Island, of which about 10-15% are engaged in seaweed farming. There is a long history of seaweed farming, indicating that people made a decent living in the past with this activity and they would still believe that seaweed farming can be a profitable business for them. The usual challenges of seaweed farming are present here, namely ice-ice during high temperatures and some grazing by herbivorous fish, but never to a degree where it seriously hampered productivity. The main species cultivated is *K. striatum*, due to its alleged higher disease resistance. Availability of seedlings is not a major issue because some strains are maintained during lean season. On Green Island, it is tradition to start with 150-200g seedlings, let them grow for 1 month (30 days) and then harvest and replant everything at once, with the harvesting and replanting takes about 2 weeks. The farming cycle is thus about 6 weeks, with the seaweed is growing in the sea for 4 weeks.

## 5 Business strategy and concept

The north of Palawan was identified as a suitable region to propose community-based business plans to improve the productivity of communities. The north-eastern coast of Palawan has exceptional climatic conditions: typhoons have not reached Palawan in the recent past (except for the super typhoon Yolanda devastated the farms in Cagayancillo and Agutaya in 2013) and the area is known for good water quality. The north-eastern coast is more sheltered from Habagat (southwest monsoon) than the south-western coast facing the south China sea. Furthermore, seaweed has been a traditional source of income in some communities of this area, hence the human capacity and mentality that seaweed farming can be profitable already exists and wouldn't have to build up from scratch. The region is politically stable, as opposed to Region 9 (Zamboanga) and ARMM (Tawi-Tawi), which is another important traditional farming region.

Aquaculture activity is sustainable when three components are present and fulfilled (Fig. 14): **1) social** – the ability of a community to persistently achieve good social well-being; **2) economic** – requires that a community uses its natural resources efficiently and responsibly so that it can operate in a sustainable manner to consistently produce an operational profit; and **3) environmental** - a community lives within the means of their natural resources ensuring that ecosystem services of coral reefs, mangroves, seagrass and seaweed communities are sustainably used. These dimensions of sustainability must be considered in evaluating the feasibility of impact investment in community-based seaweed farming.

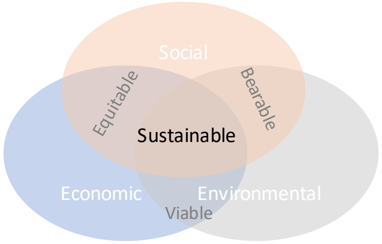


**Figure 13**: Dimensions of sustainability

The proposed investment plan seeks to institutionalize seaweed farming by seaweed farming communities, to increase the economic returns of this activity by improving the productivity and the unit value of produced seaweed on the level of the farming community, while conserving the environment.

The business model is illustrated in detail for the case of Green Island in the municipality of Roxas, Palawan. This model can then be scaled up to other communities, while essentially only the size of the farming community has to be adapted. The key objectives in Table 4 are in line with the scope of investment.

| Objectives | Actions |
|---|---|
| **Institutionalisation** | Forming a cooperative to perform the following task:<br>• represent and reply to needs of seaweed farmers<br>• facilitate training<br>• administer production<br>• administer produced RDS, marketing and sales<br>• administer finances (foreign investment generated EBIT) |
| **Increase productivity** | Productivity is increased through the following actions:<br>• follow production plans with rotational units by farm unit<br>• optimized organisation within farm units<br>• training of best practices<br>• optimized installations for farming and post-harvest processing<br>• Better quality strains and propagules from the seaweed culture lab |
| **Increase unit value** | The unit value on the community level is increased by the merits of improved farming practices and the sales management of the cooperative:<br>• Better quality strains and propagules from the seaweed culture lab<br>• Better quality due to better handling (e.g. drying process)<br>• Consolidation of volumes by cooperative and organisation of more direct supply chains to processors (absorption of trader margins)<br>• Storage capacity to balance price volatility |
| **Conservation** | Seaweed farming is an activity from which marginal environmental impact is expected. Farming techniques shall be applied that don't directly interfere with the marine habitat and potential impacts should be monitored. |

**Table 4:** Key objectives of the business plan and required actions to achieve these.

### 5.1 Investment model & investable entity

The community-based seaweed business plan assumes that a cooperative is in place in each community to plan and manage the seaweed production, handle the financial administration, provide technical support and organize the marketing and sales. The cooperative is the investable entity that will ultimately return the investment to the investor. The cooperative has contractual agreements with each farming unit to transfer the CAPEX needs and agrees on buy-back terms for the produced RDS (Fig. 15). The farm units are consequently obliged to sell the produced RDS at a price that leaves them no or minimal profitability (after depreciation) at first, but assuming a decent standard salary for the farmers. The cooperative has sufficient operational budget to buy the seaweed from the farmers, even if the seaweed isn't sold immediately. The cooperative sells the seaweed when conditions are optimal to the processors at optimal possible profitability, such that the EBIT of the operation is accumulated at the level of the cooperative. The EBIT left after paying back the investment to the investor belongs to the cooperative and its members (the farmers). At that point, it is up to the community how the EBIT is split among its members, while sufficient funds should be held back for the operational budget and potential additional investments. This logic is applied to any community in which the plan is subsequently scaled up.

Furthermore, the investment plan foresees financing a tissue culture lab operation to provide optimal seedlings to the farmers. The lab and the sea-based cage culture for grow-out are based in and around Puerto Princesa, respectively, and produce the plantlets that are subsequently transferred to the sea-based nurseries in the community farming sites (Fig. 15). These sea-based nurseries are also operated by the tissue culture lab company and will sell the propagules at a size of around >100g to the farming units for a defined price. The tissue culture lab is another independent investable entity. The demand for good quality seedlings is high and the lab will be free to work with different communities.

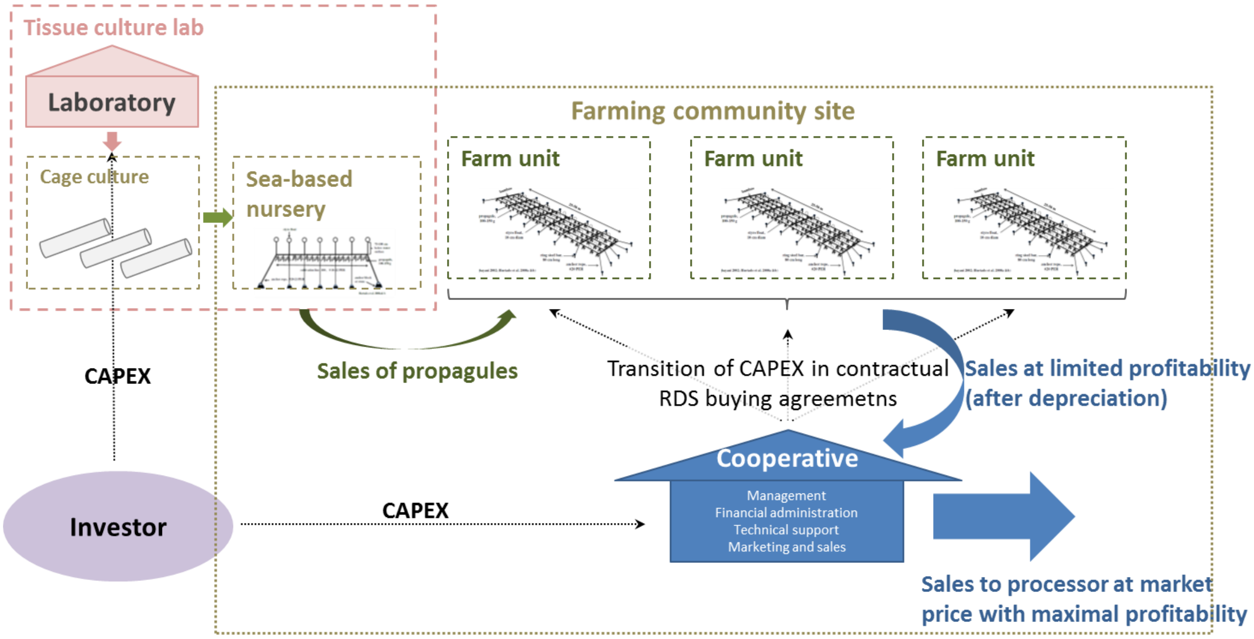


**Figure 14**: Proposed business and investment model for community-based seaweed farming.

### 5.1.1 Farm Units

Each farming unit has one main responsible farmer (cooperative member) who can employ auxiliary workers for the daily harvest and replanting work. Each farming unit has a size of around 1 ha. A SWB or SWB-like installation is recommended due to its robustness and more efficient handling. To facilitate planning, administration and comparison between the units, it is recommended that the farming units all built up and organize similarly. The drying racks might be shared by different farm units, but each farm unit has to be assigned its space on the drying rack. The farmers will get a contract from the cooperative for transferring the CAPEX that corresponds to their needs. This contract will also set the conditions for buying seedlings and selling back the seaweed to the cooperative. The farmers will obtain training, but they are responsible themselves for how they set up and construct their farming installations.

### 5.1.2 Cooperative

An effective management of the seaweed farmers cooperative is crucial for successful implementation. Community leaders that enjoy trust among the famers should be selected for cooperative management and should receive appropriate salaries to do this job reliably. The formation of the cooperative and knowledge transfer will take some resources and should be implemented by an independent entity (which needs to be determined) that is knowledgeable and experienced in this respect. The same entity shall then also monitor the operation over the 5 years to ensure that it is running according to the plan.

The cooperative will manage the whole raw material production and storage, accounting and sales logistics. To achieve better pricing, it will be important that the cooperative organizes the transportation and sales to the processor without middlemen. This task will have to be solved by the cooperative's marketing and sales team as soon as high enough volumes can be consolidated such that it would pay off for a processor to send a vessel to pick up the entire production. During the 8 months of high season, the cooperative would produce about 150-200 t of RDS per month, which is a high enough volume to send a collection vessel to directly pick up the production in the site.

The cooperative buys the RDS from the farmers for a relatively low cost, leaving a limited EBIT for the farm units but giving the cooperative the opportunity to accumulate EBIT to pay back the investment. It would be too risky and complex to give investment payback responsibility to the farming units. The cooperative works out contract agreements for the transition of CAPEX according to the needs of each farm unit, which is linked to the buying terms of RDS. In the initial phase, the farmer will sell his seaweed to the cooperative for 20 PHP/kg RDS and the cooperative is projected to sell the seaweed for around 30 PHP/kg (see section 6). The current farmgate price is of 25 PHP/kg, but there are at least 3 traders involved in the supply chain between the farm and the processor, which might add up to 5 PHP/kg (and the processor thus buys for around 30-35 PHP/kg). Since the cooperative will bundle volumes and bounce price fluctuations by storing the RDS, better selling prices will be possible compared to the status quo. The cooperative furthermore needs a working capital fund to be able to always buy the seaweed from the farmers, even if the cooperative doesn't sell immediately.

### 5.1.3 Seaweed tissue culture lab & nurseries

One of the major obstacles in seaweed farming is the access to good quality seedlings. To provide good quality seedlings, new plantlets must be generated, and one way of achieving this is a commercial-scale tissue culture lab. The lab consists of three parts: 1) a laboratory where the new planlets are induced, 2) a sea-based cage culture were the plantlets grow to a size of 3-5 cm, and 3) a sea-based nursery located in the partnering farm where the seedlings are grown to size at which they can be used by the farmers (>100 g). Since the lab is an independent investable entity, it is in principle free to sell the seedlings anywhere, but the idea as a first step is of course to apply the model to Green Island. If the lab collaborates with a community, it is allowed to use the optimal area for the nursery, and contractual agreements specify the volumes to be provided and the sales conditions the farmers are then obliged to comply with.

The business model for the farming communities could also work without the seaweed culture lab – if the community has the possibility to source good quality seedlings. It is, however, not obvious that seedlings can be sourced in i) sufficient volumes and ii) acceptable quality without a culture lab. The sources would usually be other seaweed farms in the region and the quality would never reach that of lab-generated seedlings, where new plants have been induced. The seaweed culture lab in the nurseries in the farming sites should therefore be understood as indispensable component of this proposal.

## 5.2 Marketing and sales

The marketing of seaweed is relatively straightforward as there is essentially only one product (RDS) for which there is high demand for its use in the carrageenan industry. The marketing strategy therefore merely focuses on achieving optimal pricing for RDS.

### 5.2.1 Pricing

The pricing which the cooperative receives mainly depends on the quality of the seaweed, the fragmentation of the supply chain and the capacity to balance price volatility.

Quality is measured by the moisture content and ultimately by the carrageenan content of the dried seaweed. The moisture content depends on the drying process, while the carrageenan content depends on the strain used. The moisture content simply needs to be adapted to the specification of the buyer and the carrageenan content is assumed to be optimized by the strains provided by the seaweed culture lab.

