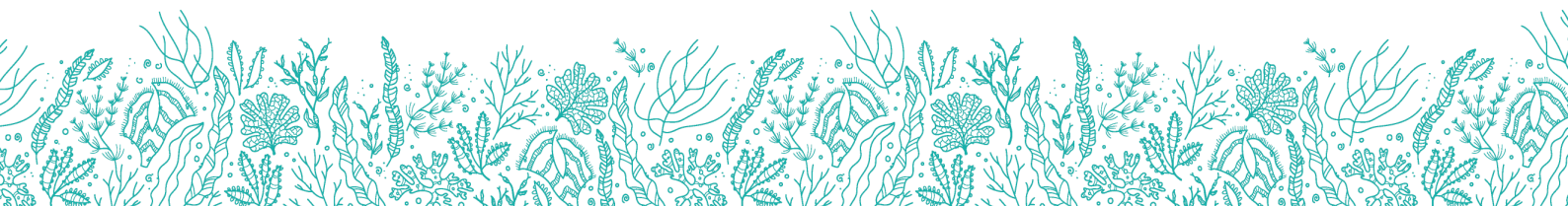


An Ocean of Opportunities:

The Potential of Seaweed to Advance
Food, Environmental and Gender
Dimensions of the SDGs



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Nations**

Geneva, 2024

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Explanatory notes

Reference to “dollar” and “\$” indicates United States dollars, unless otherwise stated.

Use of a dash (–) between dates representing years, e.g., 2015–2017, signifies the full period involved, including the initial and final years.

Reference to “t” is made for metric tons. Reference to “M” is made for millions. Reference to “kg” is made for kilograms.

To reflect the closest estimate for data, decimals and per centages are rounded off. Numbers in money are rounded to the nearest dollar, unless otherwise stated.

Decimals and percentages in this document do not necessarily add up to totals because of rounding.

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Acronyms

AfCFTA	African Continental Free Trade Area
ASEAN	Association of Southeast Asian Nations
BFA	Blue Food Assessment
BMU	Kibuyuni Beach Management Unit
CGIAR	Consultative Group for International Agricultural Research
CNRS	French National Centre for Scientific Research
DITC	Division on International Trade and Commodities
EAT	EAT Stockholm Food Forum
FAO	Food and Agriculture Organization of the United Nations
GHG	Greenhouse Gas
GSC	Global Seaweed Coalition
HS code	Harmonized System code
IPCC	Intergovernmental Panel on Climate Change
IFAD	International Fund for Agricultural Development
ILO	International Labor Organization
IMTA	Integrated Multi-Trophic Aquaculture
IPPC	International Plant Protection Convention of FAO
KFMRI	Kenyan Marine and Fisheries Research Institute
LDCs	Least developed countries
NAP	National Adaptation Plans
NDC	Nationally Determined Contributions
NGO	Non-Governmental Organization
OECD	Organization for Economic Cooperation and Development
OECS	Organization of Eastern Caribbean States
SAMS	Scottish Association for Marine Science
SDG	Sustainable Development Goal
TECA	Triggering Exponential Climate Action
TER	Trade Environment Review
UNCTAD	United Nations Conference on Trade and Development
UNEP	United Nations Environmental Programme
UNOC	United Nations Ocean Conference
UNOF	United Nations Ocean Forum
VAT	Value Added Tax
WASH	Water, Sanitation, and Hygiene
WHO	World Health Organization

Executive summary

This study aims to enhance our comprehension of the seaweed sector as a tripartite vector for economic growth, environmental sustainability, and women's economic empowerment. It builds upon the outcomes of the 4th United Nations Oceans Forum (UNOF)¹, the 2023 Trade and Environment Review (TER)², and expert interviews to present the interlinkages of the seaweed sector (production, market, trade) with food and nutrition, environmental and climate goals. The study adopts a gender lens, paying attention to women's participation throughout the seaweed value chain.

The triple environmental crises of climate change, biodiversity loss, and rampant pollution are undermining both marine and terrestrial ecosystems that support all life on the planet. The impacts of the triple crises are jeopardizing human and non-human well-being, including the potential growth of seaweed, a sustainable ocean economy product.

Seaweed's growing popularity offers potential to increase economic income, food security, preserve marine biodiversity, and empower women along the value chains. Seaweed farming and processing demonstrate how development, climate, and nature can work together to generate value that uplifts coastal communities, including women and Indigenous Peoples.

Seaweed has multiple uses including for food, nutraceuticals, cosmetics, pharmaceuticals, aquatic animal, or livestock feed, biofertilizer, textiles, and biofuels. It can also be used for producing fully biodegradable and compostable biomass for non-plastics substitute and plastic alternatives.

The global market for seaweed has more than tripled in the last two decades, growing from \$5 billion in 2000 to \$17 billion in 2021, with global exports representing about \$1 billion also in 2021. The seaweed industry is dominated by Asia in terms of production, with the United Republic of Tanzania, Chile, and the Russian Federation being the regional champions for Africa, the Americas, and the Eurasian continent, respectively. Although Asia is a major importer of seaweed, the top ten importers are located outside of the region, revealing interesting market opportunities.

In 2021, global seaweed exports were valued at approximately \$943 million, while imports were valued at \$1.2 billion. However, international trade in seaweed and its by-products only represents 14 per cent of the total market value, indicating that it is still primarily a national production and consumption market.

The seaweed industry is characterized by rapid growth across regions, with highly concentrated production in a few species offering a span of opportunities for further growth. Seaweed farming is an important source of livelihoods for women and their families, which often relies on indigenous and traditional knowledge to cultivate this versatile type of aquatic plants. Despite its enormous potential to improve food and nutrition and for economic diversification, seaweed has been underappreciated within food systems discussions.

Women already provide more than half of production and processing labour in this sector in certain countries, such as the United Republic of Tanzania. However, case studies reviewed in this paper demonstrate that women tend to be overrepresented in lower-skilled, lower-paid roles within this sector's informal areas of the supply chain.

Women seaweed farmers face similar safety, sanitary, and health issues that affect their participation in other industries such as agriculture and textile. Limited access to the internet, information about product standards, key assets, and inputs (i.e., tenure right, appropriate sanitary facilities, and technologies), social norms, and lack of financing hinder women's ability to negotiate better prices and conditions across the seaweed value chain is common. Management and decision-making in this industry are often dominated by men. Unfortunately, there is little to no quality disaggregated data by gender preventing the development of gender-informed policies for the sector.

The seaweed sector presents promising opportunities for women's business participation and revenue generation. The study suggests that women can leverage integrated multi-trophic aquaculture (IMTA)

systems to improve production quality and diversify their incomes. Bridging the digital divide and ensuring access to relevant technology, technical, and financial knowledge can also strengthen women's business opportunities.

The concluding section of this study identifies specific action-oriented considerations for governments, businesses, civil society, academia, and the United Nations.

Governments and regulators are encouraged to review regulations and policies, including marine spatial planning, permits, and taxation schemes that support women entrepreneurs' access to the seaweed sector. To strengthen the resilience of women to climate change in the seaweed sector, the study suggests promoting IMTA ventures for women and incorporating the seaweed sector into national development planning. This includes countries' implementation of the Biodiversity Beyond National Jurisdiction Treaty, Nationally Determined Contributions (NDCs), and National Adaptation Plans (NAPs).

The study also calls for promoting and regulating certain forms of sustainable use within marine protected areas to encompass kelp forests and seagrasses while assessing the impact on coastal and marginalized communities. Adoption of relevant sustainability, safety, and social responsibility guidance such as UNCTAD's BioTrade Principles and Criteria and the Draft FAO's social responsibility guide for the fisheries and aquaculture sectors are considered important steps towards environmental and social inclusion.

Businesses can facilitate the integration of women into the formal economy by promoting mechanisms such as access to insurance, finance, and technical support along the value chain. They can also advocate for targeted R&D on seaweed strains to assess whether they can effectively be used as a feed additive to reduce livestock methane emissions.

Academia and researchers can contribute by developing new seaweed strains that are more resilient to climate change, improving cultivation techniques, exploring new applications for seaweed products, and conducting research on environmental impacts.

Civil society can inform and support the harmonization of global production, quality, and safety standards for seaweed consumers and producers, as well as the introduction of appropriate risk assessment systems.

Finally, an inter-agency United Nations seaweed and gender task force could also be created to facilitate the implementation of these efforts by providing Secretariat support.

Overall, these considerations put forward a system change approach that involves all stakeholders. By raising scientific and commercial awareness of the potential of seaweed and creating an adequate regulatory framework inclusive of women-leaders in seaweed farming, the sector can deliver for people and planet at the same time.

1. Introduction

Within a sustainable ocean economy, seaweed collection, culture, processing, and trade is one of the sectors with the most opportunities to achieve sustainable growth by 2030 (UNCTAD, 2023a). Seaweed farming culture is closely linked to food security, income, livelihoods, and traditional knowledge of rural coastal communities, particularly for women and Indigenous Peoples. The value of the seaweed sector remains mostly underappreciated and untapped, while it shows clear growth potential beyond its current markets (World Bank, 2023a).

Building on the outcomes of the 4th United Nations Oceans Forum (UNOF) (UNCTAD and FAO, 2022), and the 2023 Trade and Environment Review (TER) (UNCTAD, 2023a), the objective of this study is to contribute to a greater understanding of the seaweed sector as a driver of food security and women's empowerment while addressing the interlinkages between food security, environmental sustainability, and trade.

The study analyzes the seaweed sector and explores its linkages with food and nutrition security and environmental sustainability. In doing so, it collates the most recent available data and evidence on seaweed production and trade with a focus on developing countries.

It pays special attention to the role of women in the sector at every step of the seaweed value chain. In addition, the study focuses on three concrete and practical examples of how women's participation in the seaweed sector acts as a catalyst for their economic empowerment and the promotion of sustainable practices in the industry in the United Republic of Tanzania, Portugal, and Kenya.

The concluding section identifies main responses to challenges and opportunities for developing a sustainable and gender inclusive seaweed sector and identifies some research gaps for future work. The current state of the regional and subregional seaweed industry, trade flows and women's participation, with separate analyses for developing and developed countries, can be found in the Annex. The lack of relevant and current data on the participation of women in the seaweed sector in both developed and developing countries demonstrates a gap in the literature.

The study uses UNCTAD and FAO data, as well as other authoritative and internationally recognized data sources. It is informed by a literature review and semi-structured interviews conducted with 15 leading stakeholders and experts active across the seaweed sector. While this study focuses on women in the seaweed sector, many of the issues identified are relevant to the overall development of the aquaculture and seaweed sector. The study has benefited from receiving valuable input and peer review from numerous experts, as well as representatives from relevant organizations such as FAO and the Global Seaweed Coalition.

2. What is seaweed and why does it represent a new sustainable ocean economic opportunity?

Seaweed as a marine macroalgae can be classified into three taxonomic groups: brown, red, and green. Their contributions to sustainability range from generating sustainable livelihoods for small-scale farmers and harvesters to potentially playing an important role in mitigating climate change. Several case studies have shown how the seaweed sector has been a key driver of women's empowerment in ocean communities (World Bank, 2023a). Seaweed production requires less resources and production inputs, and its export faces lower barriers to market entry than traditional fisheries. However, seaweed is often amalgamated with fisheries and other aquaculture activities, thus not yet fully recognized as a distinct sector. That can lead to underestimating its importance for economic development, especially for women.

As shown in Table 1, seaweed is a highly versatile form of biomass and has multiple applications. It can be used raw or processed for human food consumption, including as functional food, for example, protein alternatives as described in Table 2 (on seaweed nutritional composition), but also as:

- Hydrocolloids (substances that form a natural gel in the presence of water),
- Aquatic animal feed or livestock feed,
- Biofertilizer and bio-stimulants,
- Cosmetics, nutraceuticals, pharmaceuticals,
- Textiles,
- Decarbonization of the ocean economy,
- Bio-packaging, non-plastics substitutes, and plastic alternatives,
- Waste treatment,
- Biofuel, including sustainable aviation fuel,
- Resistant green construction material.

The global seaweed market is estimated today at \$17 billion (UNCTAD, 2023a) (see Outlook section below). Most of the seaweed is currently used for food, fresh feed aquaculture, and in the form of hydrocolloids. However, items made from seaweed farming may be able to replace fossil fuels used in industries like textiles and plastics. Seaweed farming can also provide ecosystem services like carbon sequestration and nitrogen cycling, which would result in improving the socioeconomic situation of vulnerable coastal areas.

Within this market, relatively new and emerging seaweed applications have the greatest market opportunities outside the established sectors. The most promising new markets, including biostimulants, animal feed, pet foods, and methane-reducing additives are projected to reach \$4.4 billion by 2030. Medium-term opportunities, including nutritional supplements, alternative proteins, biomaterials, bioplastics, and fabrics could reach a potential value of \$6 billion (World Bank, 2023a).

Their contribution to the Sustainable Development Goals is thus also multifaceted, ranging from generating sustainable livelihoods for small-scale farmers and harvesters to alleviating poverty (SDG 1), while improving food and nutrition security (SDG 2) and overcoming global challenges such as climate change, marine biodiversity loss and pollution (SDGs 7, 13, 14). Seaweed can also, due to its economic potential, increase opportunities for income diversification, new business activities and local employment (SDG 8). Several case studies have also shown how the seaweed sector has been a key driver of women's, youth, and Indigenous Peoples' empowerment in coastal communities of developing countries (SDGs 5, 10) (World Bank, 2023a). It can also serve as a unique non-food material for multiple uses including biodegradable packaging and construction material with less polluting effects (SDG 12).

Table 1. Commonly produced and traded seaweed and their uses

Scientific name	Common name(s)	Main uses
Brown seaweeds		
<i>Fucus</i> spp.	Rockweed	Nutraceuticals; pharmaceuticals (specifically thyroid regulation)
<i>Laminaria</i> spp.	Kelp	Human food alginate, nutraceuticals; pharmaceuticals, bioenergy/fuel
<i>Laminaria hyperborea</i>	North European kelp	Human food alginate, nutraceuticals; pharmaceuticals, bioenergy/fuel
<i>Lessonia</i> spp.	Strapweed	Alginate, aquatic animal feed (mainly abalone)
<i>Macrocystis pyrifera</i>	Giant kelp	Nutraceuticals; pharmaceuticals
<i>Saccharina japonica</i>	Kombu	Human food, alginate, nutraceuticals; pharmaceuticals, bio-packaging; plastics alternatives
<i>Saccharina latissima</i>	Sugar kelp	Human food, biogas production
<i>Sargassum</i> spp.	Gulfweed; sea holly	Biofertilizer or biostimulants, animal feed
<i>Undaria pinnatifida</i>	Wakame, Japanese kelp	Human food, nutraceuticals; pharmaceuticals
Red seaweeds		
<i>Asparagopsis taxiformis</i>	Red sea plume	Human food, animal feed (may reduce ruminant methane emissions)
<i>Chondracanthus chamosoi</i>	n/a	Human food, thickener, carageenan
<i>Chondrus crispus</i>	Irish moss	Human food, waste treatment
<i>Eucheuma</i> spp.	Sea moss	Human food, thickener, carageenan, animal feed
<i>Eucheuma denticulatum</i>	Spiny Eucheuma	Human food, thickener, carageenan, animal feed
<i>Gelidium</i> spp.	Jellyweed	Human food, thickener, agar-agar, bio-packaging; plastics alternatives
<i>Gigartina skottsbergii</i>	n/a	Food, thickener, carageenan, pharmaceuticals
<i>Gracilaria</i> spp.	Ogo, gulaman	Human food, thickener, agar-agar, abalone feed, bio-packaging; plastics alternatives, waste treatment
<i>Gymnogongrus furcellatus</i>	n/a	Human food, thickener, carageenan
<i>Kappaphycus alvarezii</i>	Elkhorn sea moss	Human food, thickener, carageenan, biofertilizer or biostimulants, nutraceuticals; pharmaceuticals
<i>Kappaphycus striatum</i>	n/a	Human food, thickener, carageenan, biofertilizer or biostimulants, nutraceuticals; pharmaceuticals
<i>Mazzaella laminarioides</i>	n/a	Human food, thickener, carageenan
<i>Palmaria palmata</i>	Dulse	Human food
<i>Pterocladia</i> spp.	n/a	Human food, thickener, agar-agar, bio-packaging; plastics alternatives
<i>Pyropia/Porphyra tenera</i>	Nori; laver	Human food
<i>Pyropia/Porphyra yezoensis</i>	Nori; laver	Human food
<i>Sarcothalia crispate</i>	n/a	Food, thickener, carageenan
Green seaweeds		
<i>Caulerpa</i> spp.	Sea grapes	Fish, animal feed
<i>Codium fragile</i> ssp. Californicum	Sea staghorn	Human food, skincare products
<i>Ulva</i> spp.	Sea lettuce	Aquatic animal feed (mainly abalone), waste treatment

Source: UNCTAD compilation 2024, based on (Sultana et al., 2023); (Cai et al., 2021); (Lomartire et al., 2021); (Buschmann et al., 2017); (Andersen, 2017); (Sugumaran et al., 2022).

