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Introduction

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Introduction

Zannie Langford

Seaweed seems to be the new 'super crop'. With land beset with so many competing uses, the idea of cultivating the ocean holds a lot of appeal. What if pressure could be taken off the land by producing crops in the sea, and these crops could be used for such varied uses as biofuels, carbon capture and food? Seaweed is increasingly promoted for a vast range of environmental benefits: to capture carbon, for methane-reducing cattle feed, as a sustainable food source, as a fertiliser and to replace non-renewable sources in the making of bioplastics and biofuels. It is a key component of many blue economy development programmes, and the development of oceans has been described by some as the 'blue revolution'. Yet seaweed farming is a relatively new endeavour globally. Despite the current enthusiasm for the seaweed industry, there is relatively little public understanding of it globally, how it looks today and how it is likely to develop in the future. This chapter introduces some 'seaweed fundamentals', providing a snapshot of the global industry. It situates the Indonesian seaweed industry within this broader global market and describes the approach and structure of the book.

A snapshot of the global seaweed industry

Seaweed farming is a relatively new phenomenon. Although domestication of land plants has been undertaken for thousands of years, there are only a few examples of successful domestication of seaweeds prior to the nineteenth century[1] – namely the cultivation of *Porphyra* in Japan (best known today for its use in making *nori* for sushi rolls). In 1950, the global seaweed industry was still very small, and mostly consisted of harvesting wild seaweeds (Figure I.1). Over the seventy years that followed, new cultivation methods and growing demand for seaweed products saw seaweed cultivation expand rapidly. By 2021, marine seaweed farming was a US$15 billion industry, with the Food and Agriculture Organisation of the United Nations (FAO) estimating that over 33 million tonnes (megatones (Mt)) are produced annually (FAO 2023).

Of the world's seaweed, 99 per cent is produced in Asia in just six countries: China, Indonesia, South Korea, the Philippines, North Korea and Japan. The industry is strikingly concentrated, with just six species accounting for 95 per cent of global production (FAO 2023). Three of these are food seaweeds – the well-known

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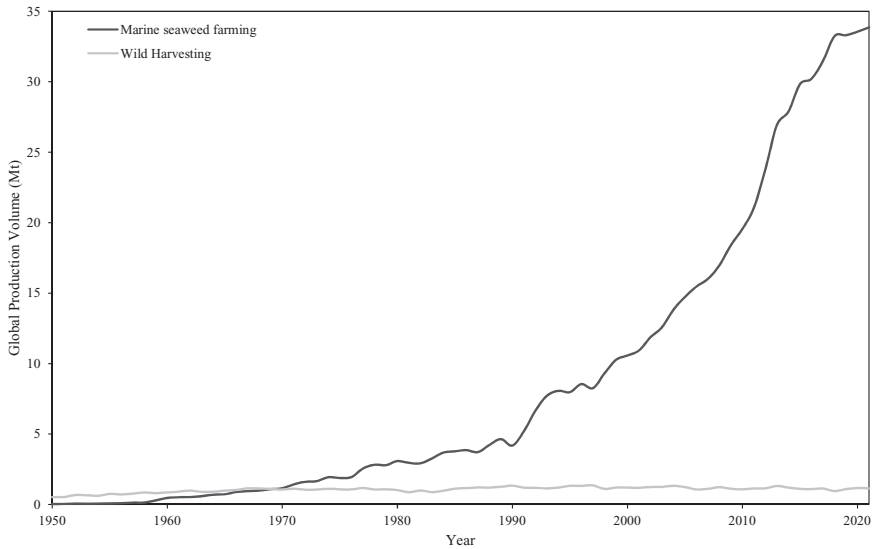

Figure I.1 Global seaweed production from farming and wild harvesting
Source: Data from FAO (2023).

varieties used to produce *nori* (used in sushi roles), *wakami* (used in seaweed salads) and *kombu*[2] (to flavour soups) (Table I.1).[3] These three food species represent the majority of global seaweed production and are produced almost exclusively in the temperate waters of China, Japan, South Korea and North Korea. The other three main commercial species are tropical seaweeds used to extract the hydrocolloids carrageenan and agar, and are produced mainly in Indonesia, the Philippines and China.

Perhaps surprisingly, many more widely known species of seaweeds are only produced in very small quantities. *Spirulina*, for example, represents only 0.2 per cent of the global industry (FAO 2023), and *Asparagopsis*, known for its applications in cattle feed to reduce methane emissions, is still exceedingly difficult to grow and process, and had its first commercial sale in 2022 (MLA 2022). China dominates production of all major seaweeds except the carrageenan seaweeds, of which the majority are produced in Indonesia and the Philippines. These carrageenan seaweeds have contributed an increasing proportion of global seaweed production over the last twenty years, and now represent 26 per cent of the world's seaweed industry by volume (Figure I.2).