Fragmentation of the supply chain should be substantially reduced by communicating directly with the processor. The community consolidates volumes of around 200 t per month in the case of Green Island, which makes it worthwhile for the processor to directly pick up the seaweeds at the community site. In the worst case, there should be no more than one trader between the community and the processor to organize the shipment from community to processor. Both the community and the processor will have benefits in pricing through less fragmented supply chains.

The community, furthermore, disposes of the capacity to store the RDS and to sell only when seaweed pricing is optimal. For this, it is important that the cooperative disposes of sufficient working capital to be able to buy RDS even if it isn't immediately sold. With this mechanism, the market currently determined by the buyers should be converted to a seller's market.

### 5.2.2 Projected outputs

The bulk of the output in northern Palawan is generated during 5 farming cycles of 7 weeks each (hence 35 weeks or 245 days in total) between January and October. January and February are used only to maintain good crops in the nursery for the subsequent season. Each farm unit consists of a hectare. Since similar farming techniques will be used throughout the project, the output of a community is assumed proportional to the number of farming units.

In the case of Green island, 100 farming units will be built up within 3 years. Each unit produces around 22 t wet per farming cycle, thus 110 t per year over 5 cycles. The total production of 100 units will thus come to around 11,000 t per year and since the drying ratio is around 1:7, around 1'600 t of RDS per year after the third year.

The production of the community during the 6-7 months of bulk production will thus come to 7.6 t RDS per day or 227 t RDS per month on average.

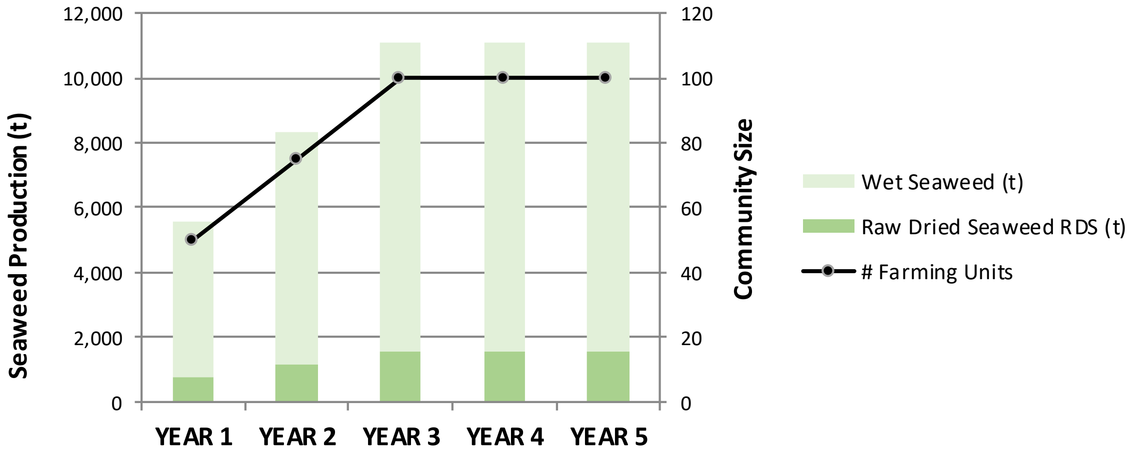


**Figure 15:** Projected output of wet and dry seaweed and number of farm units for the model case of Green Island.

### 5.3 Status quo vs. proposed model (Green Island)

Current productivity is limited by operational efficiency and lack of infrastructure for farming, drying and storing seaweeds. The current production volume is not strictly reported. BFAR usually estimates productivity by assuming a certain production per area and then extrapolating this expectation to the estimated farmed area. The derivation for Green Island is not quite clear (i.e. the assumed volume produced per unit area and time and the area being cultivated). The local BFAR office concludes that the annual production of Green Island is 5,000 – 6,000 t/yr. In our model projection, the current output would consequently be doubled. Productivity can be increased by optimizing the farming schedule by i) more robust installations and more post-harvest capacity (e.g. infrastructure for drying and storage), ii) more efficient farming schedules with rotational cycles, iii) more efficient practices for harvesting and replanting, iv) access to seedlings in line with the capacity of the farms and v) better quality seedlings.

From Green Island the seaweed goes through a trader to Roxas, from there through a second trader to Puerto Princesa, and from there through a third trader to, most often, Cebu. There are thus at least three traders in the value chain between farmer and processor, each one adding his margin to the price. The farmers sell and negotiate their seaweed individually to the traders. Apparently the farmers prefer to negotiate seaweed prices individually, probably driven by short-term monetary needs, but they would obviously have a much stronger position to negotiate prices with traders as a cooperative. Traders often help farmers when they are in financial need not only to invest but also to help in emergency situations e.g. when money is needed for medical treatment. It is therefore crucial that the cooperative has the working capital to cover short-term financial needs of its farmers, which should be covered by buying their RDS production on a daily basis. The unit value of the produced seaweed can thus be increased by i) negotiating better prices as a cooperative, ii) more direct supply chains, adding part of the current trader's margin to the unit value, iii) storing seaweeds to balance price volatility, selling when prices are good, and iv) better quality seaweed (purity, optimal moisture and carrageenan content). For any other seaweed producing community in northern Palawan, the impact should be similar.

# 6 Financial projection Green Island

## 6.1 Assumptions

The limiting factor in Green Island is human capacity and capability. There are currently more than 300 people involved in seaweed farming. We assume that 1/3 of them can be appointed as cooperative members who would thus each take the responsibility for one farming unit (1 ha). The number of farm units would thus grow from 50 to 100 within three years.

Suitable farming area on Green Island is around 800 ha. Since the 100 farming units will only use a surface of around 100 ha, the availability of suitable farming areas is not a limiting factor. As this area is already available for seaweed farming, no political issues are expected in this case, if the seaweed production is scaled up (i.e. doubled as compared to the status quo).

Each community should set aside an area that is suitable for the nursery. The nursery area should represent at least 10% of the total farming area. By default, the nursery will be operated by the seaweed culture lab, but this could be adapted on a case to case basis. If the farm units buy the seaweed from the lab, the farm units are contractually obliged to buy the 100-200g seedlings at an agreed price of around 17 PHP/kg (see section 7 below), which is close to the current market price of 10 PHP/kg for seedlings from the wild (i.e. from seedlings that have not been raised in a lab and that likely perform less well in terms of growth and disease resistance). If the community decides to operate the nursery, they would have to buy the 3-5cm plantlets coming out of the cage culture at a price that comes to about the same profitability as if they would operate the nursery and sell 100-200g seedlings, i.e. for about 1.44 PHP per piece of 3-5cm plantlet (see section 7 below). This would be unusual as there is currently no equivalent process on the market. The cost of the cooperative work would thus have to be assigned to the cooperative and the buying of raw material adapted accordingly.

### 6.1.1 Cooperative

The cooperative is assumed to buy the RDS for around 20 PHP/kg from the farmers and to sell it for around 30 PHP/kg. The main cost for the cooperative therefore is the RDS (90%). The operating costs only comprise around 9% of the total cost and the depreciation 1%. Depreciation for the cooperative consists of expenses for the storage building. A tax on the 6 million PHP of working capital is included with depreciation.

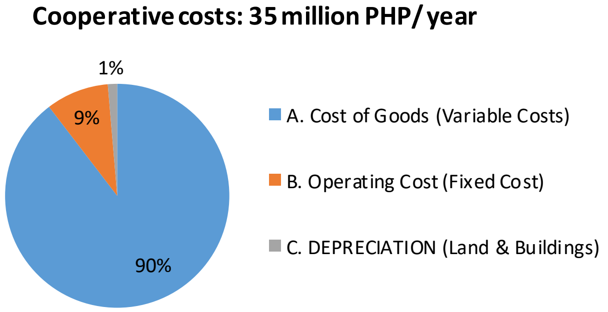


**Figure 16:** Breakdown of production cost of the cooperative.

The operating costs consist of the salaries for the cooperative personnel, training costs, some handling and transportation cost, and the monitoring and supervision costs to assure that the community operates and produces according to the investment plan. The cooperative staff consists of a manager/president, 2 people to handle the marketing and sales and 2 people to handle the administration and accounting with farmers. Furthermore, a pre-operational budget should be anticipated to form the cooperative, clarify legal status and issues, set up contracts, transfer the knowledge of the investment idea and plan to stakeholders, and recruit and build up the monitoring and supervision entity. This operating cost should not represent more than 10% of the total cost of the cooperative.

B. Cooperative Operating Cost (Fixed Cost)

| | Unit cost [PHP] | Unit | # Units per Farm | YEAR 1 | YEAR 2 | YEAR 3 | YEAR 4 | YEAR 5 |
|---|---|---|---|---|---|---|---|---|
| **Cooperative formation, knowledge transfer** | 2'250'000 | Cooperative | 1 | 2'250'000 | 0 | 0 | 0 | 0 |
| **Monitoring & supervision** | 1'350'000 | Year | 1 | 1'350'000 | 1'350'000 | 1'350'000 | 1'350'000 | 1'350'000 |
| **Training** | 1'000 | Farm Unit | 1 | 50'000 | 75'000 | 100'000 | 100'000 | 100'000 |
| **Management** | 240'000 | Person-year | 1 | 240'000 | 240'000 | 240'000 | 240'000 | 240'000 |
| **Administration / Accounting** | 180'000 | Person-year | 2 | 360'000 | 360'000 | 360'000 | 360'000 | 360'000 |
| **Marketing & Sales** | 180'000 | Person-year | 2 | 360'000 | 360'000 | 360'000 | 360'000 | 360'000 |
| **Handling & Transport to Land** | 0.5 | kg | n.a. | 396'782 | 595'173 | 793'563 | 793'563 | 793'563 |
| **TOTAL Cost [PHP]** | | | | **5'006'782** | **2'980'173** | **3'203'563** | **3'203'563** | **3'203'563** |

**Table 5:** Operating cost of the cooperative over 5 years.

Depreciation for the cooperative only covers CAPEX for the storage building. Furthermore, the working capital of 6 million PHP is included as part of the CAPEX with a 5% tax on it, which is include with the depreciation.

### 6.1.2 Farm units

The following simplified assumptions have been made for the reference scenarios (for more details see Excel files provided as Annex):

- Farming is seasonal and mainly takes place from May-November. Seedlings are purchased at the start of each farming season, within the farming seasons. Seedling can be recycled from existing plants.
- There are 5 farming cycles of 6 weeks. Currently, farmers on Green Island cultivate during 4 farming cycles of 7 weeks, the rest of the year is only used for cultivation of propagules for the next season, but since there is no rotational harvesting system, at least 2 weeks of seaweed growth are lost in each cycle. Furthermore, the lack of sufficient space of drying racks leads to a loss of time as seaweed is not optimally harvested but left growing until there is free space on the existing backyard drying racks. With a rotational system, 5 cycles will be possible.
- Propagule size is 100-200g. At the first crop, it might be less, requiring a few more days to reach harvestable size. From there on, the Green Island initial size of 200g is assumed.
- Seaweed is mainly sold dried. If it can be sold wet, the generated income will be higher, but these will be negligible amounts in a commercial operation.
- Drying ratio dry weight / wet weight is 1:7.
- The farm units consist of 8'250 m of line that is set up in an area of 1 hectare.
- The investment is higher for SWB, but the better conditions result in higher productivity. For SBW it is assumed that farmers can deal with 275 m of line per working day. The farmer will, on average, harvest 760 plants per working day with 5 working days per week.
- The farmer's work is estimated to come to a load of 2-3 full workdays per week, which is probably similar or slightly above the current workload.
- The farmers will rely on auxiliary worker for harvesting and replanting. For this type of work, there is traditionally a fixed cost per length of line (300 PHP/400m line is assumed which is 50% above the current standard). In a year, the farmer will harvest and replant around 40 km of line, for which he'd thus needs a budget of around 30'000 PHP.
- Daily growth rate of the seaweed is assumed at 3.5-4% per day using the SWB method. A 200g initial seedlings would correspondingly grow to 1244 g in 7 weeks
- "Mortality" caused by either grazing through herbivores, diseases (ice-ice) or other losses is assumed to be 20% over the farming cycle
- A farming unit consists of 8.25 km lines on 1 ha with 26'613 plants harvested per farming cycle.
- A farming unit's production results in 22.2 t wet or 2.46 t RDS per farming cycle. In a year, the unit will produce 111 t wet or 12.3 t RDS. With 100 farmers, the total output of the community will be of 1'587 t RDS per year (see Fig. 16).

The variable costs of the farm units consist of the seedlings for the first crop and some fuel for the vessels to transport the lines back and forth. The main cost are operating costs (54%), depreciation is (14%).