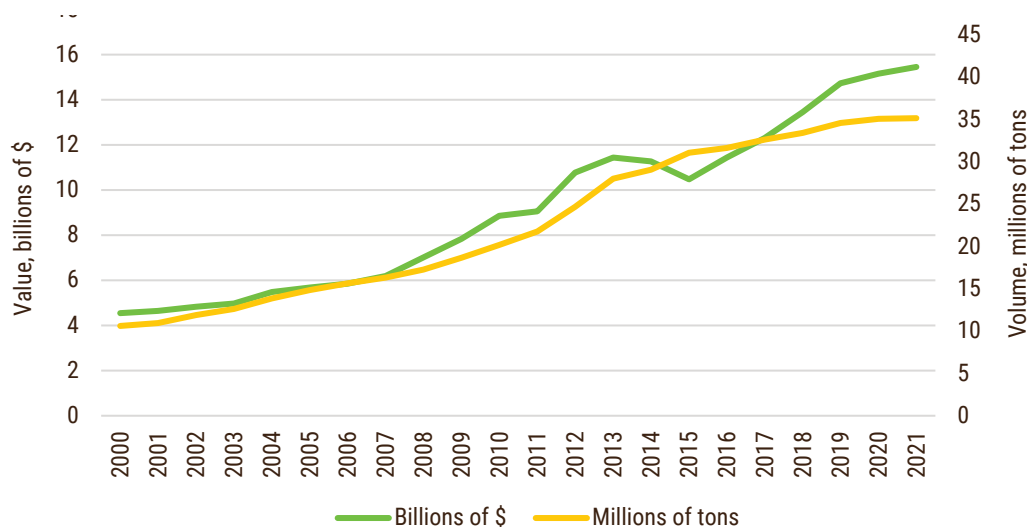
3. Outlook of the seaweed industry and its potential for food security and environmental dimensions of sustainable development

3.1. Economic and trade outlook of the seaweed industry

At a time when resources are becoming increasingly overstretched, the world must take advantage of resources that can be quickly replenished and may even contribute to the regeneration of the ecosystems that support them, such as seaweed (World Bank, 2023a). Improved value chains and increased sustainable seaweed production can be advantageous for the environment and the economy. This section presents an overview of global and regional seaweed production and trade as well as the role of women's participation in this sector. Comprehensive details on the different regions and various countries are further analyzed in the Annex.

Today, the seaweed industry is characterized by strong growth, large regional differences, and high species concentration. Seaweed cultivation in volume increased an exceptional thousandfold since 1950 (Cai, 2021). In 2021, global seaweed farmed reached 35.2 million tons (live weight) (UNCTAD and FAO, 2023). Its market value more than tripled from 2000 to 2021, from \$5 billion to \$17 billion (Figure 1). The seaweed industry's market value is forecasted to increase seven-fold, to \$85 billion by 2026 (GMI, 2021).

Figure 1. The seaweed farming boom

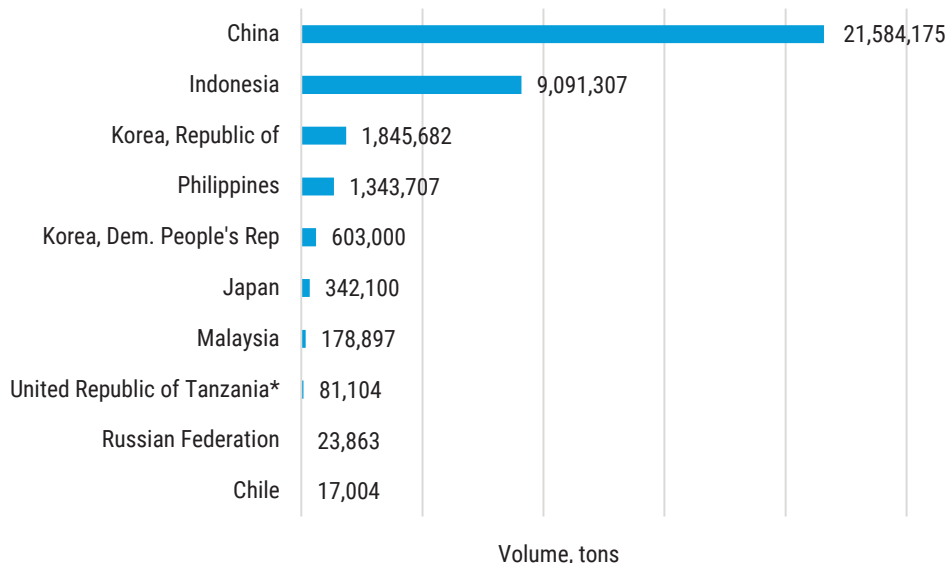


Source: UNCTAD, 2024 based on UNCTADStat

Out of 12,000 species, world seaweed production is concentrated in only five broad groups, and just 27 seaweed species items were reported cultivated in 2019 (Cai et al., 2021). Wild collection represents a small fraction, and although it is in decline it is still an important form of livelihood for women (Cai et al., 2021).³ Although most production is done in coastal waters, onshore cultivation in controlled environments is feasible, allowing for strict quality control where needed. In China, the largest world producer, almost all production is by cultivation (99.1 per cent in 2019) (Ibid.). However, China's seaweed products have gradually been experiencing declining competitiveness due to changing trade commodity structure and insufficient product differentiation among others (See Annex).

Geographically, the seaweed industry is dominated by Asia (mostly East and South Asia) with 99.5 per cent (35 million tons) of all production by volume in 2021 (FAO, 2023). China alone accounted for 61 per cent of world production that year. Figure 2 ranks the top ten producers of seaweed in 2021 demonstrating the dominance of the region in global seaweed production. Indonesia is another key player, with 26 per cent of world production, followed by the Republic of Korea, the Philippines, the Democratic People's Republic of Korea, Japan, and Malaysia. The United Republic of Tanzania, the Russian Federation, and Chile complete the list, and combined, account for 0.34 per cent of world production.

Figure 2. Top 10 seaweed producers



Source: Prepared by UNCTAD, based on (FAO, 2023)

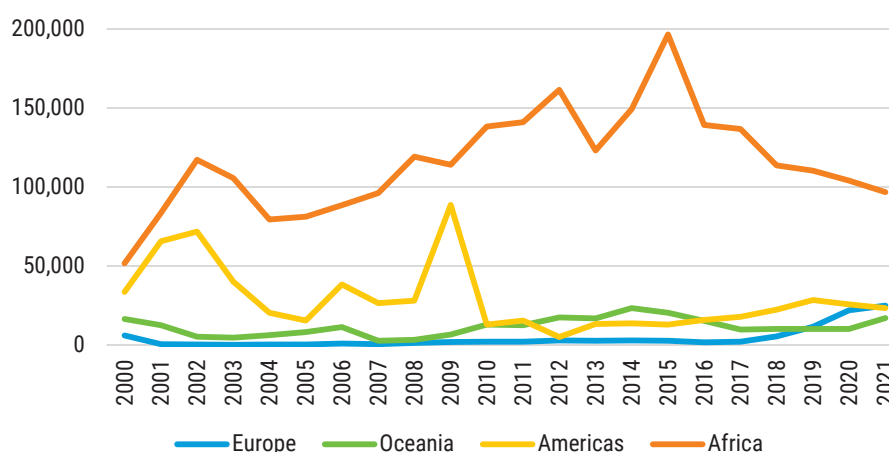
* Estimated

Developing economies lead global seaweed production, largely because of China's continued dominance. In many of these economies, production is less resource and capital intensive than traditional aquatic animals' aquaculture, making the sector more accessible to women.⁴ The main species produced by developing countries are *Laminaria japonica*, *Eucheuma*, *Gracilaria*, *Undaria pinnatifida*, and *P. Yezonesis* and *P. Tenera* (FAO, 2023). Asia's seaweed production grew by a factor of 30 between 2000 and 2021. Figure 2 highlights the dominance of the region in global seaweed production.



Seaweed production shows increasing growth rates in Europe and in Oceania due to higher internal demand. In Europe, growth since 2017 has been driven by the Russian Federation, which produced 23.8 thousand tons by 2021. In the Americas, seaweed production is dominated by Chile and Peru, whose production peaked at 88 thousand tons in 2009 before declining to 17 thousand in 2021. In Africa, total farmed production is mostly driven by the United Republic of Tanzania whose production peaked at 178 thousand tons in 2015 before declining to 81 thousand tons in 2021 (see Figure 3). This drop in production could be mainly due to disease and pest outbreaks, climate change, low biosecurity standards, and the low prices paid to farmers, which remain major constraints on the development of this industry in the region (Word Bank, 2023).

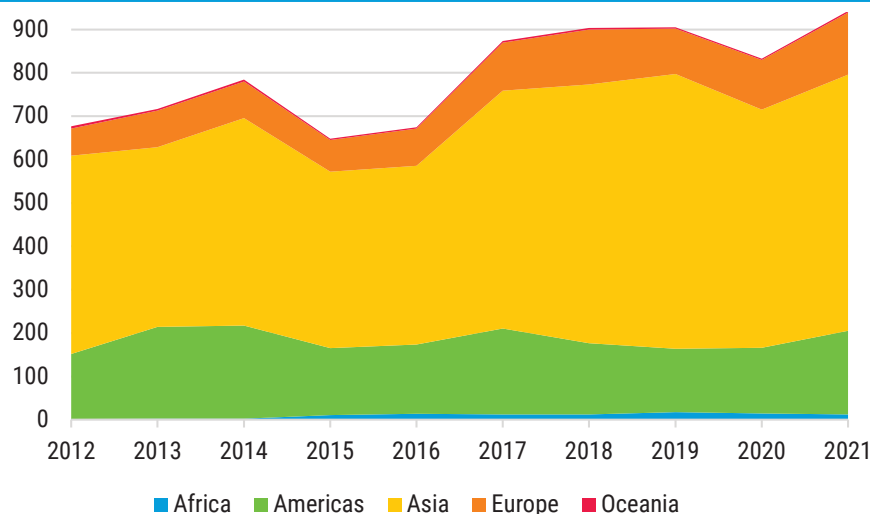
Figure 3. Seaweed production outside Asia, tons



Source: Prepared by UNCTAD based on (FAO, 2023)

In terms of global trade, reported seaweed exports were approximately \$943 million and imports \$1.2 billion in 2021. This discrepancy can be the result of cross-country differences in compilation method and reporting. Global exports of seaweed and seaweed by-products grew by 40 per cent between 2012 and 2021, largely driven by Asia, and showing important prospects for the tradability of this emerging ocean economy sector. Figures 4, 5, and 6 detail seaweed exports and imports by region.

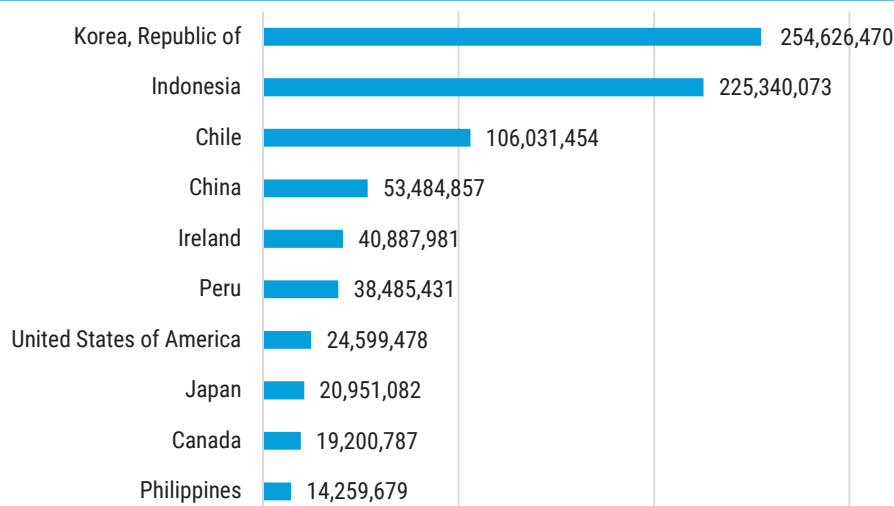
Figure 4. Seaweed exports by region, thousands of \$



Source: UNCTAD, 2024 based on UNCTADStat

Asian countries dominate both exports and imports of seaweed products, with \$590 million in exports and \$762 million in imports in 2021. Americas and Europe exported \$192 million and \$143 million, respectively, and imported \$165 and \$245 million in 2021. The participation of Africa and Oceania is still negligible, with exports of \$12.8 million and \$3.8 million respectively in the same year (UNCTADStat, 2023).

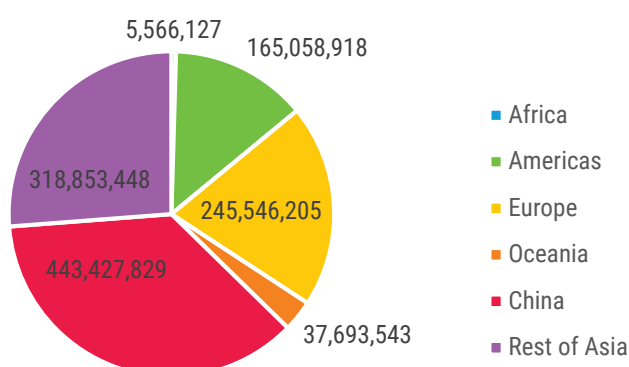
Figure 5. Top 10 exporters of seaweed 2021, \$



Source: UNCTAD, 2024 based on UNCTADStat

Despite being the biggest producer and consumer of seaweed, China is only the fourth largest exporter due to its large internal consumption, behind the Republic of Korea, Indonesia, and Chile (Figure 5). No export data on the United Republic of Tanzania could be found, despite the country being an important seaweed producer, which could mean that most of the production is for the internal market. The broad regional representation of exporters, spanning Asia, Europe, and the Americas, indicates seaweed production can be scaled up in many different environments. Given that seaweed and their by-products still are a relatively niche market outside of Asia, developing countries starting production in Africa and Latin America could make use of the UNCTAD-DOALOS Ocean Economy and Trade Strategies (OETS) (UNCTAD, 2021c) as a tool for sectoral development. The OETS is a sectoral tool for ocean economy policy and governance alignment. It seeks to enable product specialization, value addition, environmental and safety management, and higher growth export and economic diversification prospects for oceans-based sectors. The OETS has already been tested in three countries (Barbados, Belize and Costa Rica) and it could be applied to seaweed and its by-products value chain without adjustments.

Figure 6. Imports of seaweed by region 2021, \$



Source: UNCTAD, 2024 based on UNCTADStat

Although Asia dominates imports of seaweed, most of the top ten importers of seaweed are outside the region, revealing interesting market opportunities (Figure 6). In 2021, mainland China's share of global imports was 41 per cent, making it by far the largest importer (UNCTADStat, 2023). Japan is the second biggest importer, with \$193 million in 2021, followed by the United States (\$104 million). Non-Asian countries in the top ten importers include the Russian Federation (\$51 million), France (\$30 million) and Australia (\$29 million). By contrast to other large seaweed producers, Indonesia and the Philippines import very little. Though data is lacking, LDCs and SIDS could also benefit from this boom in seaweed demand.

Beyond trade in seaweed, by-products such as seaweed-based hydrocolloids (e.g., agar, alginate, and carrageenan) have a high export value. In 2021, global agar exports reached \$260 million and alginate exports \$161 million (UN Comtrade, 2023) showing great potential for market expansion. It is more difficult to estimate carrageenan exports given that they are included in a broader Harmonized System (HS) Code (130239) whose export value was \$1.5 billion in 2021. Interestingly, member States identified these by-products as priority ones for support by UNCTAD under its Blue BioTrade programmatic support and have been listed under the UNCTAD's Ocean Trade⁵ and TraBio⁶ databases for follow up by member States.

With climate change threatening predictability of harvests and the sustainability of many regional crops, the importance of trade in seaweed and novel blue food commodities is likely to increase (UNCTAD, 2023a). Ensuring that markets around the world have access to nutritious food and non-food inputs will, however, require international trade and cross-border cooperation in tariff, non-tariffs, and customs cooperation.