Ninety-two per cent of the global production of the carrageenan seaweed species *Eucheuma* and *Kappaphycus* occurs in Indonesia and the Philippines, which contribute 81 per cent and 15 per cent of global supply respectively (Figure I.3).[4] Other carrageenan seaweed producers include Malaysia (2 per cent of global production), Tanzania (including Zanzibar) (1 per cent of global production), the Solomon Islands, Madagascar, China, Venezuela, Papua New Guinea, Brazil, Cambodia, Kenya, Timor-Leste, Viet Nam and a few other countries producing less than 200

Table I.1 Intensively cultivated commercial seaweeds

Use	*Species*	*Main products*	*Proportion of global market*	*Main producers and proportion of global production (2021)*
Food	*Saccharina japonica*	Kombu	39%	China (90%) South Korea (5%) North Korea (5%)
	Undaria pinnatifida	Wakame	8%	China (77%) South Korea (21%) Japan (2%)
	Porphyra spp.	Nori	8%	China (71%) South Korea (20%) Japan (9%)
Hydrocolloid	*Eucheuma* spp. *Kappaphycus* spp.	Carrageenan	26%	Indonesia (81%) Philippines (15%)
	Gracilaria spp.	Agar	14%	China (85%) Indonesia (15%)
–	All other species	–	5%	–

Source: Data from FAO (2023).

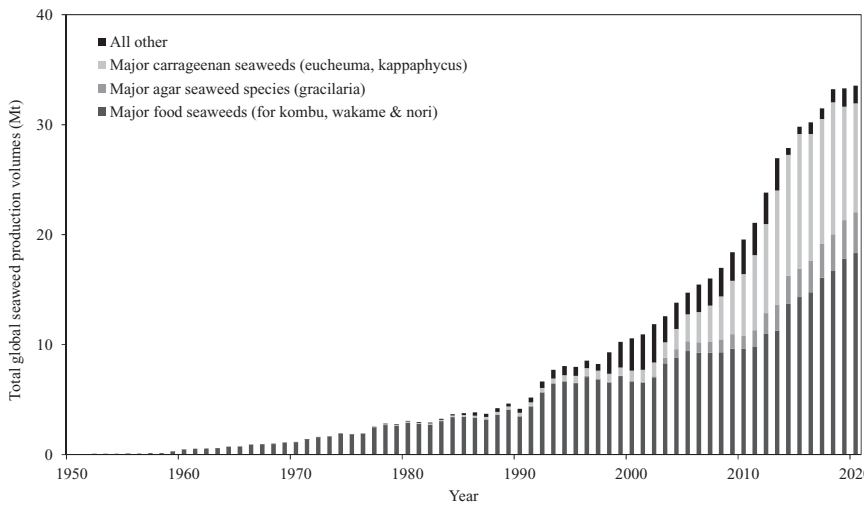

Figure I.2 Global marine seaweed production by end use

Source: Data from FAO (2023).

tonnes per year. The dominance of Indonesia, the Philippines, Malaysia and Tanzania is linked in part to their ability to compete on price as a result of exchange rate dynamics. Each of these countries have purchasing power parity (PPP) significantly lower than their exchange rates, meaning that farmers in these countries can buy more with income earned on global markets. In exchange for a kilogram of seaweed

purchased for a world market price of US$2, a farmer in Indonesia can buy goods worth US$6.03, a farmer in the Philippines goods worth US$5.14, a farmer in Malaysia goods worth US$5.20 and a farmer in Tanzania goods worth US$5.16. This is in contrast with other countries – for example, farmers in Papua New Guinea can purchase goods worth only US$3.02 with income earned from the same quantity of seaweed, and farmers in the Solomon Islands goods worth only US$2.30 (World Bank 2023). This means that seaweed prices may not be high enough to incentivise widespread uptake of the product in areas with lower exchange rate to PPP ratios, although this may change if prices rise over the long term.

In Indonesia, seaweed was reported to be a US$2 billion industry in 2021 (FAO 2023). This income is derived mostly from carrageenan seaweeds (79 per cent of national production value), as well as the agar producing species *Gracilaria* (19 per cent of national production value), small amounts of *Sargassum* and small volumes of *Caulerpa* (sea grapes), which are sold for consumption in salads in local markets. Between the years 2000 and 2015, Indonesian carrageenan seaweed production grew from 0.2 to 10.1Mt, before declining again to 7.1Mt in 2021. Despite the recent decline in production, it supports the livelihoods of around 62,000 coastal households (BPS 2022 and see Appendix 1 for a detailed discussion of statistical issues in the seaweed industry). As a result of the importance of seaweed farming to coastal livelihoods, the Government of Indonesia has outlined ambitious plans to further increase seaweed production (Presidential Decree 33–2019), particularly in the Eastern Indonesian provinces of West Papua, Maluku and North Maluku (Figure I.4).[5]