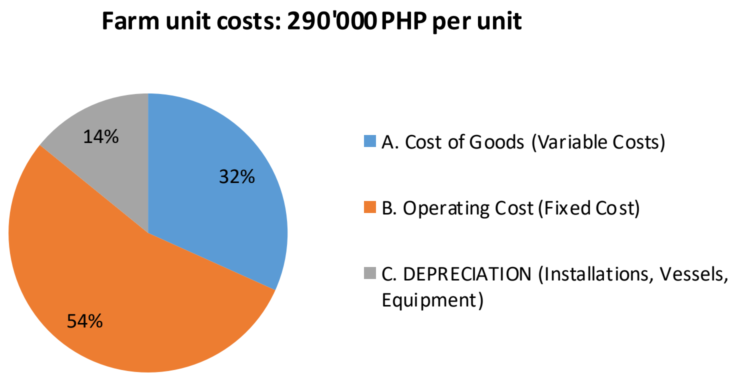


**Figure 17:** Breakdown of production cost of the farm unit.

The operating costs consist of labour costs for the farmer and his auxiliary helpers. The farmer's salary is set at 10'000 PHP/month, which is substantially more than the current earnings from seaweeds for a farmer. For the auxiliary helpers, around 30'000 PHP per farm unit is assumed. Furthermore, there are initial costs to set up the installation and some limited budget for maintenance and licensing.

The depreciation of the farm units covers the CAPEX, including installations, vessels and equipment/materials. Each farm therefore must set aside the depreciation value of 41'000 PHP per year. The planning should assure recovery of the depreciation and it will be safest to build it into the financial administration of the cooperative.

B. Farm Unit Operating Cost (Fixed Cost)

| | Unit cost [PHP] | Unit | # Units per Farm | YEAR 1 | YEAR 2 | YEAR 3 | YEAR 4 | YEAR 5 |
|---|---|---|---|---|---|---|---|---|
| **Labour (farmer's salary)** | 120'000 | farm unit | 1 | 6'000'000 | 9'000'000 | 12'000'000 | 12'000'000 | 12'000'000 |
| **Labour for installation** | 25'000 | farm unit | 1 | 1'250'000 | 625'000 | 625'000 | 0 | 0 |
| **Hired labour harvest & replant** | 300 | 400m line | 103 | 1'546'875 | 2'320'313 | 3'093'750 | 3'093'750 | 3'093'750 |
| **Maintenance** | 5'000 | farm unit | 1 | 250'000 | 375'000 | 500'000 | 500'000 | 500'000 |
| **Licenses** | 500 | ha | 1 | 25'000 | 37'501 | 50'001 | 50'001 | 50'001 |
| **TOTAL Cost** | | | | **7'821'875** | **11'732'813** | **15'643'751** | **15'643'751** | **15'643'751** |

**Table 6:** Operating cost of the farm units over 5 years.

### 6.2 CAPEX

The CAPEX investment mainly consists of installations (65%). The spider web technique is assumed for the model case. It is the most cost intense method, but also the most robust with longest amortization time, giving the best performance in terms of output per area. The investment consists of lines boys, anchors, loops to which the seaweeds are attached, and drying racks. The loops are the highest investment cost (39% of the installation costs). These are filaments intertwined to the lines, on which the seaweeds can be hooked. They are expected to increase efficiency and last for several years. The drying racks are the second highest investment (29% of the installation cost). The lack of drying racks currently represents a bottleneck for productivity. Since the land on Green Island is limited, drying racks preferably should be placed on the water. Costs for vessels and equipment/materials represent 11% of total. A vessel can be shared by 2 farm units to do the daily work of harvesting the lines, replanting seedlings, and cleaning of epiphytes (if needed). The working capital required for the cooperative to buy RDS from the farmers is taken as a CAPEX investment representing 20% of the total. This fund should, however, never disappear and is always recovered as soon as the cooperative sells the seaweed. Since the amount of about 6 million PHP nevertheless has to be put at disposition, it can be considered a loan with a certain interest rate.

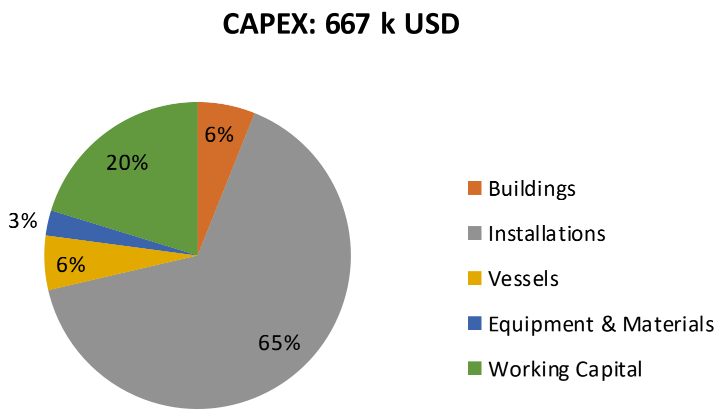


**Figure 18:** Total CAPEX and contribution of CAPEX components.

Investment for the storage facilities represent 6% of the total and will be managed by the cooperative. All other investments should be handled by the farmers themselves. The investment in installations, vessels and equipment will therefore be depreciated at the farm unit level, and only the buildings are depreciated ar the cooperative level.

### 6.3 EBIT Farms

The farms have revenue resulting from the 1'587 t of RDS per year sold and the selling price agreed with the cooperative of around 20 PHP/kg. The resulting EBITDA is 18%, and with depreciation of around 13%, an EBIT of around 5% will be left, assuming that the RDS is sold to the cooperative for 20 PHP/kg. In the first year, there are initial costs to cover, leaving no remaining EBIT or even a slight loss, but the EBIT could then grow to up to 10% depending on the productivity of each farm in subsequent years. The farmer can increase his EBIT by being more productive than conservatively projected. If a farm is less productive than projected, the difference would have to be subtracted from the farmers' salary.

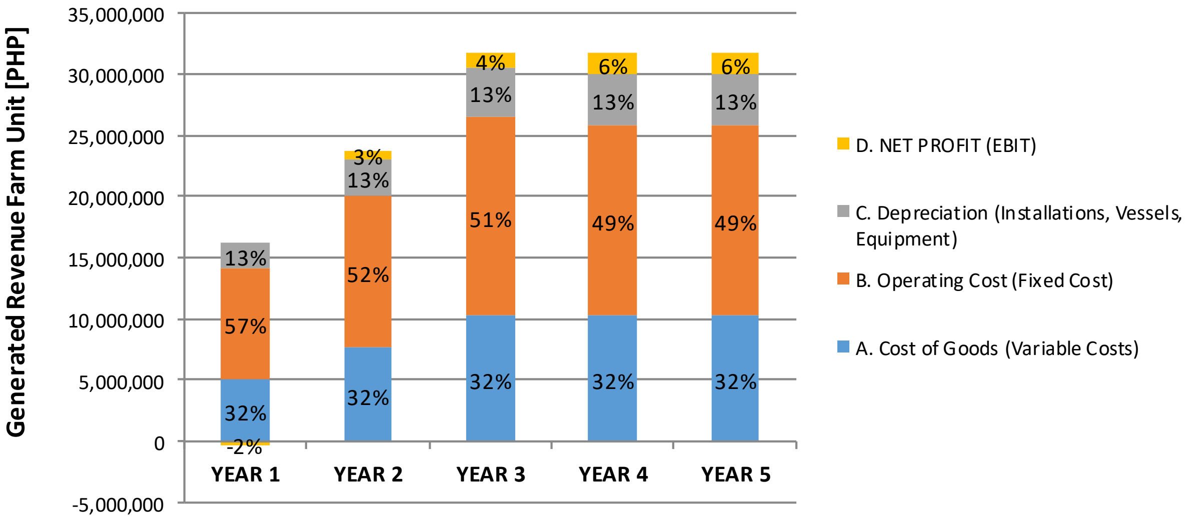


**Figure 19:** Revenue of the farming units, cost of goods, operating costs, depreciation and profit, over the first 5 years.

The farm units are contractually obliged to buy the seedlings at a certain price from the lab-operated nursery in the farming site (about 17 PHP/kg for 100-200g seedlings), and to sell the RDS to the cooperative at a certain price (about 20 PHP/kg). The scope of farming units to increase their incomes is thus not on the side of reducing cost of goods or increasing sale unit values, but merely on the side of productivity.

### 6.4 EBIT Cooperative

For the cooperative, the main cost comes from buying RDS from the farmers (67%). The operationing costs consist of labour costs of the cooperative team (7% for 1 manager and 4 assistants for administration, accounting, marketing and sales with adequate provincial salaries), and monitoring and supervision costs, and depreciation of around 1%. Assuming that the cooperative can sell the seaweed for 30 PHP/kg, the EBIT is around 26%. Due to the initial costs in the first year, the EBIT would be limited to 11% in this year, but climb up to 24% in the second and 26% in the third year.

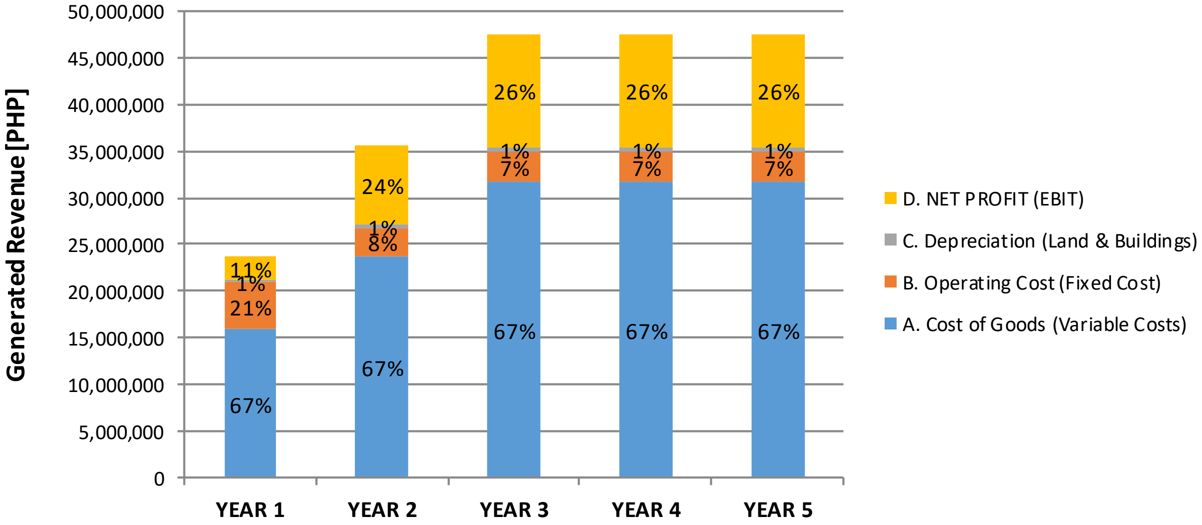


**Figure 20:** Revenue of cooperative, Cost of Goods, Operating Costs, Depreciation and Profit, over the first 5 years.

If the seaweed was sold from the farm to the cooperative for 25 PHP/kg, corresponding to the current farm gate price, the EBIT would be 11%.

## 7 Financial projection tissue culture lab

### 7.1 Assumptions

The seaweed culture lab must produce a certain number of new plants per day to be profitable. New plants are induced from thalli cut from apical meristems of seaweeds that have to be purchased as raw material. This raw material could come from wild stocks, or alternatively from farms using well performing strains, or also from outputs of the Marine Science Laboratory (PSU-MSL) in Puerto Princesa, which is running trials for spore culture. The selection of good and genetically diverse raw material is probably the most crucial aspect of the tissue culture lab operation. New plants are induced by incubation growth medium for 6 weeks, subsequently the ≥5mm plantlets are raised during another 6 weeks to 3-5cm plantlets in cage culture at sea, and at this size they can subsequently be tied to lines in the nursery, where they would grow to the seedlings size of 100-200g within 8 weeks (Fig. 22). In an initial phase, the lab is set up to satisfy the needs of the seaweed community case of Green Island about 1:1. In a later phase, the production of the lab can also be diversified to nurseries of other communities using only about 50% for Green Island, proliferating the seedlings in the nursery.