So far, the seaweed industry has experienced strong growth offering a span of opportunities for further growth, especially for women, who increasingly participate in production and processing labour. Such economic opportunities should be leveraged to reap the benefits to their full potential because increased seaweed production can be advantageous for people, the environment, and the economy.

3.2. The role of seaweed in global food chains

Seaweed (sometimes referred to as "sea vegetables") grows on almost every coastline, lakes and bodies of water, and peoples may have used them for multiple purposes as long as 12,000 years ago (Mouritsen, 2013). Seaweed has been consumed in East Asian cultures since ancient times. The knowledge to prepare different seaweed species has been shared through generations. In countries such as Japan, for instance, one-fifth of daily meals incorporate seaweed in some form (Leandro et al., 2020) and consuming packaged seaweed products has been a long-time practice. On the other hand, beyond a few limited coastal populations, western diets have historically not incorporated seaweed (Leandro et al., 2020).

The potential of seaweed to improve food and nutrition security has been underappreciated in food systems solutions because food research and policy have historically focused on terrestrially sourced foods. However, this situation is changing rapidly. Over the last decade, the popularity of seaweeds has soared in Europe and North America, in part due to more awareness around their nutritional properties and non-food uses (Peñalver et al., 2020). In addition, more people are turning to seaweed farming because of climate change impacting conventional fisheries and aquaculture, though for example sea level rise, more frequent and intense extreme weather events, and salinization.

Most seaweed is edible and a good source of macro and micronutrients in the human diet (Table 2). Approximately 700 edible seaweed species have been documented including around 195 brown, 345 red and 125 green species (Cai et al., 2021). Seaweed-derived hydrocolloids (i.e. carrageenan, agar, and alginate) are an important part of the food industry and are also used in cosmetics, nutraceuticals, and pharmaceuticals.⁷

The main species for human food are kelp (*Laminaria*/*Saccharina*, as a soup ingredient and snacks), nori (*Porphyra*, as sushi wrap, soup ingredient, and snacks), wakame (*Undaria*, as salad and snacks), sea grape or green caviar (*Caulerpa*, as salad), and Gracilaria, Kappaphycus, and Eucheuma, for salads and pickles (Cai et al., 2021) (Table 1). Western consumption is growing rapidly, especially of such products as nori, wakame, kombu, kelp, and dulse (Sultana et al., 2022).

Edible seaweeds are healthy, nutritive, and low-calorie food, rich in nutrients, including vitamins (A, B1, B2, B9, B12, C, D, E, and K), minerals (calcium, iron, iodine, magnesium, phosphorus, potassium, zinc, copper, manganese, selenium, and fluoride), dietary fibers, protein, and essential amino acids (Lomartire et al., 2021) as demonstrated in Table 2. They contain various bioactive compounds including antioxidants, flavonoids, phenolic compounds, and alkaloids that may support improved human health and help reduce the risk of various diseases when consumed as food (Choudhary et al., 2021). Seaweed can also provide nutrients that are lacking in terrestrial crops grown in micro-organism and mineral depleted soils (Sultana et al., 2023).

Table 2: Selected edible seaweed nutritional composition (2018)

Composition (dw)	Wakame	Kombu	Nori	Gracilaria	Solieriaceae
Fat	1-5	1-2	2	0.3	0.2
Total carbohydrate	45-51	52	44	74	63-67
Protein	12-23	7-8	31-44	12	5-6
Minerals	26-40	27-33	8	6	23-26

Source: Elaborated by UNCTAD from (World Bank, 2023a, 2023b).

The Blue Food Assessment (BFA), an international joint initiative of the Stockholm Resilience Center, Stanford University, and EAT Stockholm Food Forum, underscored the relevance of blue foods for reducing B12 and omega-3 deficiencies, especially for Africa (BFA, 2023). Nori has been identified as the most suitable Vitamin B12 source for vegetarians (Watanabe et al., 2014). Regarding seaweed and omega-3s, a recent study of five red and three brown seaweeds harvested in Portugal (Rocha et al., 2021) identified two species with the highest potential to contribute to a balanced dietary intake of fatty acids.

Seaweed is the one of the best natural sources of iodine available. Iodine is needed to produce thyroid hormone that the body does not produce. It is therefore an essential component of the human diet (Mouritsen, 2013). In many western cultures, the solution has been to iodize salt. Yet high sodium consumption is known to contribute to hypertension. In low and middle-income countries where iodine deficiency is a greater population-wide health threat, seaweed products have the potential to contribute to local daily needs (Smyth, 2021). The type of seaweed species and processing and cooking methods also affect the ultimate intake of iodine (Zava and Zava, 2011).

In discussions about food systems, the potential of seaweed to enhance food and nutrition security has not been adequately considered. For cases of malnutrition that are more severe, seaweed may also assist in providing iron, vitamin A, omega 3, and mitigating iodine deficiencies, which are among the most prevalent nutritional problems worldwide and particularly affect children and pregnant women.

One constraint is that standards vary widely across countries.⁸ For instance, Japan has evaluated the iodine intake of Japanese people to be adequate mainly due to their traditional marine and seaweed-based diets. However, other areas are calling for more precise assessments of excess intake with potential health consequences (Zava and Zava, 2011).

Seaweed may also be part of a low-cost solution for more extreme situations of malnutrition. For example, Feedback Madagascar, a non-governmental organization (NGO) operating in famine-stricken southwestern Madagascar is developing a project whereby local women will produce seaweed and process it into a powder that would be incorporated into children's school meals (Feedback Madagascar and Mara Seaweed, 2021).

Seaweed supplementation of livestock, poultry, and aquaculture feed, using many species, has been shown to yield significant improvements in animal nutrition, immunity health of animals, particularly for pigs, cows, sheep, poultry, and fish (Rajauria, 2015).

Rising consumption of processed seaweed has led to some concerns about safety (Besada et al., 2009; Cheney et al., 2014), as seaweed has a unique ability to concentrate heavy metals, particularly arsenic and mercury, both of which are poisonous to humans. While there is substantial evidence for the health benefits of algae-derived food products, more research is needed to quantify these benefits as well as any possible adverse effects especially from heavy metals and marine biotoxins that may be associated with seaweed farming, including for women and children as a distinct target population (FAO and WHO, 2021).

There is a lack of information on the nutritional value of seaweed, its bioavailability, how it affects human metabolism, how it is harvested, stored, and processed as food, and whether eating large quantities has any health risks which should be addressed through further research. Thus more research is needed on the: (i) nutritional composition and other factors that can substantially affect seaweeds' dietary value, such as species, geographical regions, and seasons; (ii) bioavailability and factors that affect it, including preparation and the role of the gut microbiome; (iii) the role of human metabolism; (iv) the effects of harvesting, storage, and food processing techniques (Wells et al., 2017), as well as (v) any health risk emerging from farming and their consumption. Additionally, location of cultivation needs to be assessed as heavy metals content is directly linked to ecosystem pollution and not to natural causes.

In addition, legislation, standards and guidance documents on the production and utilization of seaweed are generally still lacking. The Food Agriculture Organization (FAO) and World Health Organization (WHO) have prepared a report that identifies food safety hazards (microbiological, chemical and physical) linked to the consumption of seaweed and aquatic plants (FAO and WHO, 2021), identified food security and safety data gaps and provided a number of recommendations. The report was presented to the Codex Committee on Fish and Fishery Products, who agreed to develop further Codex Alimentarius guidance with this information. The Global Seaweed Coalition (GSC) has also worked with FAO and WHO to expand the inclusion of seaweed food species into the Codex Alimentarius, which could change nutritionists' recommendations on the use of seaweed, especially outside Asia.

3.3. Seaweed farming as a tool for climate mitigation and environmental sustainability

Achieving environmental sustainability stands as a critical global imperative vis-a-vis the triple climate, biodiversity, and pollution crises we face today. There is a need for urgent action to reduce global greenhouse gas emissions (GHG), to limit global temperature increases to 1.5 degree Celsius above pre-industrial levels, as set out in the Paris Agreement (United Nations, 2015). Marine biodiversity is deeply threatened by overfishing, different forms of pollution from heavy metals to the overflow of plastics waste. The Kunming-Montreal Biodiversity framework (United Nations, 2022) has made a call to promote the protection, sustainable use, and restoration of marine and terrestrial ecosystems and for sharing the benefits of their utilization.

It is estimated that food systems contribute to one third of global anthropogenic GHG emissions (Crippa et al., 2021). In 2019, plastics generated 1.8 billion tons of greenhouse gas (GHG) emissions, which is equivalent to 3.4 per cent of global emissions (UNEP, 2023c). Change is needed at the population and systemic level, with "hard policy interventions including laws, fiscal measures, subsidies and penalties, trade reconfiguration, and other economic and structural measures that encourage healthy and sustainable diets" (Willett et al., 2019).

Seaweed farming, as part of the circular blue bioeconomy, can significantly contribute to GHG and carbon sequestration, while providing core ecosystem services and food (Feehan, 2023). Recent studies reveal the low environmental impact of seaweed cultivation since it does not use land nor fertilizers and requires no freshwater (United Nations Global Compact, 2020). Therefore, seaweed may help mitigate climate change, biodiversity loss and marine pollution in several ways.

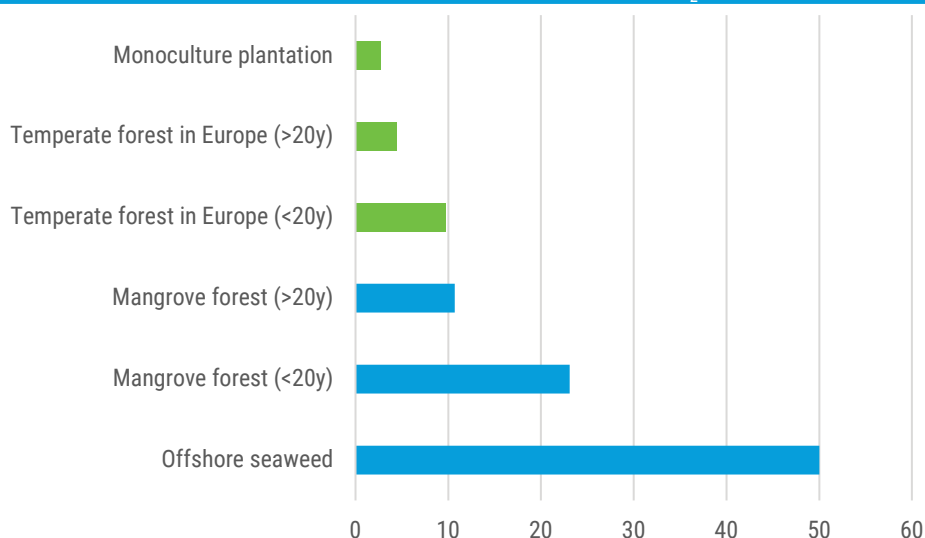
Integrated Multi-Trophic Aquaculture (IMTA) systems integrate cultivation of feed species (such as finfish or shrimp) with that of extractive species, such as mollusks (mussels and oysters), seaweeds, and invertebrates (sea cucumbers and sea urchins), such that the wastes of one resource user become

a resource (fertilizer or food) for the others providing circular benefits. These systems bring multiple ecological and economic benefits, including reoxygenation and deacidification of surrounding waters through nutrient bioremediation, mutual benefits to the co-cultured organisms (each may help the other grow better, depending on conditions), economic diversification, and increased profitability. They may also act as nodes for farm operation and maintenance (Buck et al., 2018; Chopin et al., 2001).

IMTA can be helpful in decarbonizing other aquaculture operations, as well as enhancing the value of aquaculture operations. For example, Viet Nam has a significant fish and shrimp aquaculture industry that relies on imports of soy and other vegetable proteins. On the other hand, its seaweed aquaculture is relatively undeveloped, with only a small industry cultivating seaweed for export as ingredients. Introducing seaweed into IMTA systems there could mitigate the negative environmental impact of its fish and shrimp aquaculture industry and help strengthen farmers' livelihoods.⁹

Carbon sequestration and atmospheric carbon dioxide reduction. Most seaweed ecosystems draw down the largest carbon flux of any vegetated coastal habitat (Filbee-Dexter K et al. (2023). Indeed, seaweed may have the capacity to sequester more carbon dioxide (CO₂) than any other plant ecosystem. An estimate suggests that macroalgae could sequester about 173 million metric tons of CO₂ per year (Krause-Jensen and Duarte, 2016). About 90 per cent of this sequestration occurs through transfer of CO₂ to the deep sea, and the rest through its burial in coastal sediments. Moreover, offshore seaweed has an absorption average rate of at least 50 metric tons of CO₂ per hectare (Figure 7), a much higher absorption rate than mangroves and terrestrial forests. In forest biomass, trees absorb significant amounts of carbon on land, and seaweed has been proposed to have a similar role in ocean carbon sequestration. According to Energy Futures Initiative (2020) kelp has the capacity to pull down about 1 to 10 billion tons of carbon dioxide per year. One species of brown algae has been found to release an amount of carbon dioxide from the atmosphere every year almost equivalent to Germany's entire annual GHG emissions, by secreting the compound fucoidan (Buck-Weise et al., 2023). Seaweed cultivation is a particularly appealing method for carbon sequestration due to its potential scope and comparatively low cost compared to kelp forest restoration (World Bank, 2023a).

Figure 7. Average carbon sequestration per year in metric tons of CO₂



Source: Elaborated by UNCTAD based on (KPMG, 2023). The potential of seaweed offsetting in climate change mitigation.

While seaweed has not yet been incorporated or widely accepted blue carbon credit programmes, many regions and organizations are working on providing means to compensate people who cultivate and restore seaweed for the goal of sequestering and absorbing carbon.

Several startups are currently developing technologies for removing carbon from the atmosphere using macroalgae and sinking it into the deep ocean.¹⁰ For instance, Seaweed Generation in the United Kingdom is focusing on technologies aimed at intercepting and sinking Sargassum for CO₂ removal in Antigua and Barbuda (World Bank, 2023a). However, the underlying science is complex and leading seaweed researchers today strongly advocate caution (Chopin, et al., 2024)

The growing interest into seaweed cultivation for the purpose of climate mitigation tools can present a positive opportunity for women who tend to be significantly involved in the sector, especially in developing countries. Since seaweed resources comes with benefits such as low cost, high yield, quantifiable carbon sink, and great cultivation controllability, women leading the industry can play a key role in the production of seaweed both for consumption and climate mitigation tools, especially in the creation of offshore blue carbon sinks, as a sustainable role model for future growth in coastal ecosystems (Yang et al., 2021).

Nevertheless, more case studies and data seem to be required to demonstrate how seaweed can positively contribute to carbon sequestration, biodiversity, and nutrient remediation without causing unintended environmental and social damages. Indeed, we still lack understanding of the long-term effects of these actions, such as the nutrient impact on the seabed (O'Neil, 2023; Ross et al., 2022). Women's engagement in the seaweed value chain should be extended to science and research of seaweed potential. They should be exposed to seaweed and marine science that is specific to their communities and regions while being globally connected to share experience, especially since women play such a key role in the seaweed ecosystem and in carbon sequestration.

Reducing ruminant methane emissions. Documents over 2,000 years old describe seaweed as livestock fodder in the Mediterranean and coastal European countries (Mouritsen, 2013). In the present day, adding certain seaweeds to livestock feed (De Bhowmick G and Hayes M (2023) may significantly decrease their methane emissions. Methane has a global warming potential about 30 times greater than carbon dioxide and a much shorter lifetime (about 12 years), making it an important element to consider globally and in relevant national climate change mitigation strategies (IEA, 2021).