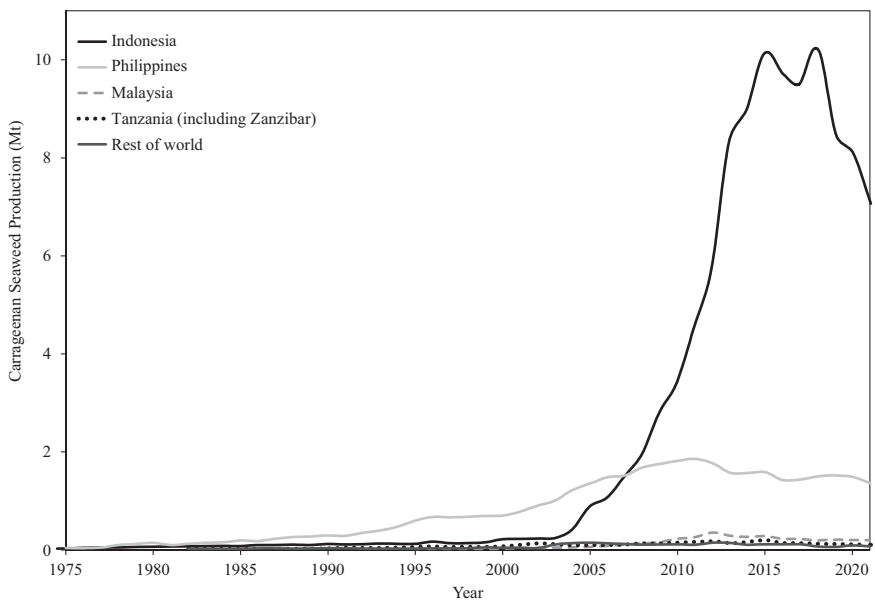

Figure I.3 Global carrageenan seaweed production

Source: Data from FAO (2023).

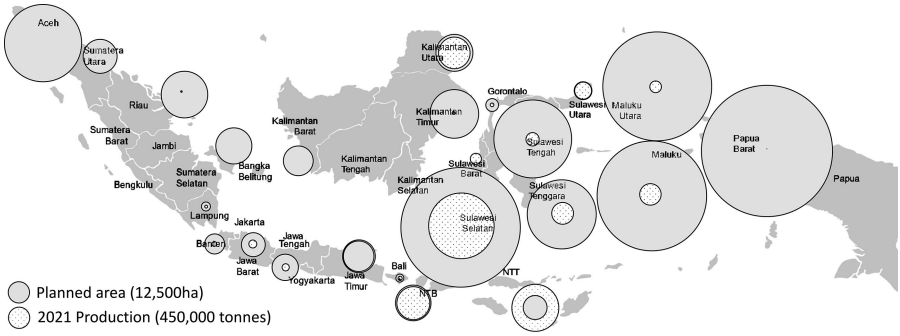

Figure I.4 Current and planned seaweed production in Indonesia

Source: Data from Presidential Decree 33–2019 and FAO (2023).

With such rapid expansion, coastal communities across the country have experienced dramatic changes in the last two decades. Carrageenan seaweeds, although relatively low value, are incredibly shelf-stable – after being harvested, they are sun dried, and when dried properly can be stored for many months before being sold. This makes these seaweeds suitable for cultivation in remote areas, including by farmers who may only have sporadic access to markets. As a result, carrageenan seaweed production has been widely taken up in Indonesia, even in remote areas. Indonesia produces these seaweeds relatively cheaply, and the cost-competitiveness of Indonesian farmers also affects its market share.

Many coastal fishermen and farmers have transitioned their livelihood strategy partially or completely into seaweed farming, and as a result have been able to build more elaborate houses, send their children to school and purchase cars and motorbikes (Langford, Turupadang, Oedjoe et al. 2022; Langford, Waldron, Nuryartono et al. 2023). In other areas, communities experienced a seaweed farming 'boom' followed by a 'bust' resulting from environmental collapse (Steenbergen et al. 2017). The farming of carrageenan seaweed is accompanied by a wide range of social, economic and environmental changes, and systems of livelihoods and community governance have had to change to accommodate this new form of cultivation. However, these livelihoods do not have a certain future: the carrageenan seaweed industry is based on consumer acceptance of the food additive carrageenan, and demand for foods with the properties that carrageenan can impart. Understanding the future of the carrageenan seaweed industry, and how the livelihoods of the farmers who depend on it may be supported, relies on an understanding of the full value chain: from global industry to local activity.

Carrageenan value chains: from global to local

Descriptive studies of how global value chains are grounded in local places can reveal important insights into how social lives are reorganised around new products (see, e.g., Dixon 2002; Tsing 2015; Weiss et al. 2016; West 2012). Such studies all

examine how a raw project is transformed through a value chain to reach the consumer. However, in most cases, the final project is easily recognisable to the consumer. This visibility enables a level of transparency in the supply chain, supporting consumers to develop certain preferences about the types of goods they consume based on a range of criteria. These criteria may include perceptible attributes such as taste, colour and texture, as well as invisible characteristics (of products known as 'credence goods') which are not immediately visible, such as being produced according to certain environmental standards (e.g. organic, rainforest alliance certified, biodynamic, sustainably grown, carbon neutral), social standards (e.g. fair-trade, free-range, humane) and safety and quality standards (e.g. BEIC 2023; FSSC 2023). The supply chains for some goods are relatively short and methods for tracking these criteria have been developed – for example, it is possible to buy free-range chicken, grass-fed beef and fair-trade coffee. In each of these cases, it is fairly clear what the product is, and there is some understanding of what production criteria are being met. Carrageenan seaweed is quite different from these products as most people do not realise that they are consuming it. Carrageenan appears on ingredient listings as E407 and E407a in Europe and is found in a wide range of products, but consumers are often not aware they are consuming these products, and as such there is very little transmission of consumer preferences.