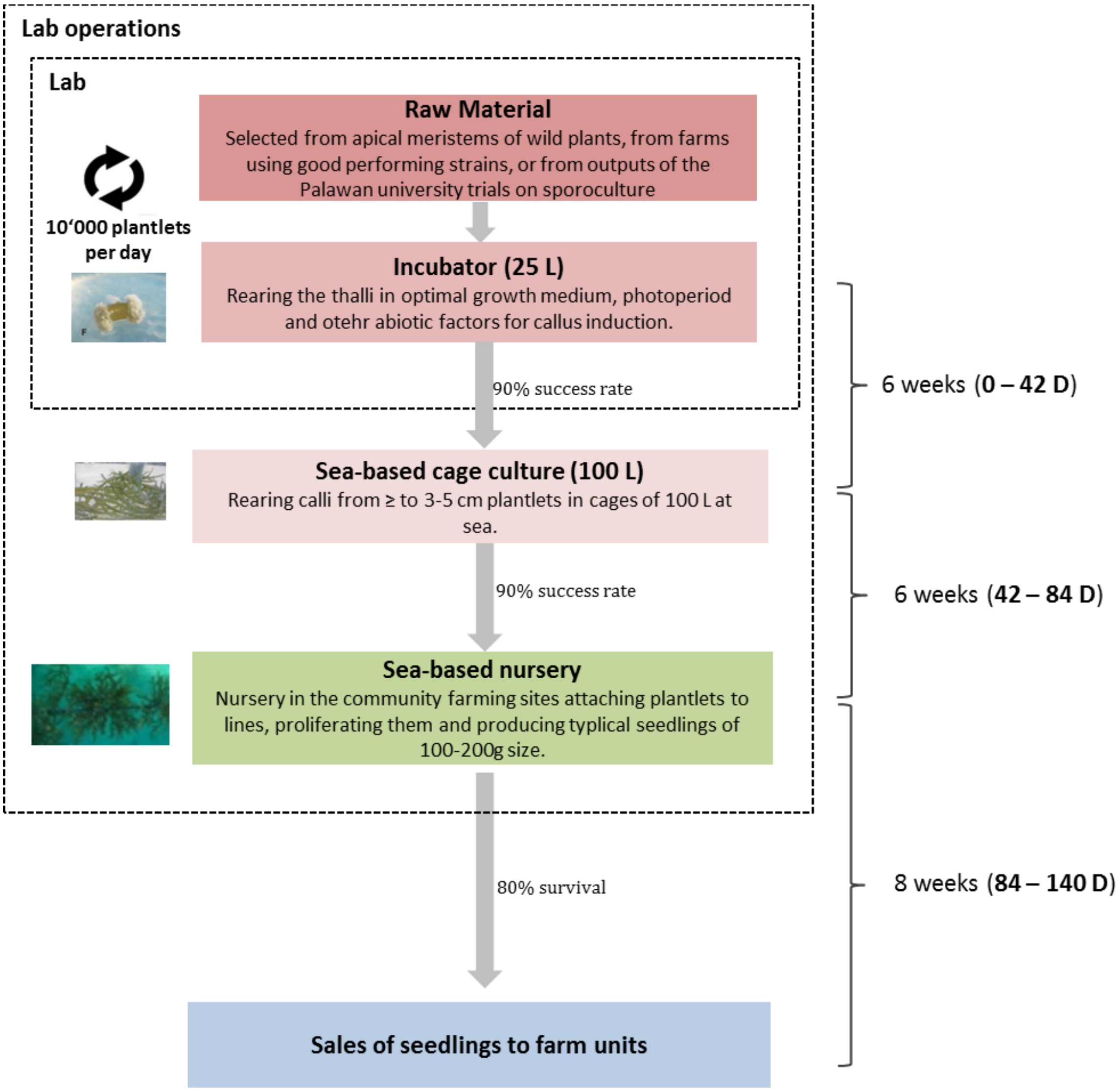


**Figure 21:** Farming cycles of plantlets in the lab and different stations in the production of seedlings until selling it to the famers at the agreed price.

The seaweed culture lab is projected to process 10’000 new plants per day. The lab can be constructed with relatively low cost material. The main investment is in labour costs. It is crucial to find adequate human resources and to factor in costs for training and supervision, because most likely the attempts in the Philippines to produce seedlings on a commercial scale have failed so far due to a lack of human capacity and management. Furthermore, these attempts were never integrated operations that were linked to farming operations, where a minimum buying price could be agreed on by contract. As binding selling prices can be negotiated in this case with the partnering communities, the proposed plan is much more likely to succeed, as compared to prior attempts.

The lab will, by default, operate a nursery in each of the partnering seaweed producing communities, where the plantlets are grown to the typical seedling size of 100-200g and sold to the farm units for 17 PHP/kg. This might be above the current market price for seedlings from the wild of 10 PHP/kg, but the likelihood is high that the cultured seedlings will result in better performance in terms of growth and disease resistance. The farmer will have to build up the trust that, despite the fact that the price of the plantlets might appear expensive on a kg-basis, the better performance of these plantlets will outweigh the seemingly high cost. Another possible scenario is that the cooperative would operate the nursery, in which case it would buy the 3-5cm plantlets from the lab (1.44 PHP per piece).

## 7.2 Processes, setup and cost of the lab

Cell and tissue culture development efforts for macrophytic red algae have focused on plants that possess terete thallus morphology consisting of branched shoots with the most active cell division at the apical meristem of each shoot. This culture development platform has two major components: (1) callus induction from explants of field-collected plants and (2) partial regeneration of shoot tissues from callus to form "microplantlets" (Fig. 23, Rorrer and Cheney 2004). These microplantlets are sub-cultured by mechanically chopping the tissues into small (ca. 2-3 mm) fragments. Individual shoots branch out to a symmetrical, ball-like overall shape that reaches about 5-10mm diameter after 30-45 days in culture.

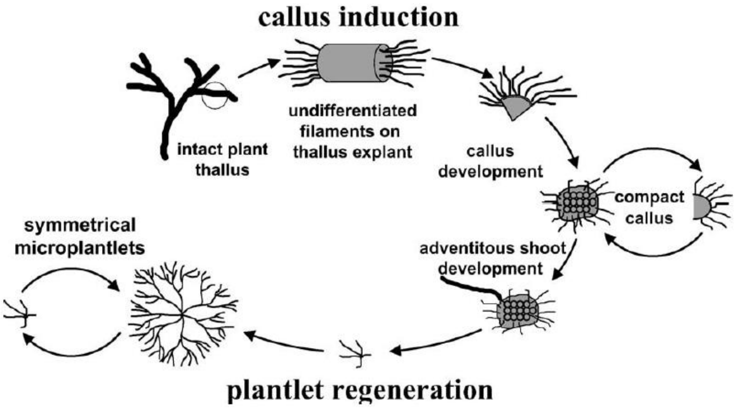


**Figure 22:** Cell and tissue culture development scheme: The parent plant for red algae possess terete thallus morphology, consisting of branched shoots with the most active cell division at the apical meristem of each shoot.

Explants should be carefully selected from seaweeds, sterilized and rinsed with autoclaved seawater, and then excised into 2-3 mm length sections. The so obtained thalli are transferred to the culture medium supplemented with different concentration of plant growth regulators (Hurtado and Biter 2007, Yunque et al. 2011). Microplantlets are ideally suited for cultivation in agitated photobioreactor systems. In the microplantlet morphology, the biomass is compacted into ball-like tissues that grow freely in liquid medium. The microplantlets are easily suspended but also easily separate from the culture liquid to facilitate biomass harvesting. Since the biomass is compacted into multicellular tissue and not dispersed in the liquid medium as single cells, the light attenuation through the culture suspension is low relative to microalgal suspension cultures at the same cell mass density. Bioreactors for macroalgal suspension culture must provide illumination, gas exchange ($CO_2$ addition and $O_2$ removal), nutrient delivery, mixing, and temperature control (Fig. 24).

Macroalgal cell suspension cultures require diurnal photoperiod defined as times the culture is exposed to light and dark within a 24 h time period. Although photoperiod is important to the development of macrophytic marine algae in the natural environment, the effects of photoperiod on biomass production still remain unclear. Continuous bubbling aeration of the culture with $CO_2$ in air accomplishes four processes: (1) transfer of $CO_2$ to the culture; (2) maintenance of the dissolved inorganic carbon level in the culture medium; (3) pH control; and (4) removal of dissolved $O_2$ produced by photosynthesis. The plantlets can be stocked at densities of 100 plantlets per liter and in order to ensure sustainable growth of explants, the growth medium has to be replaced regularly (once a week). The effects of media composition (PES, VS or f/2) supplemented with 5:1 mg/l of IAA:BAP, light intensity, and aeration on thallus regeneration of seaweeds have to be optimized, e.g. following the procedures in Kumar and Reddy (2007). AMPEP culture medium, based on an extract powder from a brown alga (*Ascophyllum nodosum*) has been shown to be the most effective and economic option for *Kappaphycus* seaweeds and is thus most suitable for large-scale production (Hurtado and Biter 2007, Yunque et al. 2011).

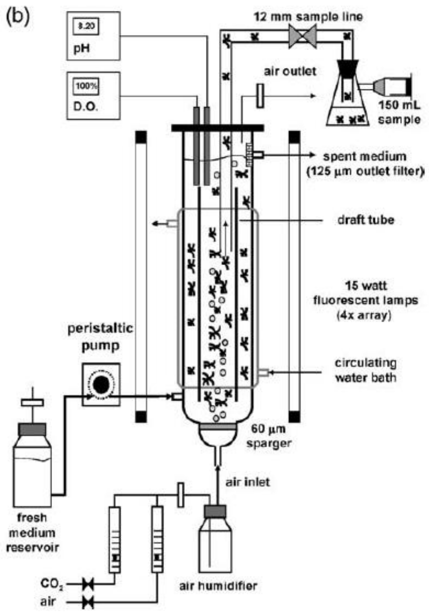


**Figure 23:** Design of an airlift photobioreactor from Rorrer and Cheney (2004).

The callus induction rate can be expected at about 90% (Hurtado, *pers. comm.*) and after about 6 weeks the 3-5mm microplants can be transferred to seawater cages for another 6 weeks, after which they'll have reached size of 3-5cm. At this size they can be transferred to the nursery, where the plants are tied to lines to grow to sizes of about 100-200g within 8 weeks.

The production costs of the culture lab, cage culture and nurseries consist of operational expenses for labour and supervision (74%). Depreciation is 21% and the cost of goods, mainly consisting of the acquisition of raw material, growth media and gas is 5% (Fig. 25).

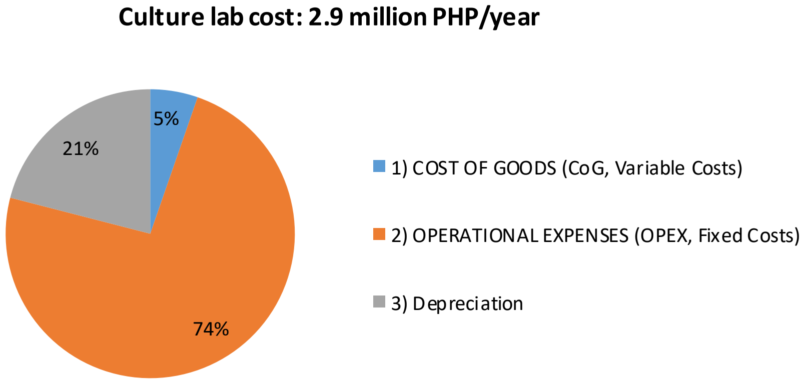


**Figure 24:** Breakdown of production cost of tissue culture lab, cage culture and nurseries.

Under the assumption of producing 10'000 plantlets per year, operating costs include labour costs for a technical manager, 4 staff responsible for callus induction in the incubators and 2 staff for the cage grow out (Table 7). Since the cycle in the bioreactor lasts for 42 days and the growth medium must be replaced every week, assuming a 5-day working week, on average 5 bioreactors should be provided with new plant material per day, and the medium should be replaced for 30 bioreactors per day. Additionally, the four staff should select raw material and cut the thalli during about half of the day.

The nursery work is seasonal, as it mainly requires work before the start of each season, when farmers will subsequently buy seedlings for the new farming season all at once. The nursery work would thus require that about 18 staff are available at once, but the workload of these over the year would average to about 4-5 months per year on a 100% basis. The planning, monitoring and supervision cost is projected at 1.2 million per year and could be reduced to half of this in the third year, once the operation is running.

**Operating costs for tissue culture lab, cage culture and nursery**

| | Unit Cost [PHP] | Unit | Amount | YEAR 1 | YEAR 2 | YEAR 3 | YEAR 4 | YEAR 5 |
|---|---|---|---|---|---|---|---|---|
| Electricity (water pump, air blowers) | 20'000 | month | 12 | 240'000 | 240'000 | 240'000 | 240'000 | 240'000 |
| Fuel (generators) | 10'000 | month | 12 | 120'000 | 120'000 | 120'000 | 120'000 | 120'000 |
| Maintenance (light, pump, etc.) | 5'000 | month | 12 | 60'000 | 60'000 | 60'000 | 60'000 | 60'000 |
| Labour Technical Manager | 25'000 | personmonth | 12 | 300'000 | 300'000 | 300'000 | 300'000 | 300'000 |
| Labour Callus Induction (cut, replace media, etc.) | 12'000 | personmonth | 12 | 288'000 | 432'000 | 576'000 | 576'000 | 576'000 |
| Labour Cage Growout | 10'000 | personmonth | 12 | 120'000 | 180'000 | 240'000 | 240'000 | 240'000 |
| Labour Nursery Farmers | 9'000 | personmonth | 12 | 432'000 | 540'000 | 756'000 | 756'000 | 756'000 |
| Planning, Engineering & Constant Supervision | 450'000 | year | 3.5 | 450'000 | 450'000 | 225'000 | 225'000 | 225'000 |
| TOTAL | | | | **2'010'000** | **2'322'000** | **2'517'000** | **2'517'000** | **2'517'000** |

**Table 7:** Operating cost of the seaweed culture lab, cage grow out and nurseries over 5 years.

## 7.3 CAPEX

The total CAPEX of the seaweed culture lab is 2.7 million PHP, assuming that an existing building can be used from government funding for this purpose, which appears likely. For the bioreactors, relatively low cost plastic jars can be used that are piped for aeration with a pump serving several jars. The production of 10'000 new plants requires 151 incubators of 25l with about 200 LED lamps and 5 air blowers and corresponding piping materials. Materials are used for sterilizing, cleaning and cutting, cages, lines and buoys for grow-out, and a vehicle for selling new plants to the sites and sourcing explants. The nurseries require lines, soft ties, buoys, and a surrounding net to keep away potential grazers and losses (mainly siganids).