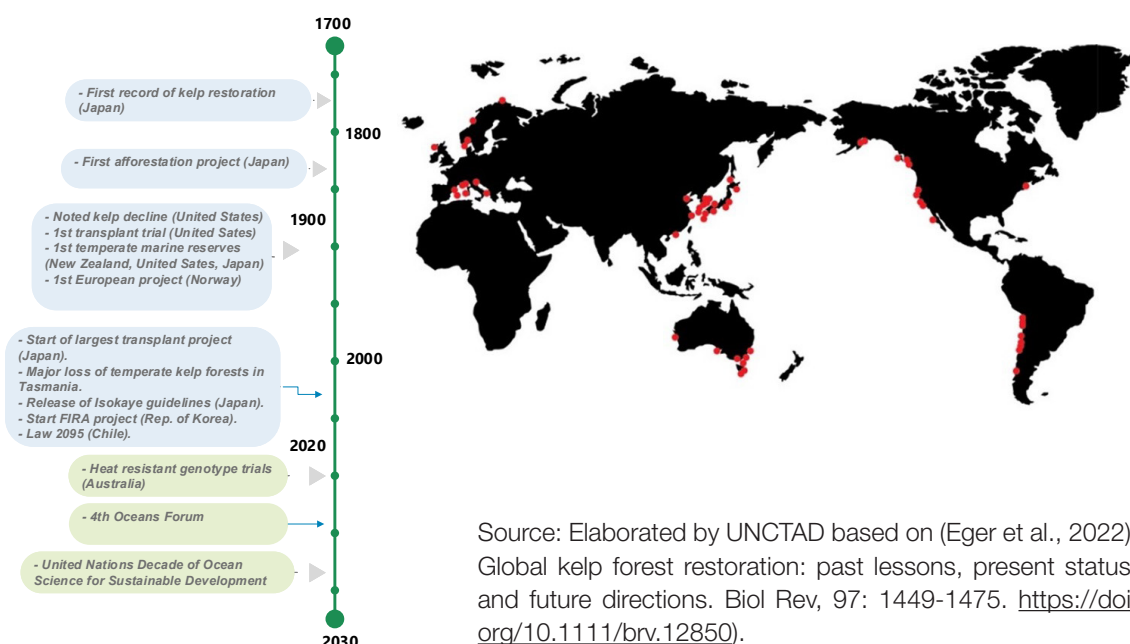
Much attention is currently being paid to the potential of the red seaweed species *Asparagopsis* to help reduce ruminant methane emissions, a significant contributor to GHG (Makkar et al., 2016). According to Friend of the Sea Global Certification Standard Founder and Director Paolo Bray, "including seaweed in cattle feed has the power to offset ruminant methane emissions. Many seaweed extracts can be used after processing as biofertilizers or bio-stimulants, among them Sargassum in China and Kappaphycus in India (see Annex for details). They can help increase yields while reducing the need for chemical fertilizers and decrease losses due to disease and insects and have been associated with improvements in the soil microbial community and the effectiveness of the nitrogen cycle (Ali et al., 2021). A recent report of the Swedish Environmental Protection Agency notes that the daily feeding of red algae to cows may lead to a reduction of methane emissions by up to 90 per cent based on a promising pilot project led by Volta Greentech solution (Naturvårdsverket, 2023). A pilot project on seaweed-based feed additives across two farms demonstrated significant methane reduction by 80 per cent a day (The Guardian, 2023).

While progress has been heralded on the use of seaweed in animal feed in Australia researchers continue to urge caution on the way it is produced and used to reduce emissions (Roque et al., 2019 and 2021). For example (Wasson et al., 2022) describes the type of specific conditions needed under which seaweed cultivation and use for feed could benefit both livestock producers and the environment.

Factors affecting adoption by producers may need to be considered, especially if it is perceived to be linked to reduced animal productivity and feed efficiency. Continued research attention to the impacts across the entire value chain, from animal health through to consumers, is warranted before any consideration is made to expand use of seaweed as a potential animal feed additive to reduce GHG emissions.

Biodiversity conservation and sustainable use. Only recently has global attention turned to the role of seaweed forests in regulating climate and supporting biodiversity. Seaweed habitats form part of the largest vegetated coastal biome.¹¹ (Pessarrodona et al., 2022). Kelp reforestation has been associated

Figure 8. Important global kelp restoration events and locations



with increasing biodiversity, for example in the United Kingdom and Portugal. Nevertheless, they are at significant risk from climate change and predation (Eger et al., 2022). As observed in Figure 8, despite 300 years of kelp restoration, kelp forest ecosystems are still in dramatic decline. Restoration projects also remain highly expensive (Eger et al., 2022).

The company Urchinomics provides an interesting example of projects designed to enable sustainable use of kelp forest, by pioneering a parallel kelp restoration and sea urchin aquaculture venture. The company pays commercial divers to harvest ecologically destructive, overgrazing sea urchins and turn them into premium seafood through aquaculture. Consequently, urchin populations were reduced, and the kelp forests began to recover. With this project the company secured the world's first voluntary blue carbon credit from their ecologically restorative operations in Japan (Hermans, 2023); (United Nations Ocean Decade, 2022).

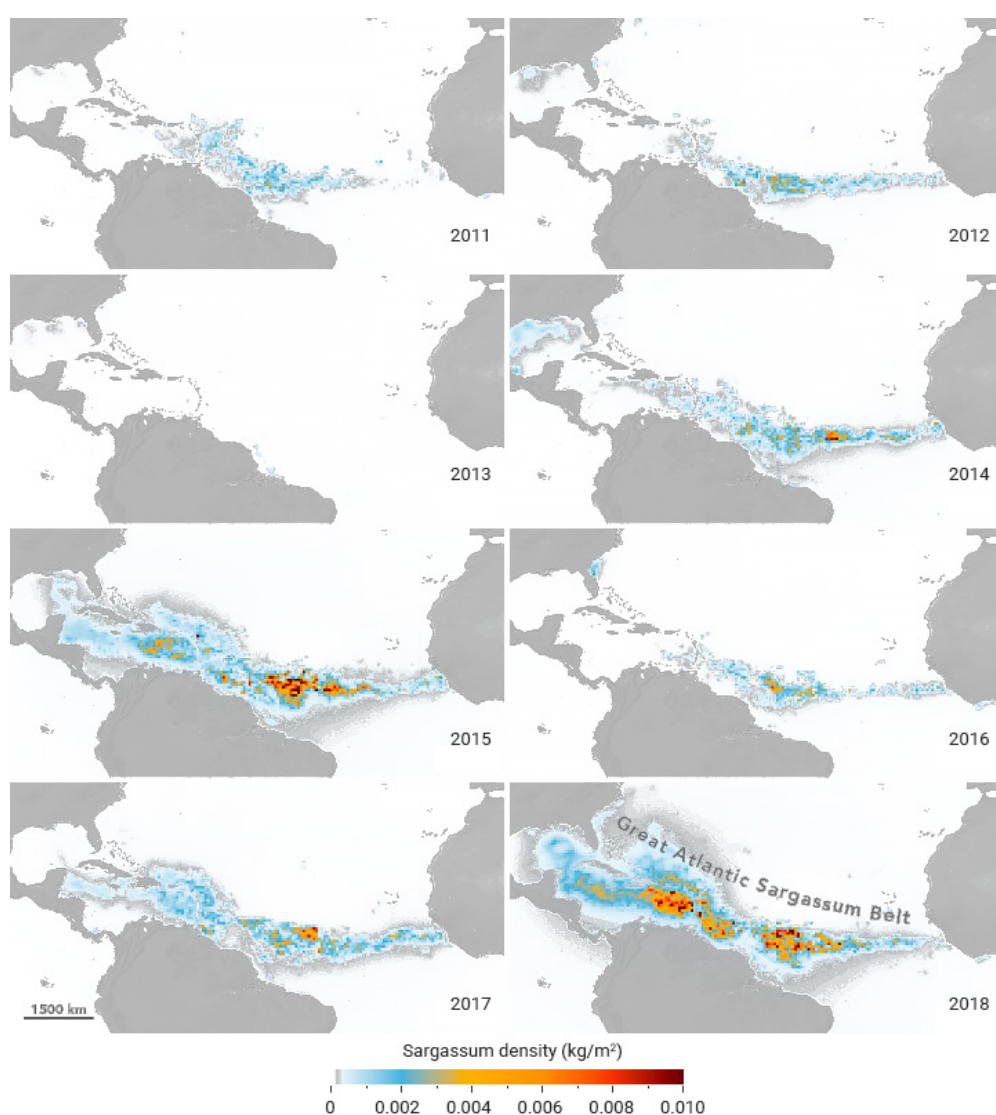
On the other hand, seaweed cultivation presents a more nuanced picture, in part because farms, especially if they are monoculture, do not necessarily mimic natural kelp forests. It has been recommended that kelp farms be evaluated on an operation-specific basis, with targeted management to achieve biodiversity objectives (Forbes et al., 2022). There is also a social dimension: smallholder and Indigenous Peoples participants at the Convention on Biological Diversity's COP15, many of them women, repeatedly urged caution regarding the implementation of policies to create protected areas that limits their rights. Even as longstanding stewards of lands and waters that are critical for their livelihoods, they sometimes found these set-asides resulted in their access and tenure right being blocked. Expanding marine protected areas to encompass kelp forests, while assessing and considering the contribution and impact of sustainable use by local and indigenous communities, could help achieve biodiversity objectives and protect livelihoods of local populations, especially women.

Seaweed blooms: a curse or a blessing? While natural seaweed blooms have a positive impact on ocean health in terms of carbon absorption and additional food for other species, in recent years, adverse climate change effects leading to changing ocean circulation patterns have resulted in an overabundance

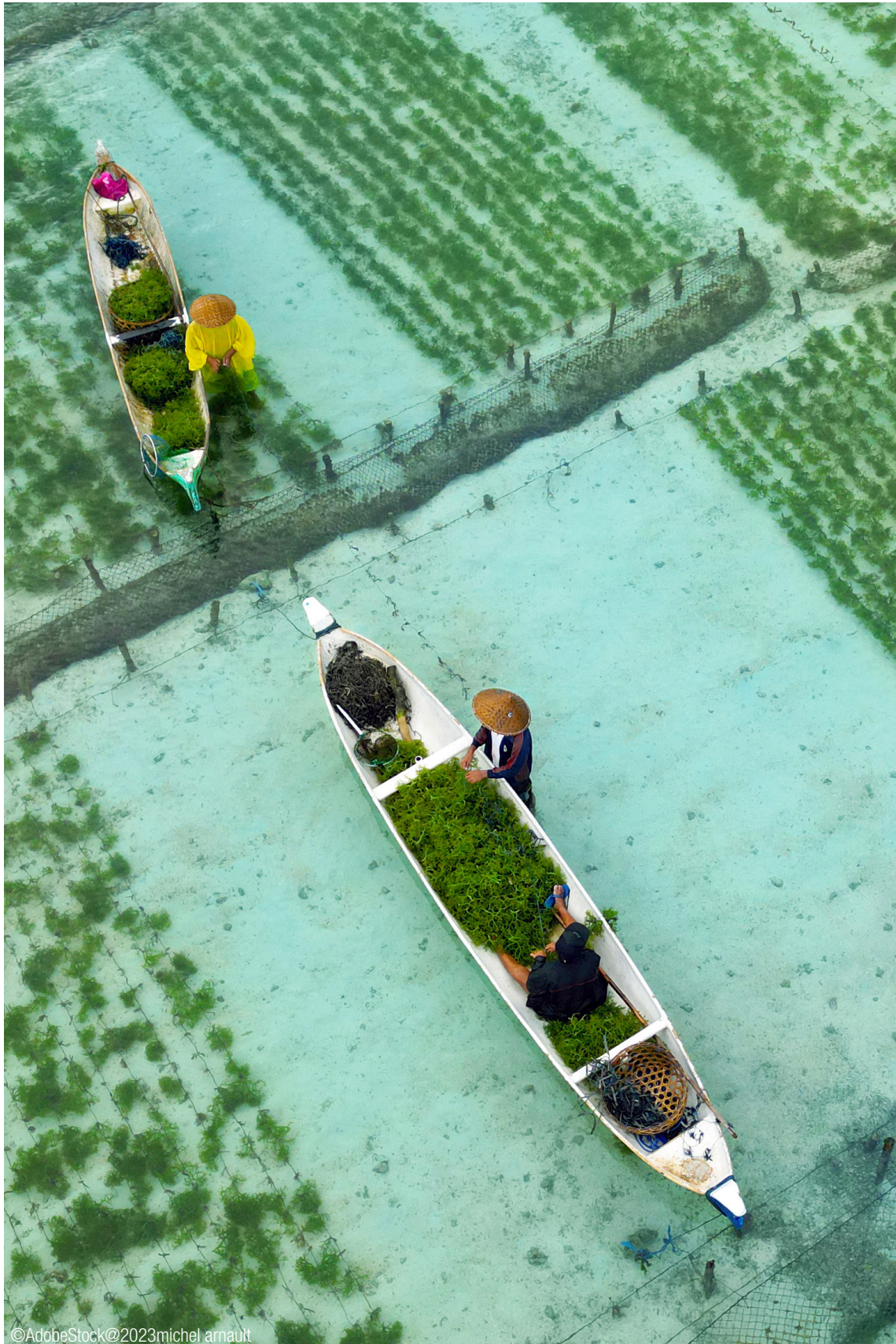
of seaweed due to warming ocean temperatures. The Great Atlantic Sargassum Belt has developed rapidly in 2023 creating a large abundance of seaweed being washed ashore (Figure 9). In March 2023, scientists stressed that the quantity of seaweed (Sargassum) around the Great Atlantic Sargassum Belt was probably the highest on record (NASA, 2023). While some might consider the abundance of sargassum as a hindering factor for local tourism as well as coastal communities' livelihoods, some are starting to see it as a trade opportunity for using the additional biomass for multiple uses including fertilizers, personal care products, non-plastic substitutes, and bioenergy.

Plastics substitutes and alternative materials. “By 2050, there could be more plastics than fish in the sea if the current production trends continue” (Macarthur E, 2024). Seaweed can be used to develop non-plastics substitutes and plastic alternatives that can assist in mitigating plastic pollution. Non-plastics substitutes include all natural materials from mineral, plant, animal, marine or forestry origin that have similar properties of plastics (UNCTAD, 2023b). They do not include fossil fuel-based or synthetic polymers, bioplastics, and biodegradable plastics. In this group of materials, seaweed and its by-products play a key

Figure 9. Development of the Great Atlantic Sargassum Belt (2011–2018)



Source: Reformatted by UNCTAD based on (NASA, 2023).



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role. Plastic alternatives tend to cover bioplastics or biodegradable plastics made from biomass, including from seaweed, but that still can be built in the form of a polymer molecule with limited biodegradability or composability.

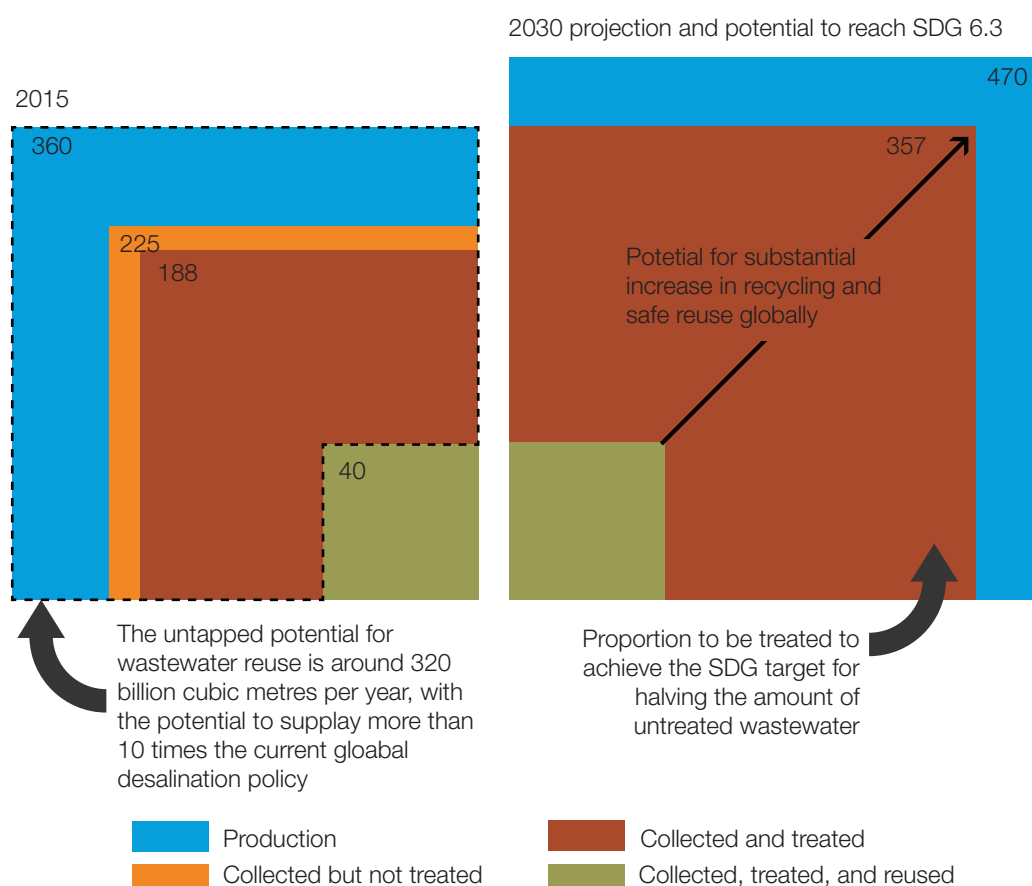
Several start-ups, many women-founded and led, such as Notpla (winner of the 2022 Earthshot prize), Evoware, Algeon Materials, Sway, and FlexSea have created innovative biodegradable packaging materials made from seaweed to replace single-use plastic, packaging materials, and even paper (Sugumaran et al., 2022; UNCTAD, 2023b). Encouraging development of non-plastics substitutes and alternatives made using seaweed could help accelerate efforts to reduce the impact of plastic pollution on the environment and the ocean, marine ecosystems, and species. For instance, the case study of Kenya below discusses the double win of adoption of biodegradable fishing nets by seaweed farmers in local villages to promote sustainable practices as well as contribute to women seaweed farmers' economic empowerment. As one of the fastest growing organisms on the planet (1.5m/day), seaweed could provide solutions to reverse the trend of non-biodegradable packaging (European Commission, 2018).