Carrageenan is a particular type of food additive known as a hydrocolloid: *hydro-* meaning water, and *colloid* meaning a dispersion of one substance in another substance – such as a gel or emulsion. A *hydrocolloid* is therefore a substance which, when combined with water, acts as a thickener, gelling agent or stabiliser. Hydrocolloids have long been used in processed foods and are not limited to carrageenan – other common hydrocolloids include gelatin, pectin, guar gum, cellulose gum, xanthum gum, arabic gum, agar, alginate and locust bean gum (Table I.2). These additives each have different properties which mean they can give foods different textures.

The most common hydrocolloids are guar gum (made from guar beans), gelatin (produced mainly from cows and pigs), xanthum gum (produced by fermenting sugars from crops such as wheat, corn and soy), cellulose gum (often produced from wood pulp or cotton seeds) and arabic gum (produced from acacia trees). These five hydrocolloids together make up 89 per cent of the global hydrocolloid market. Carrageenan makes up approximately 3 per cent of the hydrocolloid market by volume and 8 per cent by value, and in 2022 the market was worth an estimated US$872 million (Grand View Research 2023a). Carrageenan is particularly widely used in the meat and dairy industries, and as a substitute for gelatin in vegetarian and vegan foods. Because of its specific gelling properties it has been growing in popularity, projected to become a US$1.3 billion dollar market by 2030 (Grand View Research 2023b). Carrageenan is used mostly in the meat and dairy industries, but also in water gels (such as jellies, confectionary and shelf-stable desserts), toothpaste, beer and petfood (Campbell and Hotchkiss 2017). It is often used in blends with other gelling agents to achieve precise textures in processed foods (Blakemore and Harpell 2009; Thomas 1997).

Table I.2 Common hydrocolloids

	Common sources	*~Market share (by volume)*
Guar gum	Guar beans	21%
Gelatin	Animal collagen, mainly from cows and pigs	20%
Xanthum gum	Fermentation of sugars (e.g. from wheat, corn, soy)	19%
Cellulose gum	Wood pulp, cotton seeds	17%
Arabic gum	Acacia trees	12%
Pectin	Citrus fruit peels, apples	6%
Carrageenan	Various seaweeds, primarily *Eucheuma* and *Kappaphycus* species	3%
Alginates	Various brown seaweeds	2%
Locust bean	Carob tree seeds	1%
Agar	Various seaweeds, primarily *Gracilaria* species	1%

Source: Data from Grand View Research (2023a)

The demand for carrageenan is linked to demand for hydrocolloids in general (e.g., with long-term trends such as increasing global consumption of processed foods) as well as relative demand for carrageenan over competing hydrocolloids. The demand for certain types of hydrocolloids over others is linked to both the properties of specific hydrocolloids and the demand for the products in which they are used. For example, part of the growth of the carrageenan industry is attributable to the growing demand for vegetarian and vegan foods, for which animal-derived gelatin is not suitable. It is also linked to consumer taste and texture preferences, since different hydrocolloids give foods different textures– for example, carrageenan is able to mimic a 'fatty' texture which many consumers enjoy and as a result is widely used in meat and dairy products, and, as such, growing demand for meat and dairy products could be expected to bolster demand for carrageenan.

The demand for carrageenan is also linked to consumer preferences against certain products. In 2016, the US National Organics Standards Board voted to recommend that carrageenan be removed from the United States Department of Agriculture (USDA) list of organic food additives, as a result of public concern over potential health impacts (NOSB 2016). In the months that followed, Indonesian seaweed farmer and industry groups advocated against this recommendation, on the grounds that it could significantly affect the industry (Mudassir 2018; Dwijayanto 2018). This recommendation was ultimately not adopted because there are limited other options to carrageenan to provide necessary functions in processed foods, and there is a dearth of scientific evidence supporting claims of negative health impacts (USDA 2018). However, if carrageenan were to be rejected by consumers on a large scale, this could have a reverberating effect on the carrageenan seaweed value chains and the villages that grow it. Notably, the scale of this effect would depend on how widespread consumer preferences are: a rejection from consumers in the United States, for example, would have impacts that would be contained if these preferences did not extend to consumers in Asia. Chapter 1 explores these dynamics further.

The development of the carrageenan industry has involved significant amounts of 'work' at all levels of the value chain – to establish the physical possibility of seaweed farming, to develop methods for processing it cheaply in large quantities, developing products which use it and maintaining its social acceptability in processed foods. Of particular interest to this book are the thousands of Indonesian farmers who produce it – who have reorganised their social and economic lives around this new commodity, and who depend on the industry for their livelihoods. This book is organised in two parts. Part I traces the carrageenan value chain from the global to the local level. Part II examines the village-level transformations which have taken place to enable the large-scale production of this commodity. The next section describes the methodological approach taken.