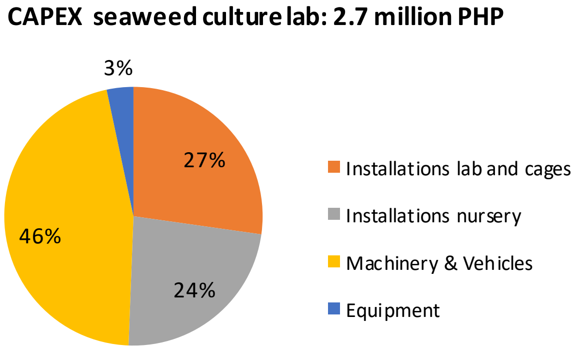


**Figure 25:** CAPEX cost breakdown for seaweed tissue culture lab.

## 7.4 EBIT

Since the main production costs of the tissue culture lab are labour and initial training and supervision cost, and because the lab won't likely produce 10'000 plants a day in the beginning but is assumed to scale up from 5'000 in the first year to 10'000 in the third year, the EBIT in the first two years is expected to be negative. Once the production is scaled up to produce 10'000 plants a day, an EBIT of 24% can be expected. If the lab manages to produce 10'000 plantlets in the second year, the EBIT would correspondingly already be positive in the second year. To compensate for the potential negative EBIT, better sales prices of the seedlings could be negotiated with the communities. The performance could be further improved if the government offers to use an existing building for the culture lab or if it subsidizes the operation, which is likely.

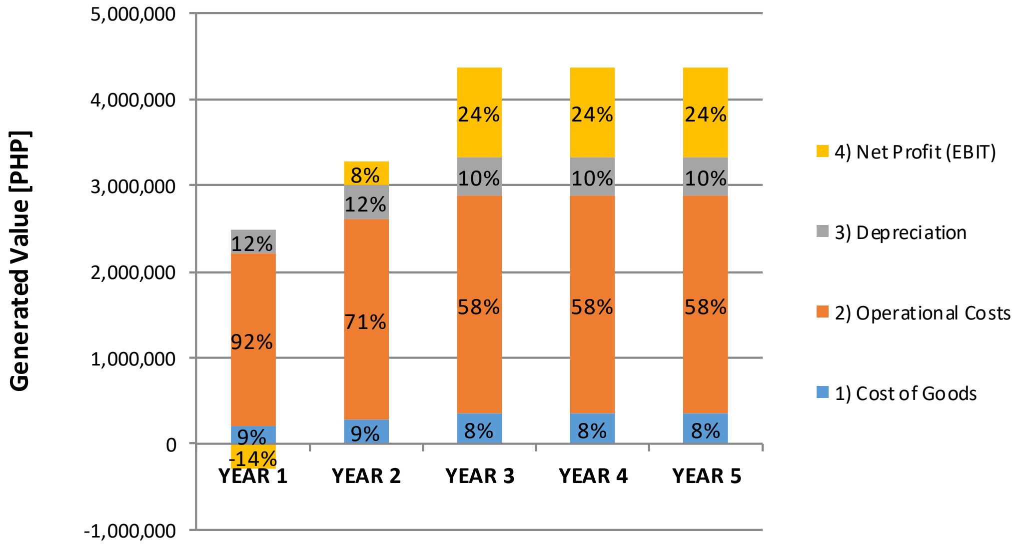


**Figure 26:** EBIT projection breakdown for the seaweed tissue culture lab in a conservative scenario.

# 8 Expected impacts

## 8.1 Environmental impact

Seaweed farming is currently an additional income in fishing communities living at the shore, while fishing is generally perceived as more profitable. If the seaweed production is better organized, as proposed here, resulting in increased productivity and income, seaweed farming might become at least as profitable as fishing. Furthermore, it has the advantage of offering more predictable incomes and allows community members to plan their finances ahead, while the income from fishing remains highly irregular. It therefore appears possible that fishermen could transition to more farming, which might have positive impacts on the environment, as fishing pressure would decrease. This prediction is often attributed to successful farming – proof that it really works, however, is scarce. A fisherman and a farmer are a different type of person with fundamentally different characteristics, and it might not be as likely as generally assumed that fishermen suddenly convert to farmers that plan ahead and act according to a projected plan. Nevertheless, the general projection might hold that households will have higher incomes and therefore rely less on fishing activities, which might reduce fishing pressure. This scenario is more likely to apply in a community such as Green Island, which is so spatially confined.

Potential negative impacts from seaweed farming might include competition for light with other marine plants, and trampling when the farmers walk on the substrate. High shading intensities might reduce the performance of small seagrass species, whereas trampling was only found to have an immpact in combination with shading at a seedling density of approximately 185’000 seedlings ha$^{-1}$ (Blankenhorn 2007). However, since the proposed model assumes use of the SWB technique, in deeper waters where there are no sea grasses or corals, and the proposed farming schedule is with seedling densities of about 26’613 seedlings ha$^{-1}$ (much below the critical threshold (Blankenhorn 2007), negative environmental impacts are expected to be negligible.

The bank on the model site on Green Island is a sand bank rather than a coral reef, with patches of *Zoostera*, *Enhaulus* and *Cymodocea* seagrasses, and patches of corals. Therefore, changes in the distribution of these patches are not expected and would be difficult to monitor. The history of the bank is, however, not well known and it is possible that the coral or sea grass density was modified due to the past farming activities. In any case, possible changes in the environment should be monitored by the community.

## 8.2 Social impact on communities

The communities currently don’t have the level of organization the cooperative work will bring. Collaboration in a cooperative will teach its members how set common objectives, work jointly on achievements, and jointly administer and distribute finances. The collaboration of the cooperative and its members will require sticking with a long-term plan, and the financial resources must be planned, including for the farmers. This anticipation of workloads and finances will be rewarded by more predictable incomes. This is much different than the current situation and probably would be the first time that community finances are jointly administrated.

Once such structures are in place, the community could use the knowledge of how to build and implement joint vision by a community administration in fields other than seaweed farming. There could, for instance, be a fisheries cooperative, raising a taxation system for fishing licences and distributing surplus production among community members, as in the seaweed cooperative, which might then be a model for other fishing communities.

### 8.3 Socio-economic impact

The socio-economic impact is most evident by comparing the status quo with the proposed model. This is complicated by the fact that, despite some available extrapolations, currently it is not known how much seaweed the farmers produce, how many people are exactly involved into farming with which workload and how much they currently earn from seaweed farming. The incomes under the proposed model are expected to be higher than current incomes due to higher productivity and higher quality.

In the status quo situation, there are more than 300 people involved in seaweed farming with probably quite diverse workloads, roles and responsibilities (Table 8). In the proposed model, there are 100 main farmers, each responsible for a farming unit of about ¾ ha. The main farmer then has auxiliary helpers he pays for tasks such as harvesting, replanting, cleaning, etc. Under the status quo, the workload of the farmers might vary between 1-3 days a week. In the proposed model, the workload should not exceed 2-3 days a week. The current annual production is estimated at 5'000 t RDS, while in the proposed model it would be around 10'000 - 12'000 t for the 100 main farmers, assuming the same plant growth rate. Growth rates could be increased if sourced from the seaweed tissue culture lab. The pricing is predicted to increase due to i) better quality, ii) more direct supply chains, saving the current trader's margin on the price, iii) consolidating volumes to reduce handling and transportation costs and iv) balanced price volatility by storing the seaweeds and selling them when prices are high.

| | Status Quo | Proposed Model |
|---|---|---|
| **Farmers** | 300+ People involved in seaweed farming | 100 main farmers with auxiliary helpers |
| **Workload** | 1-3 days/week | 2-3 days/week |
| **Production** | 5'000-6000 t wet seaweed | 10'000 – 12'000 t wet seaweed |
| **Growth** | 3-5% / day | 4-7% /day due to high quality seedlings from seaweed tissue culture lab |
| **Quality** | Limited due to lack of infrastructure | Improved due to infrastructure and high quality propagules from seaweed tissue culture lab |
| **Middlemen** | 3 | 0-1 |
| **Price** | 25 PHP/kg RDS | 30+ PHP/kg RDS due to better quality, less middlemen, and balanced price volatility |

**Table 8**: Key differences between status quo and the proposed model

The production cost in the proposed model is 20.5 PhP/kg, including depreciation. This production cost, without cost of depreciation, might be an indicator of the lower status quo production cost. Since the status quo generates less output, the per kg production cost is much higher at 32.6 PHP per kg. Note that this production costs includes the farmer's salary of 10'000 PHP/month and the additional hired labour of 300 PHP for working on a 400m line (harvest and replant).

The resulting EBIT projection of status quo and proposed model can be given as function of the selling price (Figure 27). Broken down to all farmers, the 25% EBIT of the cooperative in the proposed model results in an average monthly surplus of 2'500 PHP for every person involved in seaweed farming (300+ people). If broken down only to the 100 main farmers this would be 7'500 PHP. Since the status quo is less productive, the EBIT increases less steeply with the price and the operation is only at breakeven at 32.6 PHP/kg. This means that if the farmers under the status quo want to earn 10'000 PHP/month and pay the auxiliary helpers 200 PHP for 400m line, then the price would have to be 32.6 PHP/kg. Site visits have confirmed that the farmers currently earn substantially less than that.

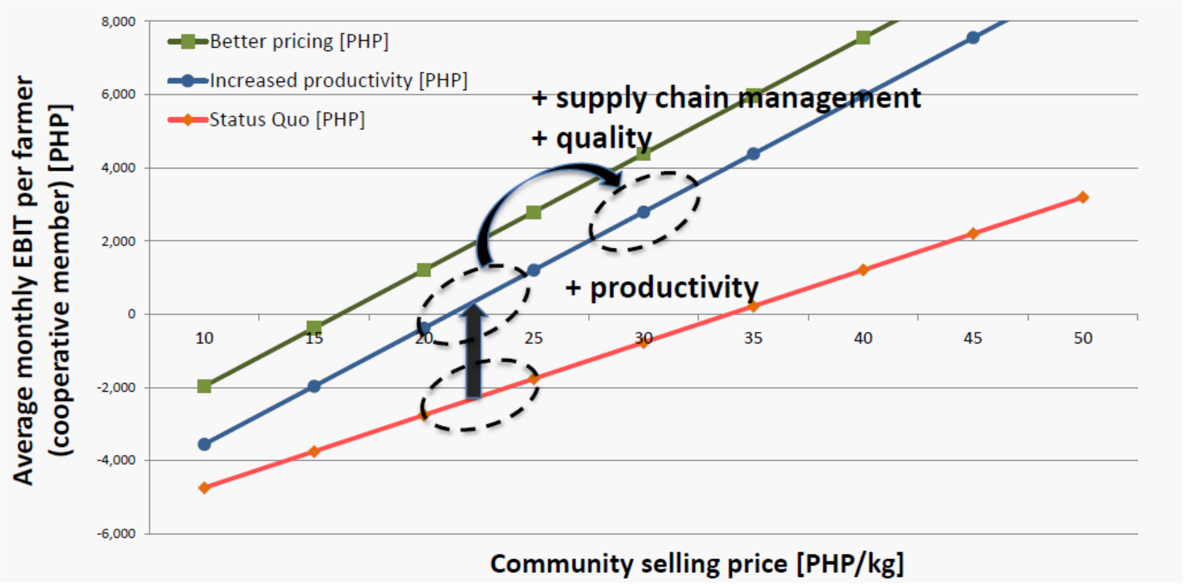


**Figure 27:** Expected average monthly EBIT per cooperative member as a function of the farm gate price, after 5 years.

These projections show that the farmers could earn significantly more under the proposed model, and relatively even more, if prices increase. As mentioned earlier, there are three main mechanisms in place that should be monitored to lead to better pricing in the proposed model:

1) Direct supply chains to the processors by consolidating volumes (cooperative). The current margin of the middleman will add to the future price of the farmers. Furthermore, the logistics will likely be less expensive if large volumes can be transported at once

2) Seaweed can be stored when prices are low and sold when prices are high. In the beginning, the cooperative will need to use working capital to cover costs (included in the project as a loan from the investor) to buy up seaweed without selling it. Over time, this working capital should accumulate from the EBIT.