Wastewater treatment. The intelligent management of wastewater presents a great potential for sustainable development. Figure 10 demonstrates how the amount of collected and reused water represents roughly only 20 per cent of the total of collected and non-reused water. The untapped potential for wastewater reuse and management could replace more than 10 times the current desalinization capacity. By safely reusing valuable ingredients that make up wastewater (i.e., nutrients, energy, and water), wastewater management can result in the reduction in dependence on synthetic fertilizers by offsetting 13.4 per cent of the global agricultural nutrient demand and diversification of the energy production (UNEP, 2023b). Seaweed can be used to remove pollutants such as dyes from textile, paper, and printing; nitrogen and phosphorous and phenolic compounds; and heavy metals (Arumugam et al., 2018). Its low cost and availability make it a viable alternative to technology used in current Water, Sanitation, and Hygiene (WASH) systems, especially in developing countries where seaweed is readily available or could be scaled up. Seaweed is being used to decrease the environmental footprint of the fashion industry. For example,



the ancient traditional knowledge technique of floating inks helps mitigate water wastage and pollution caused by dyeing and printing.¹² Wastewater treatment facilities and water management institutions can integrate seaweed as a nature-based solution to improve wastewater treatment and reduce environmental pollutants. Seaweed can be considered as a natural alternative to improve wastewater treatment and lessen environmental toxins. Due to its low environmental impact, seaweed farming can greatly reduce the effects of climate change as a component of the circular blue bioeconomy. In addition to increasing the value of aquaculture operations, IMTA can be useful in decarbonizing other aquaculture activities. More research is required to fully grasp the potential of seaweed farming as a tool for climate mitigation and environmental sustainability especially in eliciting their ability to reduce methane emissions, improve feed efficiency, and their potential seaweed ecosystems and their potential for the creation of blue carbon financial instruments.

Figure 10. The potential of intelligent wastewater management to achieve SDG 6



Source: Elaborated by UNCTAD based on UNEP, 2023b. Wastewater: Turning Problem to Solution. A UNEP Rapid Response Assessment.

4. The seaweed value chain through a gender lens: A gender inclusive value chain?

The role of women is key to achieving sustainable growth in the seaweed sector. The food security-gender nexus in the seaweed industry is critical considering that women constitute a disproportionately large percentage of the people engaged in the informal, lowest paid, least stable, and least skilled segments of the workforce. In aquaculture, women comprise 28 per cent of the workforce within the primary sector; within fisheries, this figure is 18 per cent. Spanning both the pre- and post-harvest stages of the value chain, their participation reaches an estimated 50 per cent (FAO, 2022). Beyond their pivotal role in coastal rural economies, women play a substantial part in ensuring household food security and nutritional well-being, all the while managing domestic and caregiving responsibilities.

Women's engagement is significantly influenced by social, cultural, and economic contexts, which can create gender-related barriers that limit their ability to make choices and take effective measures to advance the seaweed sector. These barriers can curtail their actions and hinder their capacity to contribute to the sector's growth (Thomas et al., 2021).

Today, the combined threats of climate change, depleting natural resources, food insecurity, poverty, and gender inequality are leaving global coastal communities at risk, particularly in developing countries. The seaweed sector has the potential to counter many of these, while transforming global food systems, improving food security, creating opportunities for new innovations and products, and putting women at the forefront (Sultana et al., 2023).

The global seaweed sector presents opportunities and challenges for women. However, several barriers remain for expanding support and training in seaweed cultivation management, harvesting, safety, processing, and recipe creation by women. This section provides a horizontal and value chain analysis of the hindering and enabling factors for expanding women's participation in the seaweed sector.

4.1. Horizontal factors affecting women participation in the seaweed value chains.

4.1.a) Scarce data availability along the value chain.

Despite the significant presence of women along the seaweed value chain, especially in developing countries, there is little to no official reporting on women's labour force participation in the seaweed industry. Women's labour contributions are thus either poorly recorded or overlooked (J. G. Suyo et al., 2021). This lack of accurate and accessible information on women in the fisheries and aquaculture sectors means that women's unique needs or perspectives are not routinely incorporated into management and policy decisions.

These "gender blind" (FAO, 2017; Gopal et al., 2020) fisheries policies translates into insufficient funding for women in the sector, which in turn further marginalizes and undervalues their work and contributions. A study of fisheries policy instruments and strategies in the Pacific found "gender commitments are often diluted and expressed through narrow and outdated strategies" that are inadequate to navigate complex gender dynamics and power relationships in the sector. An understanding of gender roles and contributions is therefore both urgent and critical to manage sustainable small-scale fisheries and move towards better coastal management (Thomas et al., 2021).

UNCTAD and FAO host the most comprehensive global seaweed databases on production and trade. These production and trade data are currently not disaggregated by gender and therefore any inferences made about it are necessarily based on anecdotal evidence. Further, these statistics are aggregates of national reporting that suffer from other issues that affect their quality.

Nevertheless, there are encouraging developments on the labour front. Although the International Labor

Organization (ILO) does not yet report on jobs in the seaweed sector, it has recently turned its attention to the potential for seaweed, among other nature-based solutions, to help improve the well-being of coastal populations and restore degraded ecosystems. For example, it has been reported that communities farming seaweed in Kenya produce several hundred tons of seaweed and employ more than 500 community members, two-thirds of whom are women (ILO, UNEP, and IUCN, 2022). In an earlier study, ILO reported women being heavily engaged in seaweed production on informal basis in Indonesia as daily, casual workers and reportedly receive low wages (ILO, 2021).

Notwithstanding recent progress on aquaculture, there is a general scarcity of reliable seaweed data, especially disaggregated by gender and socio-economic characteristics. Only a few national agencies comprehensively quantify their local seaweed production, and these volumes do not always reflect the real supply (HATCH, 2023). There are also issues of consistency across datasets and even within them because the supplying countries apply widely varying definitions. Comparisons across datasets can be challenging because of the different units and measures employed. For example, some databases use live or wet weight and some dry weight, and sometimes it is unclear whether the seaweed measure represents dry or live. Some datasets aggregate both micro- and macro-algae. Strengthening the capacity of countries and relevant institutions to collect and analyze data, disaggregated by gender and key socioeconomic characteristics, would inform better policy choices.

In consequence, setting national and international systems for gathering and using disaggregated data will help to understand the specific contributions of women, informal sector workers, and other marginalized groups; identify bottlenecks; improve traceability in the seaweed value chain; and spread sustainable and profitable farming practices. It can also assist in developing a more nuanced understanding of the specific risks faced by different groups of seaweed farmers and how different farmers respond to different economic, environmental and health risks, including climate change (Asri et al., 2022).

4.1.b) Limited women participation in decision making along the value chain

Women can play leading roles in the seaweed sector, whether in production, value addition, marketing, research, and decision-making in general. According to a case study from Maine, United States, the seaweed industry is a promising sector to increase women participation. As a result of women transitioning from male dominated wild caught fisheries to seaweed farming, gender equity has increased in Maine's fisheries: with an increasing participation of women in seaweed (37 per cent) as compared to wild-caught fisheries such as lobsters (4 per cent) (McClenachan and Moulton, 2022).

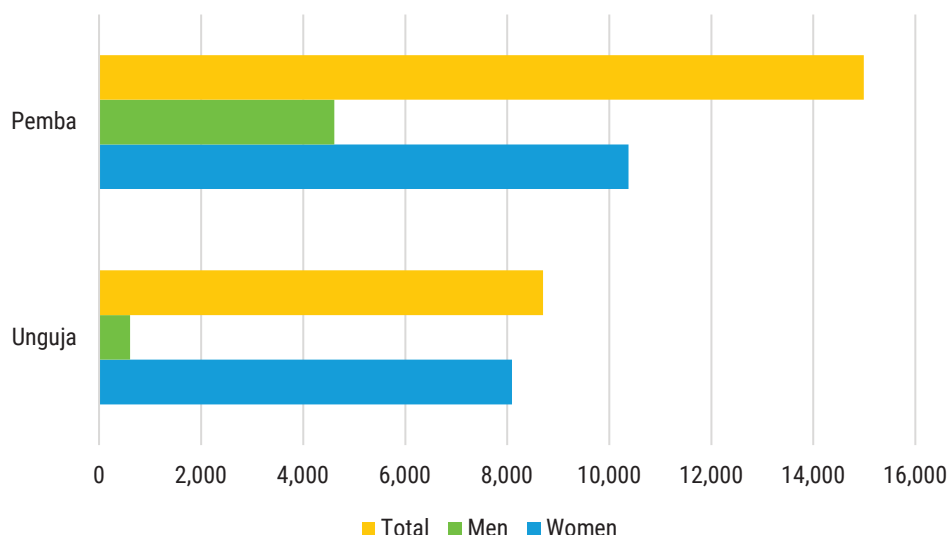
However, women tend to be overrepresented in this sector's lower-skilled, lower-paid roles as well as within the informal areas of the supply chain as stressed in case studies from Chile, the Philippines, the United States (Salazar et al., 2023; Mengo et al., 2023; McClenachan and Moulton, 2022). Women typically earn less than men and lack a voice in worker representation bodies (SMEP, 2023).

Enhanced awareness-raising to ensure the sector promotes women's development and participation is needed. In most developing countries women's participation in the seaweed industry accounts for much of the labour force in seaweed production and processing but women do not generally own farms (Msuya and Hurtado, 2017) despite being highly engaged in sector leadership roles, including in various sector organizations and groups, such as the International Seaweed Association, the Phycological Society of America, and the Global Seaweed Coalition. According to a study conducted in the Banyan islands of the Philippines on 711 seaweed farms, less than 30 per cent are women-owned seaweed farms, even if they constitute most of the workforce. Women also received a salary which is more than 50 per cent lower than those of men (Mengo et al., 2023), which could be the consequence of limited participation at management level and on decision making.

A similar pattern seems to be observed in relation to the predominance of women in the labour force of seaweed production in the United Republic of Tanzania. Recent research compiled by Msuya and Hurtado in two different locations of Zanzibar (i.e., Unguja and Pemba) based on data from the Ministry of

Agriculture and Fisheries shows that women are overrepresented in the seaweed industry. In Unguja 8094 women out of 8699 workers participate in the sector and Pemba 10378 women out of 14 990 workers do (Figure 11) (Msuya and Hurtado, 2017). The large female participation in the seaweed sector is not uncommon, as it is also found in other sectors such as agriculture, fisheries, and textile.

Figure 11. The role of women in the seaweed aquaculture of Zanzibar



Source: Elaborated by UNCTAD based on (Msuya and Hurtado, 2017). The role of women in seaweed aquaculture in the Western Indian Ocean and South-East Asia. *European Journal of Phycology*. 52(4):482–494.

4.1.c) Women safety and health concerns.

Overcoming certain safety issues emerged as a top factor affecting women's participation in the seaweed industry based on stakeholders' interviews and an Independent Food Systems Summit Dialogue organized by the GSC (GSC, 2021). Ability to swim and comfort in the water are particularly important because, compounded by the effects of climate change, women are seeking to farm in deeper waters and/or deep-water dive for seaweed. However, especially in parts of Africa and Asia, there are cultural stigmas against women swimming, which is limiting how women can farm seaweed, for instance only at low tide (Sultana et al., 2023).

Furthermore, the fact that the work takes place in the water, sometimes with heavy equipment and exposure to sharp objects, exacerbates the risk of serious accidents. Yet, basic first aid training is not typically available. Several interviewees highlighted that men and women often cooperate, co-produce and protect each other, including as family enterprises, with the men running the boats and the women handling the near-shore activities to reduce some of these risks.

In rural communities and informal operations, women do not have the same protections against conflict or violence as in a more regulated environment. Interviewees pointed to common social conflicts between seaweed farmers and others involved in marine activities, such as non-family fisherfolk. In some settings women face harassment or violence, whether it be verbal, physical, or sexual. Effectively implemented safety regulations and protections are lacking for women working in seaweed production, sometimes more broadly in the entire aquaculture sector limiting equal access to these opportunities.¹³ The effects of seaweed farming on women's health are mixed, with some experiencing pain and tiredness, while some experiencing health improvements, they attribute to being able to switch away from more physically demanding jobs (Forsberg and Vestling, 2018).

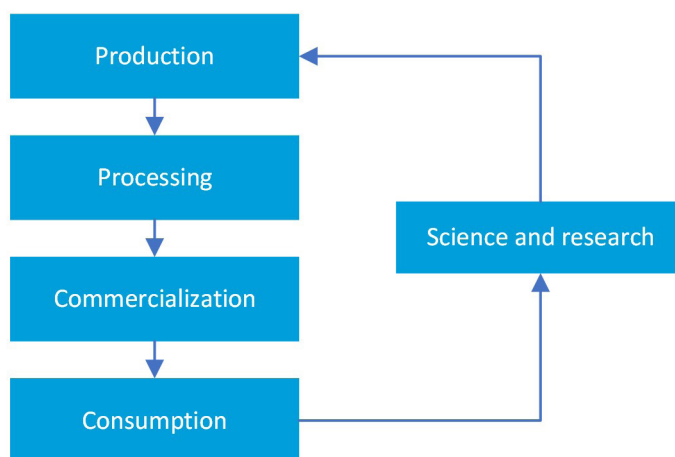
Integrating first aid and safety training into day-to-day business operations would help to reduce risks.

Expanding social security and introducing health insurance schemes for autonomous seaweed women farmers may also help respond to wider safety risks. Mediation in case of social conflict and quick guidance and support for individual and community actions in case of violence before competent authorities would be essential to prevent and repair any damage to people involved in this value chain.

4.2. Towards a gender inclusive value chain?

This section reviews women's participation throughout the value chain, from basic science and research through production, processing, commercialization, and consumption of the finished product. This section also provides a brief review of issues faced by vulnerable and marginalized groups involved in seaweed production. Few value chain studies, however, are disaggregated by gender. Therefore, this section significantly draws on the content of interviews with selected experts. Figure 12 shows a simplified flow diagram of the seaweed value chain which will be reviewed in this section.

Figure 12. The seaweed value chain



Source: Elaborated by UNCTAD, 2024.

4.2.a) Production (cultivation or wild collection)

Seaweed farming is an important source of livelihood for tens of thousands of families, particularly in Southeast Asia. Seaweed cultivation is often a family venture, with women not being directly paid for their efforts. In the Philippines and Indonesia, for example, seaweed farming is mostly considered a family enterprise in which family members assume different roles across the stages of production (Fitriana, 2017). The gender distribution of seaweed farmers in Asia is roughly even, while in Africa, seaweed cultivation is mostly done by women (Msuya and Hurtado, 2017).

Lack of regulation of tenure rights and marine special planning. Seaweed cultivation will not provide equality in access and economic opportunities for women if men are considered the “primary owners” of marine coastal activities. Lack of regulation and documentation of marine tenure rights in the seaweed industry especially affects women with informal production operations. In most countries, tenure rights have not been clarified through marine spatial planning¹⁴ tools and regulations.

To ensure seaweed production benefits women directly, tenure rights would need to be better clarified and secured. In both developed and developing countries, obtaining permits and certifications, such as specific diplomas from specific schools, can present barriers to women's entry into seaweed production. In such cases, and where shallow-water activities are not available, the proportion of women in the sector is low.¹⁵

On the other hand, as pointed out by an interviewee, lack of a clear regulatory framework can benefit women.¹⁶ In India, the concept of marine spatial planning is recent. Tenure security issues on land have

not been reproduced in the sea, allowing women to begin farming seaweed in these waters. Nevertheless, in general, marine spatial planning is an essential policy tool to avoid unnecessary competition and conflicts with other sustainable use activities such as fishing or tourism. The development of space allocation, through marine spatial planning, needs to be considered as a pre-condition to support the necessary expansion of seaweed farming (UNCTAD, 2022).