Background and methods

This research was undertaken as part of a research programme known as the 'Partnership for Australia Indonesia Research' (PAIR), funded by the Australian Government Department of Foreign Affairs and Trade (DFAT) via the Australia-Indonesia Centre (AIC). The programme ran from 2019 to 2023 and brought together researchers from four Australian and seven Indonesian universities, as well as industry and government stakeholders including the Indonesian Ministry of Research and Technology (RISTEK-BRIN) and the South Sulawesi Provincial Government (see PAIR 2023). The research was divided into four streams: this book draws on research conducted by the 'commodities' research team through a series of interrelated packages of work drawing on a range of different types of data (for published reports on these projects see Abdul Aziz et al. 2023; Cozzolini et al. 2023; Hovey et al. 2023; Komarek et al. 2023; Langford et al. 2021; Langford, Turupadang et al. 2022; Langford Zhang et al. 2022; Langford , Waldron et al. 2023; Langford, Turupadang and Waldron 2023b; Langford et al. 2024; Permani et al. 2023; Stone et al. 2023; Waldron et al. 2022; Zhang et al. 2023). This book is structured as an edited monograph to facilitate contributions from a large cohort of contributors to the research programme.

The PAIR programme was established with the support of the South Sulawesi governor and takes this province as its primary location of research. South Sulawesi is the largest seaweed producing province in Indonesia. It is home to the major port of Makassar, which has recently been redeveloped to support much greater volumes of trade and direct export to international locations. Within South Sulawesi, the regencies of *Maros*, *Baru* and *Pangkajene dan Kepulauan* (hereafter 'Pangkep') were identified as priority areas for the programme of research. The commodities group was tasked with investigating seaweed production in this region and focused research on the regency of Pangkep due to the large number of seaweed farmers in this area. In this regency, the village of Pitu Sunggu (Figure I.6) was selected as the case study location following a survey of the seaweed production characteristics of villages in mainland Pangkep (see Langford, Waldron, Nuryartono et al. 2023 for full details). A second site was identified for comparison – the village of Laikang in Takalar Regency, an established seaweed growing region which produces the

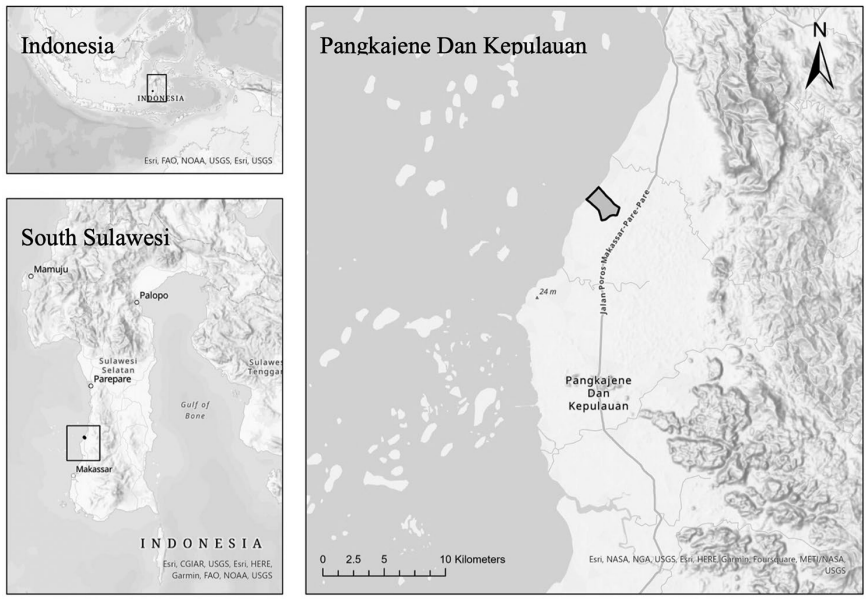

Figure I.5 Location of Pitu Sunggu village within Indonesia

Source: Map created by Alexandra Langford using ARCGis Pro.

largest quantities of seaweed in South Sulawesi. This site was chosen to facilitate comparisons with the less substantial seaweed cultivation site of Pitu Sunggu.

This book draws primarily on research collected through the main project associated with this programme of research (see Langford, Waldron, Nuryartono et al. 2023), with methods including a structured household survey, 215 semi-structured interviews and 16 months each of ethnographic research by four field researchers. The book also draws on research undertaken through three shorter projects on policy (see Permani et al. 2023), value chain margins (see Komarek et al. 2023) and on farmer resilience in NTT (see Langford, Waldron et al. 2022; Langford, Turupadang, and Waldron 2023). Full details of the methodological approach and findings of these projects can be found in the published reports from these projects, and are summarised in Table I.3.