3) The seaweed is higher quality due to improved infrastructure for drying (e.g. no sand), better controlled moisture content, and, depending on the performance of the seaweed tissue culture lab, possibly also due to higher carrageenan content.

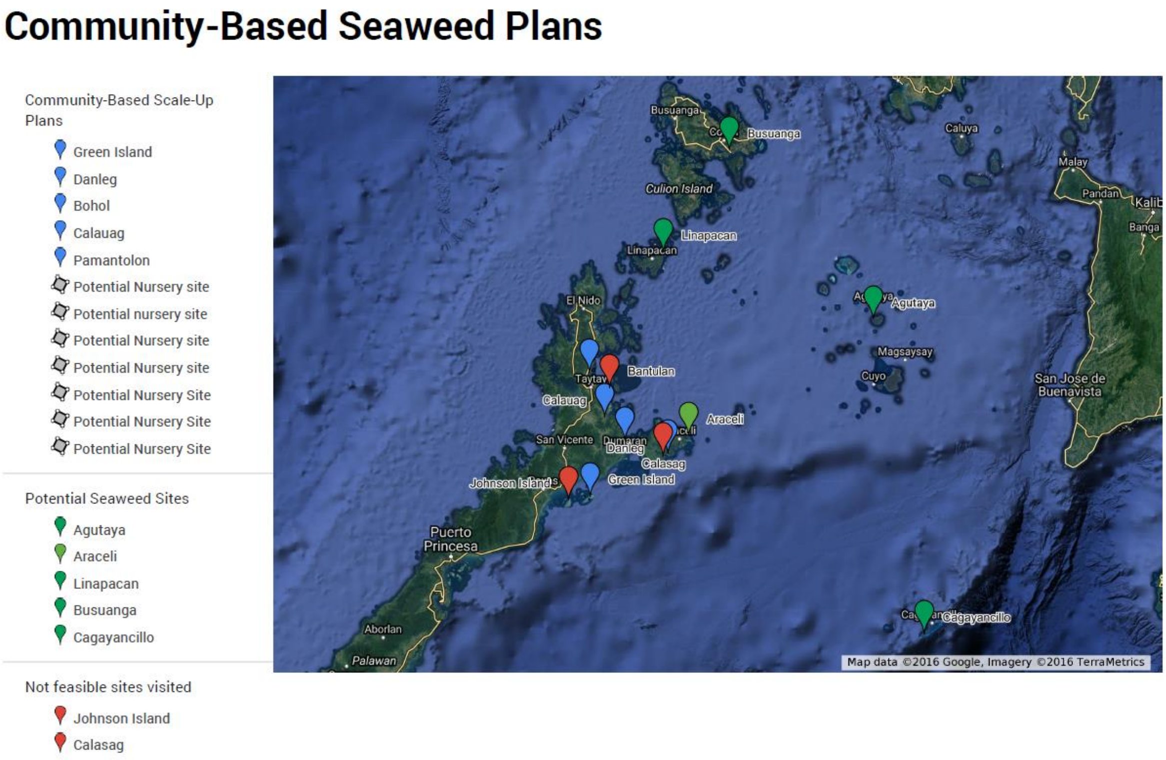
# 9 Scale-Up to multiple farming communities (northern Palawan)

The proposed community-based investment model can be scaled up to other communities in northern Palawan that display similar conditions as Green Island, namely suitable farming sites and human capacity for seaweed farming, i.e. a farming history with community members that perceive this activity as a beneficial activity. Farming communities were screened in the northern provinces of Palawan in the municipalities of Roxas, Dumaran and Taytay, and the sites deemed eligible for a similar investment case are summarized in Table 9. Some communities in the same municipalities don't appear to be suitable for investment for social and environmental reasons. For instance, barangay Calasag in Dumaran was disqualified due to regular landslides in the area which has destroyed entire seaweed harvests. Barangay Bantulan in Taytay once generated most of its income from seaweed farming, but in 2014 all famers dropped out due to continuous price decrease, switching to sea cucumber farming.

| Site | Municipality | Available Area [ha] | Cultivated Area [ha] | # of Farmers | Community leader/contact |
|---|---|---|---|---|---|
| **Green Island** | Roxas | 800 | 500 | 324 | Theresa Crujido<br>Mobile: 0928-267-1846 (smart) or 0906-614-4191 |
| **Danleg** | Dumaran | 75 | 50 | 100 | Christopher de la Cruz |
| **Bohol** | Dumaran | 120 | 60 | 152 | Jose Sonny Alvarez |
| **Calawag** | Taytay | 400 | 120 | 150 | Roberto Langcayanan |
| **Pamantolon** | Taytay | 250 | 30 | 40 | Edilberto Felizarte<br>0907 – 2269 - 380 |

**Table 9:** Communities eligible for community-based seaweed business plans in Roxas, Dumaran and Taytay.

There are other communities outside northern Palawan, particularly the islands of Cagayancillo and Agutaya, that have very high potential with respect to the selection criteria. As the former top producers in Palawan, it can be assumed that these islands are qualified to participate in a scale-up project, and they would probably result in a similar output as Green Island or even more. Due to the remoteness of these islands, the only sources of income are fishing and seaweed farming. Both communities suffered severe damage in 2013 from super typhoon Yolanda and have not fully recovered yet. Due to the shortage of seedling stocks, the estimated current production is only at 50% of its pre-Yolanda level. Due to their remoteness, however, the procedures for building up the business case, and procedures for monitoring and supervision will be more complicated. They were therefore not included in the following scale-up plan. The possibility of including them in a future case should be considered. There are sites in the municipalities of El Nido and Coron that are also not included, but are likely eligible for a scale-up project. The potentially eligible sites have been summarized in a Google Map (Fig. 29).



https://www.google.com/maps/d/edit?mid=1ZXNu9afi3EvkCMudV5utooQXonE

**Figure 28:** Eligible sites, non-feasible sites, and other potential sites for community-based impact investment.

The scale-up plan is presented for the sites that have been screened and that were deemed eligible, but including the 5 other potential sites the scale could be increased by a factor of 2-3.

## 9.1 Community profiles for the scale-up plan (Roxas, Dumaran, Taytay)

### 9.1.1 Bohol

Barangay Bohol is an Island Barangay in Dumaran about 2 hour boat ride away from the town proper on mainland Palawan. It consists of 339 households with 1444 inhabitants. The main source of income in Bohol is fishing. Seaweed farming is practiced by 152 farmers, which are organized in an association founded in 2008. The farmers claim to currently cultivate around 70 ha while around 90 ha are available in total. Seedlings are occasionally provided by BFAR, but only 100 kg per farmer. The remaining seedlings are bought in other Barangays of Dumaran and occasionally in Green Island/Roxas. The farmers clearly expressed their disappointment that no training was ever offered to them. They had to learn everything the hard way by trial and error, which led to frustration and some farmers have left their farms due to many failed harvests.

There are 3 buyers in Bohol which sell the seaweed to another trader in Roxas who sells, consolidates volumes and ships to a third buyer in Puerto Princesa. From there, the RDS is shipped mainly to Cebu. Farmers have no access to information about current market prices, hence they are totally reliant on their traders to pay them fairly. The third level traders are also uninformed, and the trader in Roxas might be the first one to be fully informed. It has to be assumed that this information asymmetry is abused and leads to a decrease in potential profit for the farmers.

### 9.1.2 Danleg

Barangay Danleg in Dumaran is located on the Palawan mainland. With approximately 300 households, there are about 30 full time farmers. Another 70 have changed from full-time farming to part-time as a subsidiary income source, due to the recent drop in price of seaweed. Alternative income is almost exclusively generated through fishing. Seaweed farming has a relatively long tradition dating back to 1981, when a cooperative had allegedly been founded, but it seems to be inactive. The only activity which could be identified by its members is the occasional distribution of new ropes whenever provided by BFAR. There are 2 buyers in Danleg that sell the seaweed to another trader in Roxas who consolidates volumes from other sites and ships to a third buyer in Puerto Princesa. From there, the RDS is shipped mainly to Cebu. Farmers have no access to information about current market prices hence they are totally reliant on their traders to pay them fairly, while the trader in Roxas might be the first one to be fully informed. Here too, it has to be assumed that this informational asymmetry leads to a decrease in profit for the farmers.

### 9.1.3 Calauag

Most of the households in Calauag, Taytay are involved in seaweed farming. In contrast to the other sites, many farmers are working as employees, paid on a fixed salary and a variable bonus depending on the success of a harvest. The reason that many farmers are not running their own farms is that farming areas have to be leased or bought. Prices per ha range between 50'000 and 160'000 PHP, depending on the potential of the farming area. The biggest owner of farming areas is also the main buyer of the other farmers, and barangay captain at the same time. Even though that seems unfortunate for the remaining farmers, they are currently getting paid 1 Php more per kg RDS than farmers in other barangays in Taytay. The overall organization of the farming setup and the planting and drying procedures seem to be better structured compared to other places visited.

### 9.1.4 Pamantulon

Barangay Pamantulon has been farming seaweed since 1980. 90% of its 420 households used to generate most their income from seaweeds. Since the price for RDS has decreased, many farmers have dropped out of the business and turned to agriculture instead. Nowadays, there are about 60 full time farmers left.

## 9.2 Synthesis: combined investment case for tissue culture lab and 5 farming sites in northern Palawan

In the scale-up plan, the findings from the model case of Green Island are extended to the other 4 eligible sites. These sites would be assumed to support another 120 farming units in total: Bohol 40 units, Danleg 30 units, Caluag 30 units and Pamantulon 20 units. The assumptions per farming unit and respective outputs are the same. Since the fixed costs of each cooperative would have to be allocated to revenues from smaller volumes, the performance of these sites might be slightly less efficient than the one on Green Island. On the other hand, the capacities built up in Green Island could be used to train the staff in the other 5 sites. The potential for increase in profitability is similar among all sites that were deemed eligible. Farming procedures are not optimal or adapted to maximize productivity, there are no drying racks or storage facility, there are suboptimal short-lived installations, and the community does not sell as a cooperative by consolidating volumes and optimizing the timing of sales, rather each farmer operates individually. The mechanisms for improvement are therefore similar to Green Island and can be addressed by 1) forming a cooperative, 2) training for better farming practices and 3) improving infrastructure, and 4) providing good quality seedlings. In summary, the combined EBIT projection (in terms of percentage) can be assumed the same as for Green Island, but the CAPEX, the production cost and the revenue is scaled up to the 220 farms instead of only 100 farm units (Fig. 30).

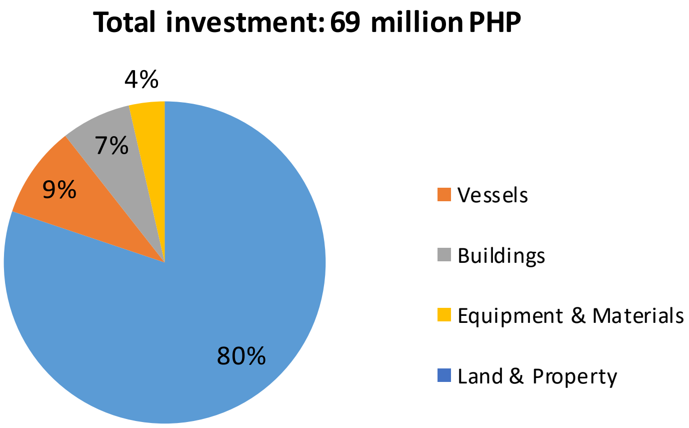


**Figure 29:** CAPEX breakdown for the 5 eligible farming sites combined (including Green Island).

The combined investment case thus comes to a CAPEX of 69 million PHP (Fig. 30), and the 5 communities together will generate a revenue of 109 million PHP with an EBIT of 29% after 5 years (Fig. 31), under the assumption that the cooperatives can sell the seaweed for 30 PHP/kg. The profitability of the farms is expected to be close to 10% after 5 years. The total revenue of the farm units represents the cost of goods of the cooperatives (70 million PHP/year). Of course, the EBIT of the cooperative belongs to its members, i.e. to the farmers also, and can be used for new investments or paid out to the members.