Low income and economic empowerment. While seaweed cultivation may constitute a source of economic empowerment, women remain disadvantaged in terms of power relations, earnings, and type of occupation within the sector. In Asian countries like India, Indonesia, Malaysia, the Philippines, and Sri Lanka, coastal women have engaged in seaweed farming to generate income and increase family earnings under community-based initiatives (Annex).

Women in the Philippines are involved in production, post-harvest, and marketing and contribute a considerable share to family income (Ramirez et al., 2020). Interviews carried out with women seaweed farmers in the Philippines suggest that gender power relations can be unbalanced in the context of seaweed farming activities. A recent case study of Bantayan Island in the Philippines examined women's influence over (1) seaweed farm operations decisions such as preparation and inputs or materials to buy, (2) use of income generated through seaweed production, (3) their ability to make health care decisions, and (4) to purchase items for the household (Mengo et al. 2023). Despite significantly more women than men engaged in seaweed farming, women on average earned less than men (regardless of whether the business was family-owned). The analysis demonstrated that roles and hours worked were different between genders, including across production phases in the seaweed farming activities.

Women were the earliest adopters of seaweed cultivation in India because seaweed was considered a source of income in a safe environment. The early success of women encouraged men to join in this sector (Msuya and Hurtado, 2017). In its fisheries sector strategy, the Indian government views seaweed foremost as a vehicle for economic empowerment of coastal women seeing both potential for employment gains as well as mitigating the risks of climate change (Ranjan, 2021). In Indonesia, seaweed farming had the most significant percentage of female involvement out of all types of aquacultures (Sultana et al., 2023). Women's involvement in it resulted in work satisfaction and social recognition, which is also observed in Malaysia and the Philippines (Msuya and Hurtado, 2017).

In a similar vein to terrestrial agriculture activities, seaweed cultivation and harvesting enables women to participate in an income-generating activity while still carrying out conventional household responsibilities (Sultana et al., 2023). According to several interviewees, women may be able to organize their household labour to have the needed flexibility to work around tidal and lunar cycles.¹⁷ Further, commercial seaweed harvesting has low capital and technological requirements for entry. In both developing and developed countries, the division of labour may involve women taking the lead in pre- and post-production, such as hatchery management, seedling preparation, cleaning, and segregation, and drying, while men take charge of farm construction, monitoring and harvesting.

4.2.b) Processing

Processing activities include cleaning, drying, and sorting seaweed before they are sold in markets, often to factories that will further process the raw material. Women face similar issues in seaweed processing as in production. Women often lack access to more advanced technology, technical knowledge and training, and suitable facilities for processing raw seaweed, creating a situation where intermediaries may have significant price-setting power.

Restricted access to and control over inputs and credit. The 4th United Nations Ocean Forum (UNCTAD, 2022), as well interviewees, highlighted a host of issues that mirror those facing women in developing countries more generally, including access to basic infrastructure, equipment, materials, technology, and finance.¹⁸ Ports, fresh water, electricity supply, drying, sorting, testing and storage technologies and facilities are preconditions to seaweed processing. In terms of finance, across many of the developing countries included in this analysis, such as Philippines, Indonesia, India, the United

Republic of Tanzania, and Kenya, women do not have access to assets for collateral (or even, assets in general), preventing them from accessing the financing needed to scale up their operations.¹⁹ As with agriculture, women often combine their financial forces to create informal mutual lending structures. Supporting financial inclusion efforts, enabling access to credit, facilitating collateral as well as the creation of women-led cooperatives would help women overcome business development barriers (Hermanson et al., 2021), thus increasing their revenue. The United Nations General Assembly resolution on “Promoting the Social and Solidarity Economy for Sustainable Development” (A/77/281) highlights how mutuals, cooperatives and other Social and Solidarity Economy entities help advance all SDGs (United Nations General Assembly, 2023).

Closely linked to unrecorded traditional knowledge. Family members from multiple generations take on varying roles across the different stages of production (J. G. B. Suvo et al., 2021). Combining technical knowledge with indigenous and local knowledge help farmers become resilient through the promotion of traditional stewardship practices on the tradability of produce and resilience of small-scale kelp fisheries. For instance, indigenous fishermen, researchers, and indigenous resource managers collectively became concerned about the resilience of feather boa kelp, culturally important for food and trade to Coastal First Nations on the Pacific coast of Canada, in the face of increased harvest pressure under warming ocean conditions and an emerging commercial market (Kobluk et al., 2021). Recording traditional knowledge and practices, with Indigenous Peoples prior informed consent, and shared benefits, still is a pending action needed to strengthen their participation in more formal value chains and to standardize production beyond the local context.

Insufficient harmonization of production and product standards. The 4th United Nations Ocean Forum, as well as GSC members, identified the lack of harmonized production and processing regulations and standards for seaweed across the value chain for multiple purposes as a top concern (UNCTAD, 2022; GSC, 2021). Their absence hinders the successful scale up of the sector, exacerbating the challenges that all producers, including women producers, and value chain actors already face. As mentioned earlier, FAO and WHO have incorporated seaweed-related standards into the Codex Alimentarius with the support of the GSC. Given that significant amounts of seaweed are traded internationally, the adoption of Codex standards applying to seaweed – or in their absence, regional or national standards regulating food safety hazards in seaweed – is recommended.

Among the few international standards, BioTrade Principles and Criteria allow for a value chain, ecosystem-based, and adaptive management approach which promotes conservation and improves livelihoods. Blue BioTrade is based on a set of agreed principles and criteria for marine biodiversity and has its own self-evaluation tools for the marine food and tourism sector (ITC, 2020). For example, the Organization of Eastern Caribbean States (OECS) recently started to develop and adapt the application of Blue BioTrade principles for seaweed (e.g., on sea moss and sargassum), by assessing their respective value chains strengths and weaknesses, and developing a regional action plan based on this experience to the queen conch mollusk (UNCTAD, 2022).

Biosecurity concerns. Biosecurity affects seaweed production and trade as a whole and therefore is also relevant for women. Pest and disease-related issues have been exacerbated by the combination of a rapidly expanding and globalizing industry with climate change impacts and increased coastal eutrophication. Seaweed farmers in the Philippines sustained income losses of \$32 million in one year between 2011 and 2012 due to seaweed disease outbreaks, poor quality cultivars, and natural disasters (Cottier-Cook et al., 2022). Similar economic losses have been experienced in Republic of Korea, the United Republic of Tanzania, and Indonesia (Cottier-Cook et al., 2022). The European Union, a large importer of seaweed and its extracts, identifies food safety as a top priority for expansion (CBI, 2023). In a positive development, Parties to the FAO’s International Plant Protection Convention (IPPC), which seeks to protect plant resources and farmers from economically devastating consequences of pest and disease outbreaks, have recently recommended the inclusion of aquatic and algal species within its coverage (Rusekwa et al., 2020 ;FAO, 2017).

4.2.c) Commercialization

Price negotiating capacity. Several interviewees underscored the limited access of small-scale women entrepreneurs to price and other market information and services that could help them to expand their operations. This is exacerbated by the added markup intermediaries, usually men, included to the price of products to international buyers.²⁰ Without real-time basic market data such as prices, women have limited negotiating power with intermediary as exemplified in Table 3. Better access to price and market information could help women negotiate and target appropriate buyers. Another associated challenge is the fact that in several countries the tax system does not explicitly incorporate seaweed production as an economic activity.

Table 3. Annual costs and returns of woman and man owned off-bottom plots in Zanzibar

Item	Woman owned off bottom plot (Tsh.)	Man owned off bottom plot (Tsh.)
Revenue	171,990	343,980
Labor cost		
Tying seed	9,600	19,200
Planting	600	600
Farm management	900	900
Harvesting	3,150	45,150
Carrying to dry: cart	14,000	28,000
Packing	66	131
Carrying to market: cart	1,050	2,100
Tie - tie separation	4,500	9,000
Depreciation	33,712	44,246
Total annual costs	67,577	149,327
Annual net profit	104,413	194,653

Source: Elaborated by UNCTAD based on (Msuya FE, Shalli MS, Sullivan K, Crawford B, Tobey J, Mmochi AJ, 2007) A comparative economic analysis of two seaweed farming methods in Tanzania. The Sustainable Coastal Communities and Ecosystems Program. Coastal Resources Center, University of Rhode Island and the Western Indian Ocean Marine Science Association.

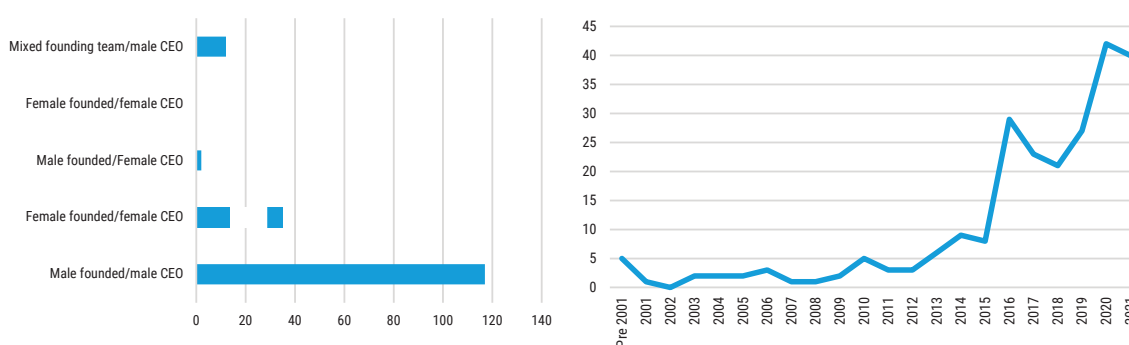
Complex product and safety registration. Due to the complexity of product and safety registration, women entering the formal sector may face unexpected hurdles. Many women engaged in transformation activities want to tap into higher value markets like nutraceuticals, food, and personal care. These markets typically have higher quality standards and require information about sourcing, product harmlessness, safety, and traceability from farm to consumption. Usually, safety and claims standards for nutraceuticals and food are much higher than those for cosmetics and beauty. Experience from the Blue BioTrade regional plan of action for the Eastern Caribbean on the queen conch value chain (UNCTAD and OECS, 2022) can provide an interesting road map and methodology to respond to these concerns.

Scarce access to digital literacy for commercialization. Another issue for small-scale women producers is the “closed and limited support network” in which they receive low pay with high daily targets. Cultural norms and practices can be biased towards men, affecting women’s access to business training and capacity building activities, including in digital literacy. As a result, they often learn about seaweed farming and marketing either from family members or other farmers in the community. Similarly, women disproportionately lack access to the internet, especially in the LDCs, where 43 per cent of men but only 30 per cent of women use the internet (ITU, 2022). These asymmetries can be even worse in rural and

coastal areas. Governments, from national to local levels can support by expanding new technologies use and digital literacy to women for commercialization and payment systems.

Start-up opportunities and for women-led value addition. There is a rising number of startups in the seaweed production industry demonstrating the growing interest of investors to seize opportunities stemming from the rich nutritional, cosmetic, and material properties of seaweed. Since 2016, a significant increase in the number of female-founded startups have entered the seaweed space as show in Figure 13 (Phyconomy, 2022) demonstrating the women's will to engage in adding value and developing product and innovation based on seaweed, despite financial limitations.

Figure 13. Number of startups and gender-based leadership in the seaweed sector



Source: Elaborated by UNCTAD 2023, based on Hermans S (2023). State of the seaweed industry Report.

4.2.d) Consumption

Diverse consumption patterns. Seaweed consumption varies widely across the globe, with sharp delineation between East Asian and Western culinary cultures. Accessibility to diverse types of seaweed depends on location and the national market with prices that vary globally. Especially in developing countries, distance from the coast limits access to seaweed products. In countries with only a short history of seaweed consumption, people may not know how seaweed can help address food and nutrition insecurity.

Food and nutrition choices. Women are often the food decision-makers in a household, their food and nutrition choices influence the level of seaweed consumption for other family members (Sariyev et al., 2020). Age, job status, and education levels of food-decision makers may each affect seaweed consumption decisions. The relative easiness with which seaweed can be prepared can also facilitate their adoption (Peng et al., 2021).

Research on seaweed's nutritional value for women remains sparse. At least one study showed that consuming dietary iodine and seaweed may help reduce metabolic syndrome in postmenopausal women (Park et al., 2021). Seaweeds can also help address deficiencies in iron, Vitamin A, and iodine, which are some of the most common malnutrition issues globally, with of micronutrient deficiencies more pronounced in developing countries (WHO, 2023), especially among pregnant women and children.

Introducing seaweed to women, awareness of their dietary knowledge, and how to use of cook them, especially in coastal communities where it is readily available, can contribute to global food and nutritional security. This can be facilitated by tapping knowledge of seaweed consuming cultures. Where seaweed is not a traditional food source, greater efforts to integrate it into daily diets would likely be more effective than introducing it directly as a standalone food.²¹

4.2.e) Science and research

Women's engagement in the seaweed value chain extends to the science and research sphere. The issues identified above point to a need for more research, based in biology, economics, sociology, psychology, and other social science disciplines, to better understand women's involvement in the seaweed sector.

Young women researchers in developing countries have limited access to technology, technical training, and greater opportunities for advanced education.²² Women researchers should be exposed to seaweed and marine science that is specific to their communities and regions while being connected globally. Researchers in developing countries generally, and by extension women researchers there, do not have centralized access to the global networks that are essential to connecting with other seaweed researchers around the world.

Knowledge-sharing in the seaweed scientific community is essential as the sector is emerging and new methods and findings may allow different regions to grow a more sustainable and scalable seaweed industry. Interviewees evoked the sustainable agriculture sector as a possible model to follow, noting that the Consultative Group for International Agricultural Research (CGIAR) comprises several research institutes, such as the International Food Policy Research Institute (IFPRI), the International Rice Research Institute (Philippines) and International Potato Center (Peru).²³ While the mandate of WorldFish (Malaysia) extends to both fisheries and aquaculture, no international research center is devoted uniquely to seaweed.

Low level of gender inclusiveness in scientific research. There is a growing recognition of the importance of integrating social, economic, and political research with scientific analysis (Chopin and Ugarte, 2006). For women researchers and practitioners supporting the seaweed sector, career advancement can depend critically on access to networking opportunities, including by attending global seaweed conferences and trade fairs and joining existing industry coalitions or research consortiums.

A recent study of seaweed producers from central-southern Chile explored the role of psychological differences between men and women to understand why women producers remained at a disadvantage (Salazar et al., 2023). Results show that female producers may exhibit more positive psychological traits such as patience and interpersonal trust. However, women's choices in seaweed farming may be incongruent with these characteristics, as they may need more immediate returns than males.

To co-develop gender-sensitive and inclusive approaches to seaweed production that better support farmers' diverse needs, policymakers can build on research on attitudes, risk responses and coping strategies, combining this with emerging scientific understanding of biosecurity and environmental change (Asri et al., 2022). In considering introducing industrial scale commercial production of seaweed, public and private sector actors alike can more thoroughly assess the potential impacts of scaling up by explicitly assessing the economic and social impacts for women. These may include extra income earned from seaweed and other factors affecting well-being such as transport, housing, basic needs, and education (Larson et al., 2020). More such applications of social science may be useful to better understand the nuanced experience of women in this sector. Assessing different economic models, such as cooperative and other collective models, could also benefit women.

Empirical research indicates that women are crucial to the production, processing, commercialization, and consumption of seaweed. Yet several horizontal and specific variables tend to limit the growth of women's engagement in these activities. While women's participation in the seaweed industry accounts for a large portion of the labour force, there is little to no official reporting on women's labour force participation along the value chain. The absence of harmonized production and processing regulations leaves a gap between practice and knowledge in the seaweed industry negatively impacting women. Developing gender-sensitive and inclusive approaches to seaweed production that better serve the variety of demands of women farmers requires further scientific research.