This approach to long-term, in-depth, qualitative social research offers a few key methodological advantages:

1. Long-term social research produces a holistic understanding of seaweed farmer livelihoods

   Much social research with seaweed farmers is based on short periods of fieldwork, and as such relies on farmers' reports of their motivations, perceptions and goals. These reports are snapshots in time and vary considerably as the circumstances change. Our research has the benefit of providing a more long-term view of the livelihoods of seaweed farmers over the course of more

Table I.3 Research methods

Project component	*Details*	*Timeline*
Pilot project	Desktop research providing a baseline understanding of the industry (see Nuryartono et al. 2020 for results).	July–December 2020
Village survey	Survey of village characteristics in coastal villages of Pangkep, and assessment of community willingness to participate in the research (internal reports on each region produced).	August 2021
Structured household survey	Extended structured survey of 273 seaweed farming households in Pitu Sunggu and Laikang (see Langford et al. 2024 for method and results).	October–December 2021
Ethnographic research	16 months of ethnographic research by four of the contributors to this book, two based in each village (R. Ruhon and Z. Z. Wulyandra in Pitu Sunggu, R.A. Armis and I. Lapong in Laikang). They observed and participated in the daily life of seaweed farming communities and recorded their observations in detailed fieldnotes.	August 2021–December 2022
Semi-structured interviews	215 semi-structured interviews (in Pitu Sunggu (n = 89), Laikang (n = 82) and NTT (n = 44)), with seaweed farmers, village residents and local government workers. Interviews were undertaken in either Indonesian or local language according to interviewee preference, were transcribed in Indonesian and analysed thematically.	January–December 2022
Satellite imagery analysis	Satellite imagery for Pitu Sunggu in 2022 was analysed manually (see Langford et al. 2021 for method).	January–December 2022
Industry personal communications	Extended personal communications with industry stakeholders including collection of information on seaweed sourcing and processing.	January 2021–June 2023
Policy document analysis and interviews with government officials	A comprehensive investigation into 67 policy documents sourced from both desktop research and interviews with key informants (see Permani et al. 2023 for full methods).	April–October 2022
Value chain analysis	34 face-to-face interviews with actors in the value chain, including 5 seedling suppliers, 15 farmers, 12 traders (including 10 village traders, 1 Takalar-level trader and 1 Makassar-based exporter) and 2 processors (see Komarek et al. 2023 for full method). Data from these interviews was assessed using descriptive statistics.	June–August 2022

than a year, which allowed observation of changing seasons, as well as farmers' responses to weather and price events, and variations through different cultural and religious periods. This allowed us to observe the variations in livelihoods that occurs over time – through the wet season of high waves and frequent occurrence of diseases, the transition season in which one by one, farmers stopped

cultivating one species and started cultivating another, through the dry season in which high water temperatures led to outbreaks of epiphytes and poor growth of seaweed and then back to the wet season, when farmers again moved their plots to adjust to the changing weather. This long-term observation meant that field researchers gained a detailed understanding of seaweed farming livelihoods and the strategies that seaweed farmers employ to produce seaweed year-round, despite drastically changing oceanic conditions. It also means that we gained a greater understanding of how seaweed production techniques changed throughout the year, and the interconnected ways that biophysical, social and economic phenomena affect farmer decision-making.

2. Grounded in the technicalities of seaweed production

   All four of the field researchers hold qualifications in marine sciences, and as such are attentive to the technical details of seaweed production, including the characteristics of the species being grown, the diseases and epiphytes farmers experience, the differences in productive strategies they employ (such as farm plot locations, planting spacings, seedling sizes, yields). This has allowed them to critically engage with farmers' choices in order to understand how social factors – such as the management of sea space – lead to different production choices (such as rope spacing) and generate different results (such as more intensive use of labour and lower yields by newer entrants to the industry). These insights are invaluable in understanding the factors which contribute to different experiences of seaweed farming livelihoods. Our multi-disciplinary approach allows a more holistic analysis of the interactions between social, economic and environmental dynamics in the villages. The focus on seaweed farmers, rather than more generally on livelihoods, allows a targeted analysis of how this crop is experienced by the people who grow it.

3. Triangulation of multiple perspectives

   By undertaking research with not only farmers, but also the people they sell to (local traders), the people they employ (seaweed binders, who tie seaweed propagules to ropes) and professionals involved in seaweed industry governance (such as village and provincial government professionals), this study is able to contribute a balanced understanding of the roles of different village actors in the Indonesian seaweed industry. Personal communications were undertaken with a range of industry actors to gain greater insights into the structure of the industry, and focus groups in conjunction with government provided insights into challenges and priorities in the governance of the industry. This provides an in-depth understanding of the various actors involved in negotiating the structure of the Indonesian seaweed industry.

Translations and use of gendered language

All quotes are translations by the authors from either Indonesian or the local language of the respondent (Makasarese or Buginese). We have endeavoured to reflect the style of speech, emphasis and meaning of the speaker in these translations. In the quotes and discussion of the book, where gendered language reflects the

gendered nature of work involved, this language is used in the translations – for example, all crab netters in Pitu Sunggu are men, so when respondents describe the activities of certain men in crab netting, gendered language is used in the translations. In the chapter exploring the work of local traders, which includes male and female participants, gendered language is avoided to protect the anonymity of the traders involved. Where names of farmers are used, these are pseudonyms.

Notes on statistics

Indonesian seaweed data is reported by a range of agencies (including the Ministry of Marine Affairs and Fisheries, the Central Bureau of Statistics and the Ministry of Industry) for several production indicators (production volume, export volume, processing volumes, area under production, number of households engaged in production, and number of farmers engaged in production). Attempts to reconcile data from these different sources demonstrate that they rely on very different assumptions and therefore generate vastly different estimates of the size of the seaweed industry. Appendix 1 provides a full outline of data produced by different sources that was consulted in the process of researching this book and demonstrates the inconsistencies between them.