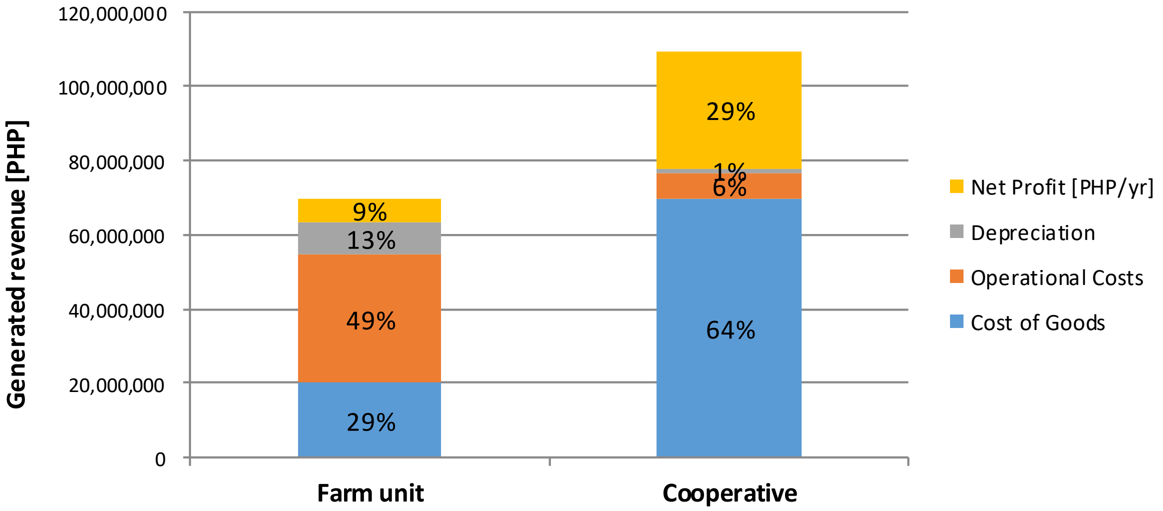


**Figure 30:** Revenue of farm units and cooperative combined for the 5 eligible farming communities including Green Island, after 5 years.

The tissue culture lab would thus have to provide all five communities with seedlings. Since the lab would produce about 3 million new plants per year, but the five sites require almost 6 million seedlings per year (Table 10), the lab would thus produce only half of the required amount. This means that the seedlings must be proliferated in the nurseries, i.e. each plant has to be cut in two at a size of e.g. 100g, and the two plants are grown again to a size above 100g.

| | Green Island | Bohol | Danleg | Calauag | Pamantulon | Total |
|---|---|---|---|---|---|---|
| **Farm units** | 100 | 40 | 30 | 30 | 20 | **220** |
| **# plant requirement** | 2'661'290 | 1'064'516 | 798'387 | 798'387 | 532'258 | **5'854'839** |
| **# seedlings provision** | 1'363'636 | 545'455 | 409'091 | 409'091 | 272'727 | **3'000'000** |

**Table 10:** Number of farm units per community, required and provided seedlings from the lab.

The lab will have to deliver the seedlings to farming sites on schedules that make sense logistically, given the geography of the participating farming communities (see Fig. 32).

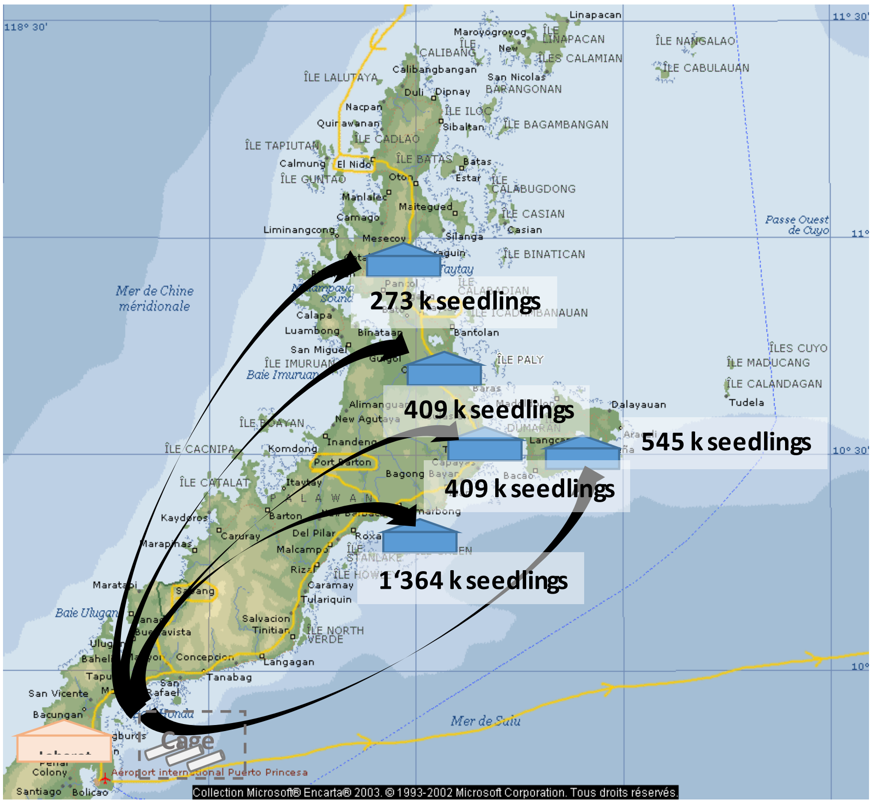


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**Figure 31:** Locations and seedling supply for scaled-up investment case.

# 10 Project implementation

The implementation of the project starts with the set-up of the cooperative. Once farmers have fully understood the terms and conditions of their participation they can join by signing a contract with the cooperative, which subsequently hands out the needed funds to establish the farming units. Farmers must be fully aware of conditions and consequences as they are receiving a loan that must be paid back.

## 10.1 Project Management

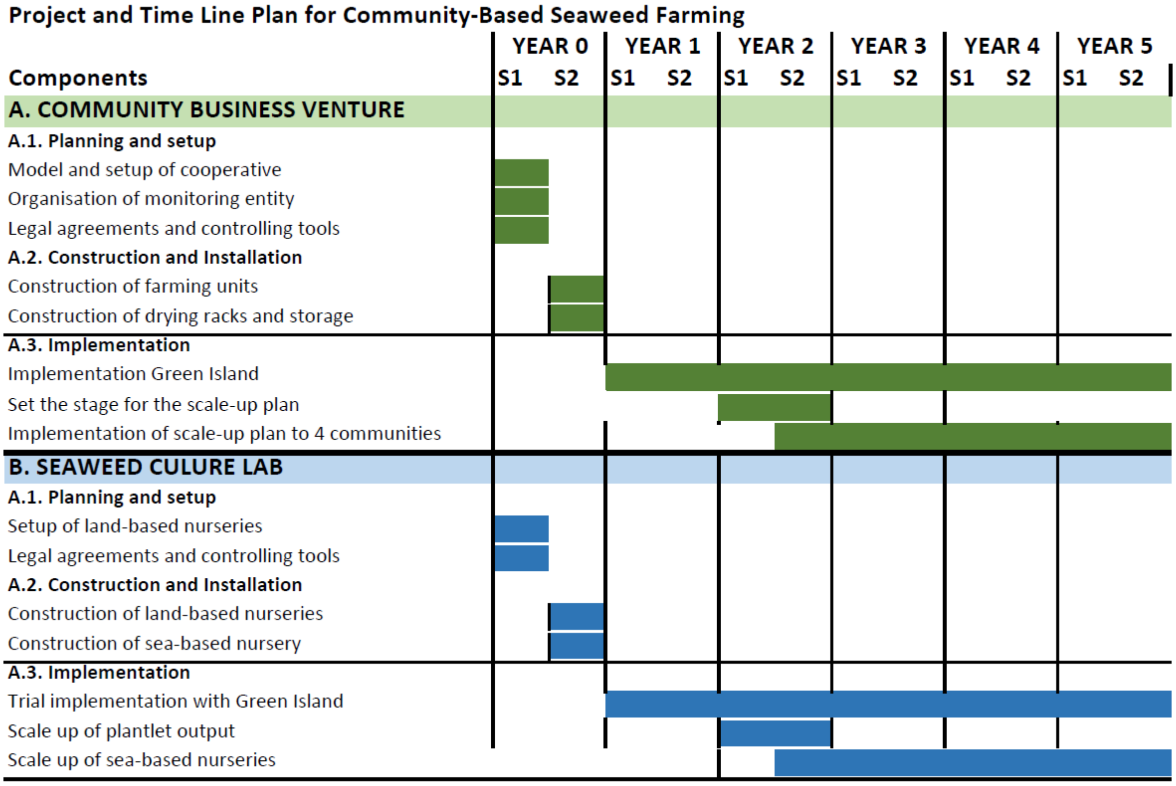
The community-based project should be managed by a carefully selected entity. This entity will be responsible for building up the cooperatives, setting the legal stage, work out contracts and defining all implementation procedures. The entity will need to provide the cooperatives with the necessary tools for data collection, controlling and financial accounting. This entity will be responsible for monitoring and supervision, such that the cooperative operates and produces seaweed according to the investment plan. The communities should be supported by experts in the first phases of implementation. Intensive training is needed on all aspects of management and farming to enable the participants to succeed with the business in the long-term. The entity would start with Green Island, but could then ideally handle the implementation in all other farming sites in the scale-up plan. Responsibility is then gradually transferred to the cooperative president/manager, until the cooperative operates independently according to the plan. The cooperative manager should be a well-integrated and well respected member of the community who fully understands and supports the planned business. He/she must ensure that negotiations with processors on the selling price of RDS are done appropriately.

The cooperative manager will for instance be responsible for setting up contracts for participating farmers who should be aware that the cooperative will sell the RDS for a higher price than they receive to pay back the loan, interest and the initial investment. The cooperative manager should also create a saving fund on behalf of the farmers for further investments and replacements of materials in the future (for the funds accumulated under depreciation).

For the management of the lab, another entity that is knowledgeable in the field of tissue culture should be selected. This entity is responsible for building up the lab, building up and training the lab team, and monitoring and supervising the implementation. Personnel running the nurseries in the farming sites should be trained on how to properly propagate seedlings. Responsibility is then gradually transferred to the lab manager, until the lab operates independently according to the plan. Training personnel is available from PSU-MSL as well as from SEAFDEC AQD at affordable costs.

## 10.2 Implementation procedure and timeline

Building these management structures and resources is projected to take 6 months. Once the stage is set, the lab can be set up and the cooperative can transfer loans to the farmers to set up the first 50 farm units. This implementation is projected to take 4-6 months (Year 0, Fig. 33). Hence, after one year, the seaweed production can start for the model case, in line with the first phase of the culture lab (at a scale of 5'000 plantlets per day). In the second year, the model case should be profitably running such that resources can be used to set the stage for the scale-up plan. Since this is ideally implemented by the same entity, it could now be done more efficiently. Possibly within 6 months, the agreements could be settled and the farms constructed such that at the end of Year 2 the scale-up plan would already be fully operational. The farm scale-up would be in line with the scale-up of the seaweed culture lab with output of 5'000 to 10'000 plantlets per day (Fig. 33).



**Project and Time Line Plan for Community-Based Seaweed Farming**

| | YEAR 0 | | YEAR 1 | | YEAR 2 | | YEAR 3 | | YEAR 4 | | YEAR 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Components** | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 |
| **A. COMMUNITY BUSINESS VENTURE** | | | | | | | | | | | | |
| **A.1. Planning and setup** | | | | | | | | | | | | |
| Model and setup of cooperative | 🟩 | | | | | | | | | | | |
| Organisation of monitoring entity | 🟩 | | | | | | | | | | | |
| Legal agreements and controlling tools | 🟩 | | | | | | | | | | | |
| **A.2. Construction and Installation** | | | | | | | | | | | | |
| Construction of farming units | | 🟩 | | | | | | | | | | |
| Construction of drying racks and storage | | 🟩 | | | | | | | | | | |
| **A.3. Implementation** | | | | | | | | | | | | |
| Implementation Green Island | | | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 |
| Set the stage for the scale-up plan | | | | | 🟩 | 🟩 | | | | | | |
| Implementation of scale-up plan to 4 communities | | | | | | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 |
| **B. SEAWEED CULURE LAB** | | | | | | | | | | | | |
| **A.1. Planning and setup** | | | | | | | | | | | | |
| Setup of land-based nurseries | 🟦 | | | | | | | | | | | |
| Legal agreements and controlling tools | 🟦 | | | | | | | | | | | |
| **A.2. Construction and Installation** | | | | | | | | | | | | |
| Construction of land-based nurseries | | 🟦 | | | | | | | | | | |
| Construction of sea-based nursery | | 🟦 | | | | | | | | | | |
| **A.3. Implementation** | | | | | | | | | | | | |
| Trial implementation with Green Island | | | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 |
| Scale up of plantlet output | | | | | 🟦 | 🟦 | | | | | | |
| Scale up of sea-based nurseries | | | | | | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 |

**Figure 32:** Timeline for implementation of integrated community-based seaweed farming and tissue culture lab.

# 11 Risks and mitigation

## 11.1 Competitor analysis

The vast majority of RDS is produced in family businesses. There is not yet any community in Palawan which has implemented a management structure of any kind to increase productivity and selling prices. The usual investment model in seaweed farming sees local investors who finance seaweed farms and share the profit with the farmer on a 50/50 basis. However, this cannot be seen as a serious competing model.