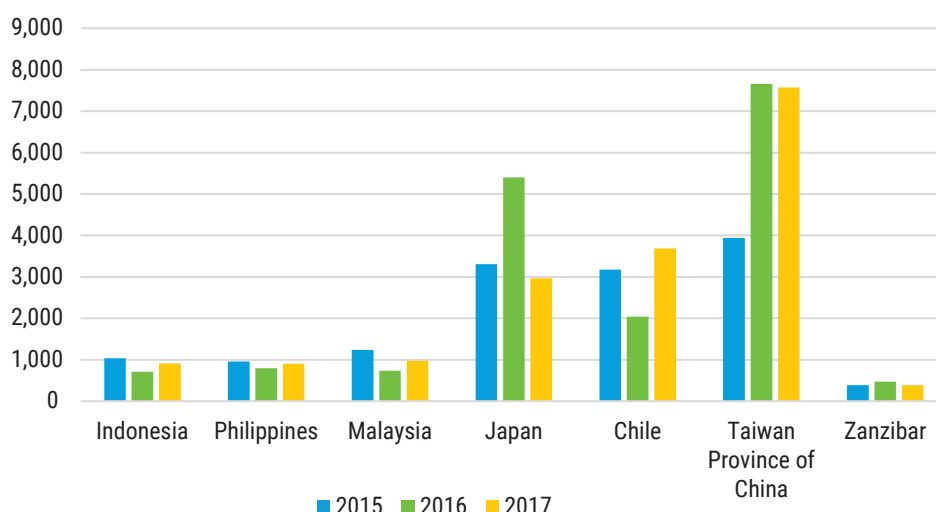
4.3. Lessons learnt from the United Republic of Tanzania, Portugal, and Kenya

4.3.a) Women empowerment in Africa's largest seaweed producer and exporter

The African continent is just beginning to explore its potential for seaweed development. The African Union Development Agency has started working on seaweed and the blue economy.²⁴ However, seaweed is not yet included as a product in the Africa Continental Free Trade Area (AfCFTA) e-Tariff Book and Portal (Annex). The United Republic of Tanzania is the largest African producer and exporter of seaweed,

thanks to an industry built around farming of spiny Eucheuma and elkhorn sea moss (Kappaphycus) in Zanzibar. The fluctuation of its seaweed output has undermined its position in the international market (Msafiri, 2021). When compared to top producers which export value-added seaweed products with higher prices, Zanzibar seaweed's lower seaweed prices are probably caused by the seaweed's minimal processing and value addition (Figure 14).

Figure 14. Seaweed price differentiations in international market



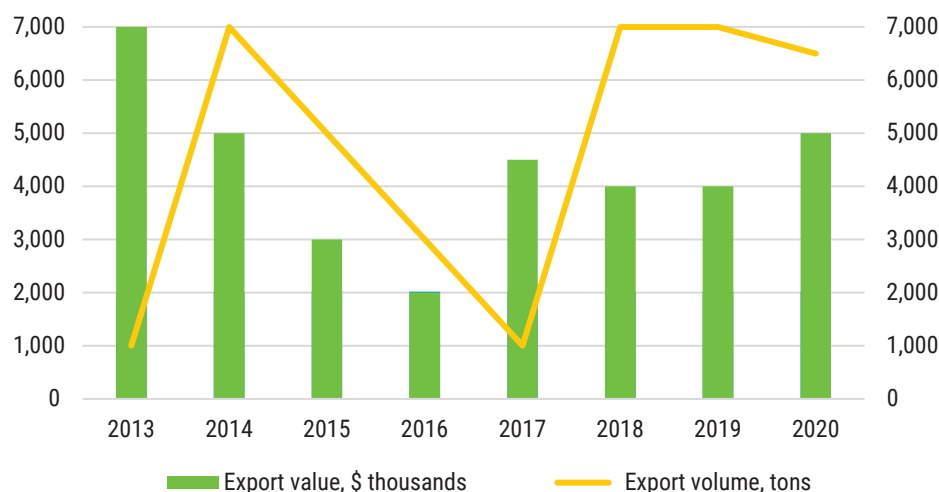
Source: Elaborated by UNCTAD based on (Msafiri, 2021). Enhancing Competitiveness of Seaweed Industry in Zanzibar. Repoa Brief 6/2021.

In 1989, fisherfolk in Zanzibar began farming seaweed to diversify their incomes. As men continued to fish or work in tourism, women dominated the nascent seaweed farming industry (Brugere et al. 2020). They saw seaweed farming as an untouched and underrated opportunity. Women from marginalized groups, such as divorced or widowed women, turned to seaweed with limited capital (Msuya, 2006). The seaweed industry has created new opportunities for women to generate incomes²⁵ as women farm, process, and market seaweed (Brugere et al. 2020).



In the mid-2010s declining production attributed to warming seas pushed production farther out to sea, initially leading to issues as the women were unable to swim (Figure 15). To help ensure the activity remained accessible to women, other farmers, research groups, and industry stakeholders began to offer them swimming lessons (GSC, 2020). The rise of diseases, such as ice-ice disease and epiphyte infestation (FAO, 2020) as well as climate instability have also put in jeopardy the ecosystem upon which 20,000 seaweed farmers' livelihoods are based, affecting mostly women and youth (FAO, 2021).

Figure 15. Seaweed export value and volume in Zanzibar (2013–2021)



Source: Elaborated by UNCTAD based on (Msafiri, 2021). Enhancing Competitiveness of Seaweed Industry in Zanzibar. Repoa Brief 6/2021.

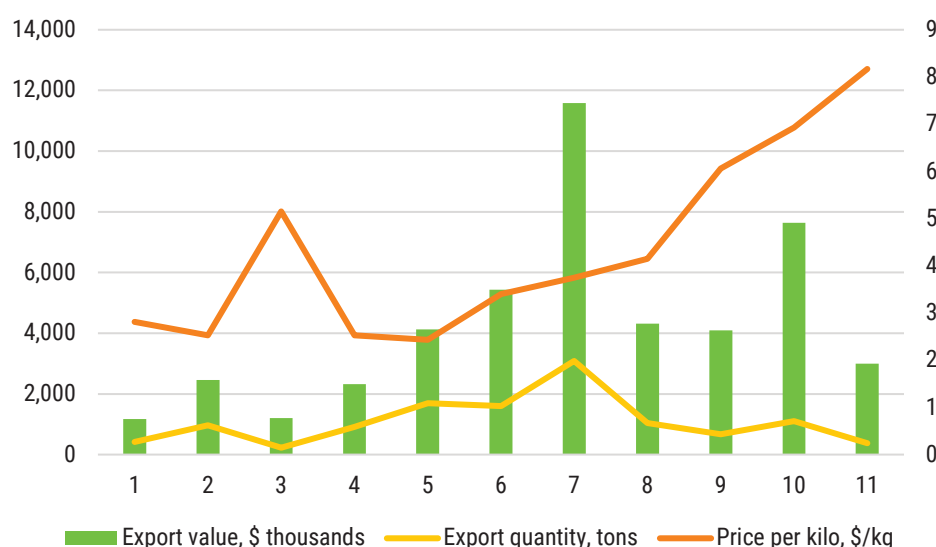
Women saw an opportunity to become more involved in the industry, but they struggled to make it lucrative and sustainable. They worked in harsh conditions, with excess exposure to sun and saltwater through long hours of work with little technical and safety knowledge (GSC, 2020). Through women-led training activities and support, education, and growing access to resources provided by multistakeholder coalitions and government support, Zanzibar began addressing these challenges and furthered the seaweed industry as a vital opportunity for women's development and involvement. More is needed to add value addition, biosecurity planning, use of modern technologies and product differentiation to ensure a fairer, more competitive, and better prices for Zanzibar and other the United Republic of Tanzania producers.

Today, women in Zanzibar produce and sell many seaweed-based items such as soaps, skincare, food, and sanitation products. These items are typically sold within the community, but there is interest by the women to expand their trade across the African continent and even globally. The women-led seaweed industry in Zanzibar also created social and cultural ripple effects. With their newfound products and income, women socialize while working, travel to share their knowledge of seaweed cultivation, create value-added products, and strengthen their family's health outcomes by integrating seaweed into their diets (Msuya, 2006).

4.3.b) Portugal's innovative women led land-based system to farm seaweed

The seaweed ecosystem on mainland Portugal and its two archipelagos - the Azores and the Madeira Islands- is particularly diverse. Environmental factors, such as the latitudinal gradients have a distinctive impact on the continental Portugal's maritime shoreline, contributing to its vast diversity (Gaspar et al., 2019). Seaweed has been harvested for use as fertilizer since at least the 14th century (Netalgae, n.d.). Portugal used to be a major global supplier of seaweed-based agar in the 1960s. Portuguese seaweeds are currently an underutilized natural resource, despite being abundant and lucrative, especially considering that the price per kg of seaweed almost tripled in 10 years between 2012-2022 (Figure 16).

Figure 16. Export value of seaweed in Portugal (2012–2022)



Source: Elaborated by UNCTAD based on (Selina Wamucci, 2023). Portugal Seaweed Prices. Insights.

Currently, the trend is being reversed with increasing investment and research in seaweed production and farming “to cultivate seaweed varieties which have been selected according to producer and consumer preferences” (European Commission, 2023). As noted by an interviewee, “in Portugal seaweed is available to people, [both] fresh and dried seaweed” and in all supermarkets—large wholesalers (Abreu, 2023). Azores-based SeaExpert harvest nine different species of algae they dry in green houses and solar dryers, to be sold to makers of cosmetics, supplements, and livestock feed under global sustainable seaweed production standard “Friend of the Sea” (Geoffrey, 2021). A pilot project was recently launched south of Lisbon to produce seaweed in the open sea for distribution and commercialization in the pharmaceutical industry, for human consumption as well as biofuels and plastics (TPN, 2022).

From the numerous examples, ALGAplus, a woman-led business founded in 2012, stands out because it uses an innovative land-based system to farm several seaweed species, including the only European commercial-scale hatchery of the species *Porphyra* (also known as Atlantic nori).²⁶ Its production model integrates organically certified fish aquaculture, with controlled and sustainable seaweed farming. It processes Atlantic seaweed species to serve mostly food and cosmetics markets all the while promoting quality seaweed which have been grown in Portugal, sustainably, with transparency and traceability (Interview with ALGAplus).

The firm’s mission also includes educating the next generation. It receives students of all age ranges and provides tours of its IMTA facilities and educational programming. ALGAplus has partnerships with municipalities and at the country level through the “Blue School” initiative, which provides activities for schools to engage with their facilities. Through this programming, ALGAplus familiarizes students with its aquaculture production operation and different seaweed species together with the diverse range of products that can be produced from them. It also highlights its research and development and innovations in seaweed production and applications beyond food, into biomaterials, biomedical applications, and animal feed additives.

4.3.c) Women’s leading role in removing plastic in seaweed farming practices in Kenya

Seaweed farming is an environmentally friendly industry that has gained popularity in recent years. However, there are environmental impacts that must be considered and mitigated. Seaweed farms use plastic ropes to attach spores during the growth process. This farming method of farming is effective, but these plastic ropes are non-biodegradable and hazardous to the environment while in use and are a major

source of micro-plastic pollution. Old and discarded ropes are either burned or discarded in nature.

Global warming has forced farmers to adapt their farming practices and to move their farms to deeper cooler waters with higher prevalence of the ropes being lost. To mitigate these impacts, Catchgreen, in partnership with the Kenyan Marine and Fisheries Research Institute (KMFRI) and the Kibuyuni Beach Management Unit (BMU) in Kenya, is piloting Biodolomer®Ocean ropes with the support of UNCTAD (UNCTAD, 2023b). These biodegradable ropes are designed to reduce toxic plastic accumulation in the ocean as it only takes approximately only 2 years for Biodolomer®Ocean to break down without any toxins or microplastics.

The women in Kibuyuni village in Kenya are taking part in the piloting of the Biodolomer®Ocean ropes. The women have planted seaweed with the Biodolomer ropes side by side with normal plastic ropes and will take weekly measurements to compare the growth rate and dry biomass of the two types of ropes. The ropes will be tested regularly for strength and biodegradability and to ensure that their natural decomposition does not harm the marine ecosystem. The one-year pilot started in August 2023. The first measurement of the ropes taken after two weeks showed that the seaweed had taken to the biodegradable ropes and grown to a similar size as to those that were planted on normal plastic ropes.

Seaweed farming in Kibuyini in Kenya village presents an opportunity for women to take part in scientific seaweed research allowing them to take ownership of their own future by enabling them to improve their livelihoods while also benefiting the environment. Local women seaweed farmers have reported how it allowed them to send their children to school, renovate their homes, while contributing to the health of the local ecosystem. With the support of KMFRI scientists, the women have been taught how to plant, harvest, and process seaweed for the export market. Some of the village youths have been encouraged to add value to the seaweed industry by making various cosmetic products.

Overall, relevant countries would benefit from including seaweed gender inclusive policies in their national development strategies given the seaweed's significant growth potential and contribution to food security, gender equality, and climate action. Because the production of seaweed uses fewer resources than traditional aquaculture, it makes the industry more accessible to women than traditional aquaculture. However, significant technical assistance and financial support is needed to formalize existing cultivation in developing countries and improve disease control, value addition, product differentiation, fair pricing, and ultimately competitiveness in this emerging sector. Women-owned businesses in developing countries can then successfully combine seaweed cultivation with ecology along the value chain.

5. Conclusions

This section presents various lines of action to respond to the challenges and to seize the opportunities identified in this study for developing a gender inclusive seaweed sector that advances many of the SDGs. It also offers a pathway to remove the barriers to scaling up seaweed production.

These considerations also draw upon the outcomes of from the 4th United Nations Oceans Forum on Trade-related Aspects of SDG 14 (2022) and the 2022 United Nations Ocean Conference, and the Global Seaweed Coalition dialogues. They are aimed at strengthening women's economic empowerment and food security while advancing climate and other environmental goals. They are classified by actors: government and regulators, businesses, civil society including women's organizations, and academia and research centers.

5.1. Responding to challenges

Addressing safety and health concerns. A top priority for government regulators is providing adequate infrastructure, including sanitary facilities where women engage in production and processing activities such as seaweed drying and cleaning. Technical cooperation, business support agencies and academia engaged in the development and delivery of gender-oriented training programs, can consult women in the sector on their specific priorities and review the content and delivery of training programs while incorporating specific cultural dimensions to tailor to the beneficiaries.

Promoting cooperation and access to information. Supporting the creation or broadening of cooperatives of producers and processors is critical to strengthening women's market position in the seaweed industry. Ensuring reliable and affordable internet access can ensure that women have timely and direct access to relevant technical and financial information, and market intelligence.

Improving data gathering, availability and quality. This report draws on data available through open-source databases managed by UNCTAD and FAO, as well as individual papers and interviewee observations. The analysis has confirmed that the lack, poor quality, and inconsistency of data remain a fundamental issue. Employment data for seaweed production and processing are not gender disaggregated at national levels. Further, jobs in the seaweed sector are typically not disaggregated from those in aquaculture. This absence of data undervalues women's involvement in the sector, even in countries where their engagement is significant, such as the Philippines, Indonesia, Malaysia, the United Republic of Tanzania, and India. Nationally produced seaweed data is needed to feed into global databases and record consistently and accurately production, trade, and labour force participation, disaggregated by gender.

Advocating for production standards and sector formalization to promote market access. Government regulations have played a mixed role. While some have facilitated sustainable aquaculture expansion, for example in many Asian countries, Norway, and Chile, in other regions, including the European Union and the United States, government regulations may often slow down growth. Effective marine spatial planning to avoid user conflicts is frequently lacking. The absence of harmonized cultivation and processing standards, including operational, environmental, and consumer safety standards, creates a barrier for expansion of sector. Standardizing and regulations of seaweed commercialization can unleash opportunities for the seaweed sector. Governments and supranational institutions have an important role to play, however, to ensuring women have equal access to these opportunities. Governments will need to monitor the formalization of these enterprises and start issuing seaweed farming licenses at the appropriate moment. Furthermore, the lack of institutional attention to seaweed could be considered to constitute a non-tariff barrier to trade. For example, not tracking seaweed's origin and nutritional information explicitly or meaningfully, as is the case for many countries, obscures issues related to seaweed trade in both internal and external markets.

Assessing biosecurity risks. Recognizing the risks and potential impacts of pathogen transfer to

receiving nations is fundamental for expansion of international trade. Seaweed cultivation faces chronic risks of pathogens, parasites, and pests, amplified by the intensification of production and increased trade and supply chain integration since 2000. Technical remedies to combat these problems have included therapeutics and selective breeding (Sugumaran et al., 2022). Introducing scientifically established and tested biosecurity protocols will form an integral component of a whole value-chain approach for de-risking aquaculture supply chains.

At the international level, clearly including cultivated seaweeds in international biosecurity measures will help identify the respective roles and responsibilities of international organizations and their frameworks. Further, more evidence-based research is needed to develop effective biosecurity frameworks that better align measures in international frameworks with the seaweed industry's biosecurity challenges. The IPPC measures mentioned earlier can be developed for all cultivated seaweed species and include all the biosecurity challenges faced by the seaweed industry. The development of global sanitary and biosecurity standards and best practices for biosecurity would support national and regional efforts.