This chapter has outlined the features of the global seaweed industry using FAO data. For Indonesia, we have suggested that these are probably overestimated by around 4.8x (see Appendix 1). Indonesia is not the only country to inaccurately report seaweed production statistics to the FAO. Hatch (2023a; 2023b) recently compared industry and production estimates for major seaweed reporting countries and found that data reported by China, Indonesia, the Philippines, and Malaysia were inconsistent.[6] They estimated that in 2021, Indonesian carrageenan seaweed production statistics were overestimated by 5.1x, Philippines carrageenan seaweed production statistics by 2.6x and Malaysian seaweed production statistics by 6 times. Unfortunately, they did not estimate the overestimation of Chinese seaweed production. This makes it difficult to reconcile inaccuracies across countries. As such, FAO statistics are used in this chapter despite known inaccuracies, because they highlight the dominance of Indonesia and the Philippines in the carrageenan seaweed industry. Their dominance is so great that even if they were revised down using the overestimation factors provided by Hatch, they would still represent 92 per cent of the global carrageenan industry. As such, the figures provided in this chapter provide a realistic insight into the concentration of carrageenan seaweed production in these two countries. For the remainder of the book, data is used selectively as follows.

Chapter 2 relies only on *Badan Pusat Statistik* (BPS) (Central Bureau of Statistics, Indonesia) (2022) survey data, which as Appendix 1 describes, is realistic. Chapter 3 examines the South Sulawesi seaweed industry and therefore uses data from the South Sulawesi Ministry of Marine Affairs and Fisheries (*Kementerian Kelautan dan Perikanan* (KKP)), reminding the reader that of this data, household participation data is likely to be realistic, while production volumes and cultivation areas are not (but still demonstrate the geographic distribution of production around the province). Part II of the book focuses mainly on village-level livelihoods and uses BPS (2022) survey data to contextualise these where appropriate.

Structure of the book

This book is structured in two parts. Part I provides an overview of the development of the global value chains that have emerged to drive the global carrageenan seaweed industry, while Part II explores the negotiation of these changes at the village level. Readers primarily interested in the global dynamics of carrageenan use and production are advised to start with Part I. Readers who would like to focus more particularly on the village-level changes driven by the industry are advised to read Part II.

Part I: The global carrageenan seaweed value chain

The first part of the book telescopes down from the global to the provincial level to explore how global carrageenan seaweed value chains are organised at different scales.

Chapter 1: The global carrageenan market

Chapter 1 explores the long-term drivers of carrageenan demand, production and trade at the international level, demonstrating how the industry has been transformed by decades of sustained growth and development, and the dominance of Indonesia, China and the Philippines within it.

Chapter 2: The Indonesian seaweed industry

Given the global context and trade patterns outlined in Chapter 1, this chapter examines developments in the Indonesian seaweed industry at the national level. It provides industry-wide context, examines the sectors of production, marketing and processing and then describes some of the cross-cutting issues in zoning, investment, product development and food safety.

Chapter 3: The South Sulawesi seaweed industry

Chapter 2 explored how Indonesia has worked to support the development of the seaweed industry through investments in production, marketing, processing and research nationally. This chapter looks in more detail at the provincial level, focusing on South Sulawesi Province, outlining key features of the South Sulawesi seaweed industry, including production, trade, processing and export.

Part II: Livelihood transformations

The second part of the book focuses on one seaweed farming village: Pitu Sunggu, in South Sulawesi, Indonesia, and explores in detail the environmental, social and economic transformations which have taken place to enable the production of this commodity, beginning in the sea, where the seaweed is grown, and moving up to examine changes in social and economic organisation resulting from the industry and systems for marketing the product to the traders and processors who use it.

Chapter 4: Export commodity frontiers and the transformation of village life

This chapter explores the local transformations that have occurred in Pitu Sunggu village to accommodate the introduction of new commodities over the last century. It describes a series of livelihood transformations which have taken place – from field rice to wet rice, from wet rice to fish and shrimp farming, and from marine fishing to seaweed farming, and how this history of change has shaped the structure of the seaweed industry in Pitu Sunggu today.

Chapter 5: From communal access to private ownership: Negotiating access to the sea

Rights to the sea in South Sulawesi are widely communal and non-exclusive: anyone may make their living from the sea, and in Pitu Sunggu this has traditionally involved fishing and catching crabs. Yet to farm seaweed, a person must be able to claim exclusive rights to an area of the sea, prevent others from using it and ensure the exclusive right to harvest the seaweed when it is grown. This chapter explores how village members have negotiated these transitions, in just two decades transforming the sea from a communal resource to individual ownership of plots which may be bought, sold and rented.