Philippine seaweed competes with the production of seaweed in Indonesia, which can be assumed lower cost. The RDS in Indonesia was recently at 6'000 – 7'000 IDR/kg (0.46-0.54 USD/kg). Compared to the current Philippines farm gate price of 25 PHP/kg (0.56 USD/kg) there is thus only a small difference, which would probably be balanced by the transportation cost, if a Philippine carrageenan producer buys seaweed from Indonesia. Furthermore, the perception of Philippine producers it that Philippine seaweed is of better quality than Indonesian seaweed. As a consequence, the risk that Philippine seaweed communities could not sell their seaweeds because the processor is already saturated with seaweed from Indonesia is relatively low. Most likely, the Philippine carrageenan producers mainly purchase seaweeds if the supply in the Philippines is scarce.

Even though the world market is demanding more and more carrageenan, prices for RDS in the Philippines have been steadily decreasing, mainly due to continuously increasing production in Indonesia. The selling price of RDS in this business plan has been assumed at an all-time low to be conservative, however it can't be known if prices will decrease further.

## 11.2 Social and environmental impact risks

The importance of a strong management structure within a cooperative has been described in detail. This requires the farmers to detach their business from their traders, which might be difficult for the farmers as they are often emotionally attached to their traders due to a family relationship or friendship. Farmers can feel indebted to traders as they often lend money in times of need e.g. when medical bills need to be paid or when small investments for their farms are needed.

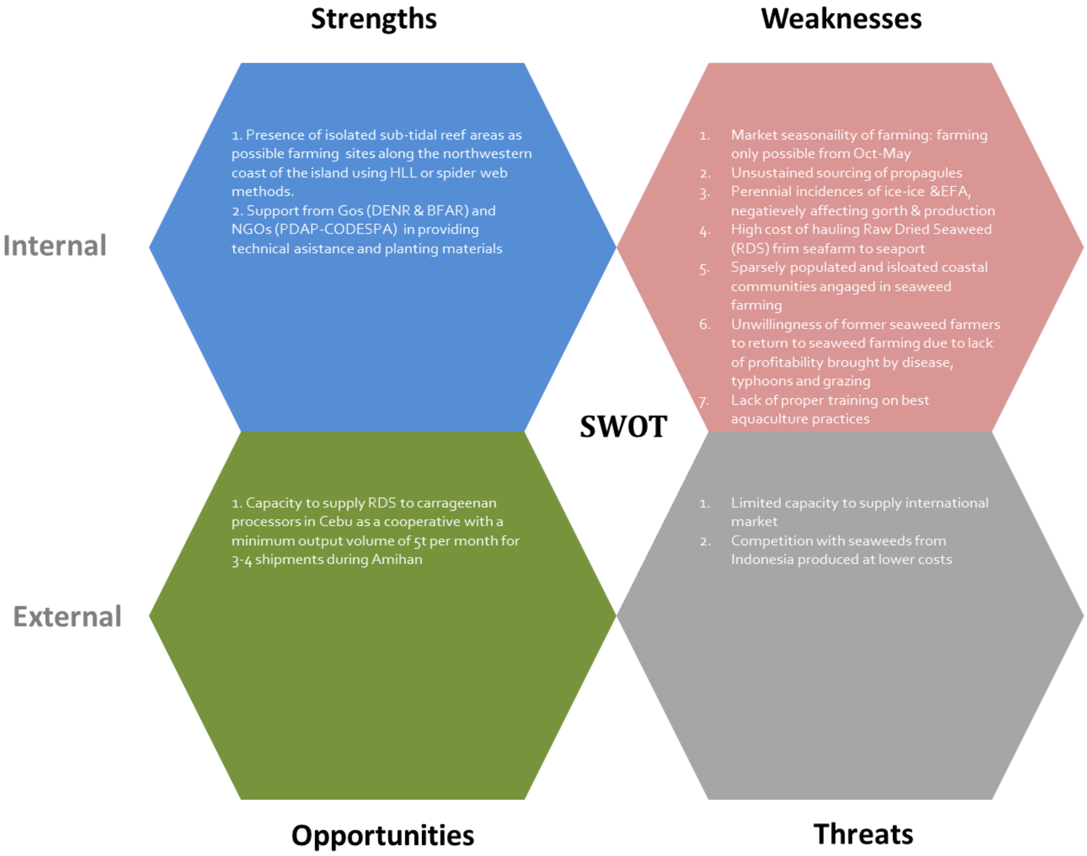
Another risk is susceptibility to diseases. In the past, some farming areas have experienced fatal losses due to ice-ice and other diseases. This risk can be mitigated by choosing the right farming site and method and buying good quality seedlings.

A major risk, as discussed earlier, is human capacity and capability. Farms were selected based on the criterion that the human capacity for seaweed farming is already present, i.e. there are people motivated to engage in seaweed farming, but their productivity is currently limited due to lack of organization, training, infrastructure, and the availability of good quality seedlings. The issue of human capability shall be covered by trainings, workshops and cross-visits to other successful farming areas.

Community members must understand the plan and its potential benefits and, second, they need to implement it. The right human capacities must be carefully selected from within the community to execute the tasks at hand. Furthermore, the farmers should collaborate and produce according to the investment plan by selling the seaweed to the cooperative at a price they might perceive as being low. In the long term, it should become obvious to all farmers that the advantages of operating as a cooperative outweigh the benefits of short-term flexibility of individual operations, but in the short-term there is a risk that farmers don't want to plan ahead or don't see the benefit of cooperation and flip back to their traditional buyers.

## 11.3 SWOT analysis

Green Island shows optimal conditions for a community-based investment. Since there is a motivated community adjacent to an optimal seaweed farming site, which is limited in funds to invest in improving the operation, it appears highly likely that the community could implement an investment plan.



**Strengths**

1. Presence of isolated sub-tidal reef areas as possible farming sites along the northwestern coast of the island using HLL or spider web methods.
2. Support from Gos (DENR & BFAR) and NGOs (PDAP-CODESPA) in providing technical asistance and planting materials

**Weaknesses**

1. Market seasonaility of farming: farming only possible from Oct-May
2. Unsustained sourcing of propagules
3. Perennial incidences of ice-ice &EFA, negatievely affecting gorth & production
4. High cost of hauling Raw Dried Seaweed (RDS) frim seafarm to seaport
5. Sparsely populated and isloated coastal communities angaged in seaweed farming
6. Unwillingness of former seaweed farmers to return to seaweed farming due to lack of profitability brought by disease, typhoons and grazing
7. Lack of proper training on best aquaculture practices

**Opportunities**

1. Capacity to supply RDS to carrageenan processors in Cebu as a cooperative with a minimum output volume of 5t per month for 3-4 shipments during Amihan

**Threats**

1. Limited capacity to supply international market
2. Competition with seaweeds from Indonesia produced at lower costs

**Figure 33:** SWOT analysis for impact investment in community-based seaweed farming in northern Palawan

## 11.4 Factors for success

Based on factors for success learned from other community-based aquaculture projects, the Green island site covers most conditions for successful impact investment (Table 11).

| | Principal | Rationale |
|---|---|---|
| 1 | Understand People's Needs and Visions | Long history of seaweed farming as source of livelihood. Farmers have challenges with farming efficiency and market access and are willing to improve these issues. |
| 2 | Communities' Capacities and Capabilities | Relatively large community (3'000 people with about 10-20% available for farming) adjacent to an optimal seaweed farming site. |
| 3 | Local Site Conditions | Optimal seaweed farming site with shallow water in open sea area with constant water movement, exceptionally mild climatic conditions, seaweed farming is also feasible during lean season. |
| 4 | Business case vs. Development project | Seaweed farming has been demonstrated as a profitable business, which could be further improved. |
| 5 | Proper Value Chain Analysis | Value chains are already in place and can easily be analysed for improvement. |
| 6 | Understanding Markets and Supply Chains | Supply Chain efficiency and market access are suboptimal and could be improved by providing infrastructure, training and a management structure. |
| 7 | Data Availability and Critical Verification | Data only available through interviews. |
| 8 | Realistic Assumptions for Planning | Technical assumptions based on experience of farmers. |
| 9 | Critical Risk Analysis | No imminent risks |
| 10 | Importance of Management and Organization | Management structures through cooperative feasible. |

**Table 11:** Success factors for community-based impact investment.

## 11.5 Risk & Mitigation

### 11.5.1 Farming community

The main risk for the farming operation is that practices and processes are note implemented according to the plan, for instance farmers don't adapt their practices as indicated to maximize productivity or don't stick to the cooperative model, selling all produce to the cooperative for the agreed price.

**Mitigation:** This risk can be mitigated mainly by awareness raising and good management, and furthermore, by creating adequate economic incentives. The cooperative must monitor to ensure that farmers return all their RDS to the cooperative. As the farmers will initially get a lower income/profit than just selling the RDS to a freelance trader, temptation might be high to sell the RDS to their old trader and cut the cooperative out. Hence, monitoring will be needed, regularly cross-checking the harvested amount of each farmer with the returned RDS to the cooperative. Strong management will be obtained only through training and empowerment. Furthermore, the cooperative should have the financial means at any time to buy the produced RDS from the farmers, thereby giving the economic incentive to collaborate with the cooperative. This capacity of the cooperative shall be mainly covered by the working capital.

### 11.5.2 Seaweed culture lab

The main risk of the seaweed culture lab is it ability to set up a capable team in due time to produce the output of seedlings necessary for the operation to be profitable (as indicated above, this should be about 10'000 plantlets per day for the assigned personnel). Hence, the main risk is a performance and profitability risk. It is projected that a capable team can be built up during 3 years, and already in the second year the operation would exceed the breakeven of generated costs and revenues. If this point cannot be exceeded because the team doesn't perform as it should, the lab is at risk of generating losses every year.

**Mitigation:** This risk should be mitigated by economic incentives for the laboratory workers, and by potential backup through governmental funding. The manager of the lab should therefore receive a competitive salary, enabling recruitment of a qualified person. Furthermore, there should be budget included in the plan to support the manager with external experts. To incentivize the lab workers to reach the required output, a bonus system should be considered in addition to their salary, i.e. a part of the EBIT should be used to pay the workers a bonus in case of good performance, relative to the projected outputs of seedlings per month or year.

Having a commercial seaweed culture lab is a key priority of local governments and public funding could be made available to support profitability of the operation, e.g. by paying part of the CAPEX costs. Public funding is, in a sense, already considered in this case as it is assumed that the existing facilities for a seaweed lab can be used for this purpose, without having to pay for leasing the facilities.

# 12 Annex

Financial Projection Green Island.xlsx
Financial Projection Seaweed Culture Lab.xlsx
Financial Projection Synthesis for 5 communities

# 13 References

Blankenhorn, S.U. 2007. Seaweed farming and artisanal fisheries in an Indonesian seagrass bed - Complementary or competitive usages? Univ. Bremen PhD Thesis.

FAO. 2016. FishStat (Database). FIGIS. Available from Accessed Aug 2015: http://www.fao.org/fishery/topic/18238/en.

Hurtado, A.Q. 2013. Social and economic dimensions of carrageenan seaweed farming in the Philippines. *In* Social and economic dimensions of carrageenan seaweed farming. *Edited by* D. Valderrama, J. Cai, N. Hishamunda, and N. Ridler. pp. 91–113. Available from http://www.fao.org/3/a-i3344e.pdf.

Hurtado, A.Q., and Biter, A.B. 2007. Plantlet regeneration of Kappaphycus alvarezii var. adik-adik by tissue culture. J. Appl. Phycol. 19: 783–786.

Hurtado, A.Q., Gerung, G.S., Yasir, S., and Critchley, A.T. 2013. Cultivation of tropical red seaweeds in the BIMP-EAGA region. J. Appl. Phycol.: 1–12. doi: 10.1007/s10811-013-0116-2.

Kumar, G.R.K., and Reddy, C.R.K. 2007. Callus induction and thallus regeneration from callus of phycocolloid yielding seaweeds from the Indian coast. J. Appl. Phycol. 19(August 2016): 15–25. doi: 10.1007/s10811-006-9104-0.

McHugh, D.J. 2003. A guide to the seaweed industry. FAO Fish. Tech. Pap. No. 441 FAO, Rome,: 105. Available from www.fao.org/3/a-y4765e.pdf.

Rorrer, G.L., and Cheney, D.P. 2004. Bioprocess engineering of cell and tissue cultures for marine seaweeds. Aquac. Eng. 32(August): 11–41. doi: 10.1016/j.aquaeng.2004.03.007.

Yarish, C., and Redmond, S. 2012. Gracilaria Culture Handbook for New England.

Yunque, D.A.T., Tibubos, K.R., Hurtado, A.Q., and Critchley, T.A. 2011. Optimization of culture conditions for tissue culture production of young plantlets of carrageenophyte Kappaphycus Optimization of culture conditions for tissue culture production of young plantlets of carrageenophyte Kappaphycus. J. Appl. Phycol. 23(August 2016): 433–438. doi: 10.1007/s10811-010-9594-7.

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