Chapter 6: Environmental and socio-economic constraints to seaweed farming and Chapter 7: Farmer decision-making in the Indonesian seaweed industry

Having established the right to sea space in which to farm seaweed, the next challenge is to grow the seaweed. These chapters examine the environmental and biophysical challenges of seaweed farming that farmers have had to solve to make seaweed driven livelihood transformations happen. Growing at often unpredictable rates throughout the year as the ocean salinity changes with the tropical monsoon, and frequently dying and turning white and clear like ice, this is a crop that has often defied attempts to control and promote its growth. These chapters explore how rapidly changing ocean conditions affect seaweed growth, and how farmers make decisions within environmental, economic and social constraints.

Chapter 8: Gendered work and casual labour in the Indonesian seaweed industry

Growing seaweed is not just about production being physically possible: to be produced in large quantities over the long term, seaweed households must also reorganise their labour and relations in order to enable the work required to take place. This chapter explores how a range of people, including seaweed farmers, but also women and children in and outside of seaweed farming households, and casual labourers from neighbouring villages, have come to be incorporated in the seaweed industry, and how their work is integral to the industry.

Chapter 9: Seaweed marketing: village-based traders as financial and market intermediaries

The production of seaweed depends on the ability to sell it in the marketplace. For carrageenan seaweeds the final buyers in Indonesia are processors and exporters.

However, farmers do not sell to these entities directly, but through several layers of middlemen. This chapter explores the work of traders who have established operations in the village to connect farmers with global markets. It explores their work buying, packaging and transporting seaweed, and the tactics they employ to capture supply from farmers, including providing a range of financial and retail services. These key intermediaries finally provide the last connection of the village to the wider industry, bringing the seaweed into the global value chains described in Part I.

Chapter 10: Conclusion

This chapter reflects on the industry as presented through the chapters of this book. This is a study of a product and a crop not well known to consumers – an ingredient which reaches households through many layers of processing and blending to appear towards the end of ingredient listings as an unassuming code, with no clear connection to the coastal households across tropical Southeast Asia who produced it. This book shows how global trends, such as in food manufacturing, are transmitted through value chains to meso and local levels, and how changes in local dynamics form part of feedback loops which in turn create changes through the value chain. It has important practical implications in understanding Indonesian efforts to 'upgrade' these value chains. It also highlights that paths of translation are not frictionless, but negotiated by a range of actors operating at different scales and with different goals. This chapter analyses the key findings from the book, provides policy recommendations and suggests areas for further research.

Through this approach, Part I of this book first traces the contours of the global carrageenan seaweed industry, from global trade and consumption of carrageenan to the development of the Indonesian carrageenan seaweed production and processing industries, to the provincial dynamics of the South Sulawesi seaweed industry and the position of the region of Pangkep, and the village of Pitu Sunggu, within it. Part II explores the day-to-day work of seaweed production in Pitu Sunggu, how it has reshaped village livelihoods and use of the sea, how farmers have developed strategies to minimise risk and increase production, how casual wage labourers, women, children and people with disabilities have been incorporated into the industry and how all these activities respond to price signals transmitted by local traders via regional warehouses. This book seeks to demonstrate the interrelatedness of environmental, social and economic dynamics on seaweed production, and also argues for key policy interventions to support the sustainable development of the industry in the face of climate change.

Notes

1 Domestication involves control of the reproductive cycle, as opposed to merely propagating from cuttings (Wikfors and Ohno 2001).
2 *Saccharina japonica* is used to produce *kombu*, but also to produce a type of hydrocolloid known as alginate. While estimates of the scale of production of *Saccharina japonica* derived alginates are difficult to reach, it appears that the amounts used for alginate production are not large (Peteiro 2017).
3 *Saccharina japonica* also known as Japanese kelp, and formerly known as *Laminaria japonica*. *Porphyra* spp. here includes FAO categorisations of 'laver (nori)' and 'nori

nei'. *Eucheuma* spp here includes FAO classifications of 'eucheuma spp nei' and 'spiny eucheuma'. The statistics for *Eucheuma* and *Kappaphycus* species are combined here to avoid issues arising from reporting inconsistencies between countries.

4 Note that until the year 2000, Indonesia did not report carrageenan and agar containing seaweeds separately, but reported both as 'Red seaweeds'. Data prior to 2000 is for 'Red seaweeds' and from 2000 onwards is for '*Eucheuma* seaweeds nei'.

5 Planned area data from Presidential Decree 33–2019. Existing production data from BPS 2023. The planned area is the total maximum planned area for each province. The area and quantity estimates were made equivalent at 1 ha = 36 tonnes of seaweed using the 2016 reported quantity from *Badan Pusat Statistik* yearbook (9,773,055 tonnes) at the 2016 estimate of current area under production noted in Presidential Degree 33–2019 (271,336 ha). It is notable that Nusa Tenggara Timor appears to have already exceeded the planned production area. This is probably due to overestimation in provincial production data (see Appendix 1A).

6 The data for China for *Undaria*, *Saccharina* and *Gracilaria* were reported to be 'inconsistent', with data for the carrageenan seaweeds ('eucheumatoids') were of 'unknown' accuracy. The data for Indonesia, the Philippines and Malaysia for the agar containing seaweed *Gracilaria* and the eucheumatoids were reported to be 'inconsistent'.

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