5.2. Seizing opportunities

Building on integrated multi-trophic aquaculture (IMTA). Incorporating IMTA systems into marine spatial planning and national development strategies could help achieve multiple sustainability objectives and may encourage women, especially in developing countries, to explore IMTA systems as a means of improving the quality of their products, diversifying their incomes and enable circularity of production.

Adding value. Processing and transforming seaweed stuffs locally presents an opportunity for women in developing countries to benefit directly from income generation and value-addition. Developing countries may wish to explore how to transfer the Zanzibar model which showcases how women seaweed farmers can also generate sustainable livelihoods through value addition, such as creating soaps, lotions, and food products.

Adopting systemic approaches. Systemic approaches, such as a parallel food and ecosystems management approach through adequate policies and programs can help ensure more robust development of seaweed farming while respecting surrounding ecosystems. Doing so will help identify interlinkages across a broad set of dimensions, including nutrition, equity, justice, environment, and trade-offs across land and sea use. In another example, an integrated seaweed/eco-tourism strategy could involve linking hotels and tour operators with seaweed entrepreneurs, to make locally made value-added seaweed products available to tourists, hotels, and restaurants and showcase the local economy, ecosystems, and culture.

Incorporating socio-economic considerations. Explicitly assessing the economic and social impacts on women of new policy initiatives, including through ex ante gender impact assessments and data gathering, can help ensure new policy initiatives are supportive of women's engagement in the seaweed sector.

Facilitating women seaweed entrepreneurship. By supporting women to organize themselves into cooperatives or other associations can help strengthen their agency and redress power imbalances across the value chain.

5.3. Next steps for stakeholders

5.3.a) For governments and regulators

- Incorporating the seaweed sector into national development and ocean economy planning, including countries' implementation of the Biodiversity Beyond National Jurisdiction Treaty, Nationally Determined Contributions (NDCs), and National Adaptation Plans (NAPs), under gender lenses with explicit attention to increase women's resilience to climate change in the seaweed sector.
- Promoting IMTA trainings and ventures for women, especially in developing countries, to strengthen livelihoods and improve environmental sustainability and circularity. Countries with intensive aquaculture

industries can introduce seaweed specific projects both to mitigate the environmental impact and foster economic diversification.

- Promote and regulate certain forms of sustainable use within marine protected areas to encompass kelp forests and seagrasses while in parallel assess the impact on coastal and marginalized communities (including using ex ante gender impact assessments), to help achieve biodiversity objectives and protect livelihoods of local populations, especially women.
- Reviewing regulations and policies, including marine spatial planning, permits and taxation, to ensure they incentivize women entrepreneurs' entry into the formal sector and review marine tenure rights and how women can access to benefit from these rights.
- Exploring the interest of seaweed women producers and traders to adopt relevant and available safety and social responsibility guidance and standards, including the Draft FAO's social responsibility guide for the fisheries and aquaculture sectors, UNCTAD's BioTrade principles and criteria and certifications such as the Aquaculture Stewardship Council and Marine Stewardship Council Seaweed Standard.
- Encouraging the training, use and adoption of Codex standards applying to seaweed – or in their absence, regional or national standards regulating food safety hazards in seaweed to facilitate international trade in seaweed.

5.3.b) For businesses

- Invest in targeted R&D to assess whether certain seaweeds can effectively be used as a feed additive to reduce livestock methane emissions while paying close attention to impacts across the entire value chain, from animal health through to consumers, with emphasis on women.
- Promoting and supporting mechanisms that allow women to access insurance, finance, and technical support at all levels of the value chain so they can be better integrated into the formal economy.

5.3.c) For civil society/women's associations

- Participating and advocating for the harmonization of seaweed production, quality, and safety standards taking into account women's health needs.
- Consolidating responsibility for tracking progress with a single organization.
- Leading the creation of a classification and risk assessment systems for quality.

5.3.d) For academia and research centres

- Developing rigorous scientific research into development of best practices for measuring and using seaweed to sequester carbon and reduce atmospheric carbon dioxide.
- Investing in collaboration on seaweed research and development, in developing countries and at the global level, through the creation of a global research consortium on seaweed that convenes seaweed stakeholders including women scientists, policy experts, civil society, international institutions, and the public and private sector.
- Using this consortium to help female students in developing countries access top researchers throughout the world, including helping them overcome language barriers.
- Relying on this collaborative space to support integrated and interdisciplinary seaweed thinking that recognizes women contributions across issue areas. That would include incorporating seaweed into SDG14 tracking and integrating it into other SDG indicators, such as the Food Insecurity Experience Scale used for Goal 2 – Zero Hunger.
- Developing a strong scientific evidence base of biosecurity risks and best practices for their management, while ensuring that international policy frameworks explicitly include the global seaweed industry, to limit the impact of diseases and pests.
- Adapting terrestrial biosecurity mitigation measures, when appropriate, to prevent the circulation and persistence of pathogens and combat declining seaweed production in certain developing countries.
- Supporting additional research to quantify seaweeds' nutritional benefits and any possible adverse effects (from hazards such as heavy metals and marine biotoxins), particularly for women as a distinct target population.

Important areas for research include: (i) nutritional composition and other factors that can substantially

affect seaweeds' dietary value, such as species, geographical regions, and seasons; (ii) bioavailability and factors that affect it, including preparation and the role of the gut microbiome; (iii) the role of human metabolism; and (iv) the effects of harvesting, storage, and food processing techniques.

As an overarching support to facilitate the implementation of these recommendations, an inter-agency United Nations seaweed and gender task force could also be set up to coordinate these efforts through UNCTAD secretariat and research support.

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Annex – Regional and subregional analysis on production and trade

Developing countries

- East Asia

As mentioned above, China dominates global kelp cultivation and production. The three top species of seaweed China produces are *Saccharina Japonica*, *Gracilaria*, and *Undaria Pinnatifida*. China's main seaweed trading partners are Japan, Association of Southeast Asian Nations (ASEAN), Chile, Peru, and the Republic of Korea. Its total trade value of seaweed products has grown rapidly, with imports gradually exceeding exports from 2011. Chinese demand can be a pull factor for production and trade of seaweed in Asia, Africa, and Latin America.

However, its aquaculture industry is suffering from several factors, including: “declining germplasm diversity, degradation of agronomic traits, the presence of polluted environments, changing ocean conditions and increasing anthropological interference” (Hu et al., 2021). Losses in *Porphyra* farming due to disease reached \$410 million in 2021 (Cottier-Cook et al., 2022). Further, China's seaweed products have gradually been experiencing declining competitiveness, likely owing to “changing trade commodity structure, insufficient product differentiation of the main exported commodities in the last decades, low support by China's industrial policies, increased government support in competitors, and trade barriers among the partners” (Kang et al., 2023).

- Southeast Asia

Southeast Asia's total production is reported at 11.3 million tons (live weight). Indonesia, the Philippines, and Malaysia dominate production in the region. The main species produced in the region include *Eucheuma*, *Gracilaria* spp., and *Kappaphycus alvarezii*. Southeast Asia exported \$228 million of seaweed in 2020, making the region the world's top exporter (FAO, 2023).

The top producers in Southeast Asia include countries that are experiencing warming temperatures, sea level rise, and extreme weather events such as intensifying and more frequent typhoons. Some countries outside of Southeast Asia are thus seeing an opening in the market and new opportunities to grow their seaweed sectors to meet global demand.

Seaweed production in Indonesia comes almost exclusively from community-based farming activities. The industry has expanded at an unprecedented rate since 2010 to position the country as a major producer (Larson et al., 2020). In 2020, Indonesia produced 9.7 million tons of seaweed species such as *Eucheuma* and *Gracilaria* exported \$183.4 million of seaweed, and imported \$6.1 million (FAO, 2023). Here too, women are highly involved in seaweed production, processing, and post-harvest activities, yet despite these contributions, they are often denied fair pay, have limited access to markets and resources to scale up operations, and are not equitably represented in key decision-making processes.

The Philippines is an important exporter of red seaweeds, producing 1.5 million tons in 2020, mainly elkhorn sea moss, spiny *Eucheuma*, and *Caulerpa*, and exporting \$28 million worth (imports were \$4 million) (FAO, 2023). As with other producers in Southeast Asia such as Indonesia and Malaysia, the Philippines' exports decreased in 2020 and its imports increased.

Malaysia, not far behind the Philippines and Indonesia, is the eighth largest producer of seaweed globally. Production in 2020 was 182,100 tons, mainly elkhorn sea moss (*Kappaphycus*) (FAO, 2023). Malaysia imports more seaweed than it exports, however its exports are steadily on the rise notwithstanding a slight decrease between 2019 and 2022. In 2020, Malaysia exported \$36.4 million worth of seaweed and imported \$62.5 million.

- South Asia

India is the main seaweed producer in South Asia, reporting production at 23,300 tons (live weight) in 2020 (FAO, 2023). With its long coastline and variety of ecosystems, India has significant potential to develop its seaweed industry for food and multiple other uses. India mainly produces green seaweeds, followed by red and brown seaweeds. The government has identified six cultivable species: *Kappaphycus alvarezii*, *Gracilaria* (*edulis* and *dura*), *Sargassum*, *Turbinaria*, and *Gelidiella acerosa*. It envisages significant growth in production from 25,000 tons in 2020 to 1.12 million tons in 2025 (Department of Fisheries, GoI, 2020). In 2020, India reported imports at \$2.9 million, making it one of the major global importers of seaweed, while exports were \$773,000 (UNCTADStat 2023; See Msuya and Hurtado (2017) for a historical overview of seaweed production in India. India also sees potential for employment gains as well as mitigating the risks of climate change (Ranjan, 2021).

Government priorities include supporting formation and promotion of producer organizations and supporting cooperatives and women's stakeholder groups in coastal areas with seaweed cultivation potential. Additional policy measures identified by the Indian Department of Fisheries include enhancing seed availability, promoting Indigenous species, allowing collection of native species outside areas restricted for industrial use, and scaling up production through collaboration between research institutions and state governments (Interview with Department of Fisheries, GoI, 2020).

India's seaweed sector also holds promise on the biotechnology frontier. As but one example, a firm developed seaweed into a biodegradable material that can be used for plastic substitutes and alternative packaging such as bags, film for food, and several other plastic packaging alternatives.²⁷

- Africa

Over 2,000 species of seaweed, some of which are already successfully cultivated in other parts of the world, have been recorded in Africa. Multiple ecosystems across the African continent, from warm and tropical to cooler and nutrient-rich, enable cultivation of a rich variety of seaweeds. Native seaweeds range from dense kelp forests in the cool southern waters to carrageenan-producing red algal species in the warm tropical waters of the United Republic of Tanzania. Women dominate seaweed aquaculture in Africa, and interest in seaweed cultivation is growing.

Yet, Africa is just beginning to explore its potential for seaweed development. Continent-wide, institutions are beginning to pay attention to seaweed. The African Union Development Agency has started working on seaweed and the blue economy.²⁸ However, seaweed is not yet included as a product in the Africa Continental Free Trade Area (AfCFTA) e-Tariff Book and Portal.

Africa reported total production of 134,600 tons in 2020. the United Republic of Tanzania is by far the continent's largest producer and exporter, with 92 per cent of its production (91,700 tons in 2020), followed by Morocco and South Africa (FAO, 2023). The main species cultivated are *Eucheuma* and *Kappaphycus* in the tropical waters and *Ulva* and *Gracilaria* in South Africa. Africa is the third-largest producer of red eucheumatoid seaweeds in the world, led by the United Republic of Tanzania, with Madagascar a distant second (FAO, 2023). Countries such as the United Republic of Tanzania, Morocco, and Madagascar are scaling up their seaweed industries. Others, including Kenya, Morocco, Mozambique, Namibia, and Senegal, are either producing or have just recently started producing seaweeds (FAO, 2020, 2023). Trade is dominated by exports, mostly to Asia; in 2020 exports were \$14.7 million and imports \$3.8 million (UNCTADStat, 2023).

- Americas

Chile is South America's largest producer of seaweed and the sixth producer of seaweed globally. In 2020, Chile reported production at 428.9 thousand tons (live weight), mainly *Durvillaea antarctica* (Chilean kelp), followed by *Lessonia trabeculata* and *Gracilaria* (FishStatJ, 2022). Its exports were \$87.4 million in 2020, while its imports were \$13.8 million (UNCTADStat, 2022). Chile produces a rich variety of seaweed species that historically were used either to produce hydrocolloids or exported as dried material to processors in

Asia and Europe. In 2018, the government began exploring subsidies to support the emergence of more sustainable, localized seaweed farming and value addition (Buschmann AH et al. 2017), (Oyarzo-Miranda et al., 2023).

Many countries in the Caribbean, like others globally, have depended on traditional mariculture industries. The Caribbean reported seaweed production for 2020 at 128.56 tons, with the main producer being Saint Lucia. The major species produced in the region are *Eucheuma* and *Kappaphycus alvarezii* (elkhorn sea moss) (FAO, 2023). In 2020, Caribbean countries' seaweed exports were worth \$165,000 while imports were \$336,000 (FAO, 2023). The Organisation of Eastern Caribbean States (OECS) is currently exploring a new line of cooperation with UNCTAD and the Caribbean Biodiversity Fund to map the sea moss value chain for vegan foods and nutraceutical products and prepare a Blue BioTrade Action Plan as it has already occurred with the queen conch.

The Caribbean has good potential for seaweed cultivation for both export (alginates) and local food consumption (Smith and Renard, 2002). However, this potential has been overshadowed by the deleterious impact of the wild brown macroalgae *Sargassum*. *Sargassum* historically has grown in low nutrient areas of the North Atlantic and remained in the open sea for its entire life cycle.

Recently, a significant increase in the amount and frequency of blooms has been reported along the coasts of the West Indies, the Caribbean, Brazil, and West Africa. These blooms are most likely caused by higher sea temperatures and additional nutrient inputs from the continent, principally from the Amazon River, themselves mainly due to deforestation and agro-industrial and urban activities in the Amazonian Forest (Djakouré, 2017) and by agriculture activities and fertilizers use in West and Central Africa. They impose a major burden on residents (often women), local economies, and coastal ecosystems, who become overwhelmed by beached *Sargassum*, which emits an unpleasant odor and toxic gases as it decomposes. Local tourism and aquaculture industries have been losing business and incurred the associated costs for remediation.

Among proposed solutions to sustainably manage this serious issue, is an idea to turn *Sargassum* into an economic, social, and environmental asset by ship-based harvesting of excess biomass and refining it to deliver renewable liquid fuels (Marx et al., 2021). Other potential industrial uses include production of alginates, cosmetics, recycled paper, bioplastics, and fertilizers, and as raw material for civil construction (Rossignolo et al., 2022).

Developed countries

- East Asia

The Republic of Korea is the third largest global producer and Japan the seventh. Beyond their own production, both Japan and the Republic of Korea import significant quantities of two seaweed species produced by China, the brown algae *Undaria pinnatifida* and *Saccharina japonica* (Sugumaran et al., 2022). The Republic of Korea reported production in 2020 of 1.8 million tons (live weight), with the main species produced being Japanese kelp (kombu), laver (nori), and wakame (FAO, 2023). The Republic of Korea's exports were \$242 million in 2020, mainly towards Japan, China, and the United States of America.

In 2020, Japan reported production at 460.2 thousand tons (live weight) (FAO, 2023). Like the Republic of Korea, the main species produced in Japan are nori, kombu, and wakame. These species are some of the most popular for food consumption and are a vital part of Asian culture and food traditions. Although Japan is a major seaweed producer, it imports more than it exports, with 2020 exports of \$19.3 million and imports of \$220 million (UNCTADStat, 2023) Imports are mostly from the Republic of Korea and China.

- Europe

Europe is a relatively small but growing seaweed producer and processor. Countries producing seaweed either through cultivation or wild collection include Portugal, Norway, France, the United Kingdom (including

Scotland), Ireland, and Denmark (the Faroe Islands). Europe's production in 2020 was reported at 284.7 thousand tons (live weight) (FAO, 2023). The main species grown are North European kelp, North Atlantic rockweed, tangle, brown seaweed, and red seaweed. Europe has grown its seaweed trade since 2012, with exports in 2020 reported at \$113 million and imports at \$198.7 million (UNCTADStat, 2023). Across Europe, from Portugal to Norway, hatcheries are often managed by women, and in France, more than 60 per cent of seaweed actors are women.

Numerous European countries process seaweed for food and products ranging from paper to furniture and design materials. The European Commission, with France, is actively supporting the development of the algae sector, including by co-organizing with the GSC an European Union Algae Summit in Paris for policymakers in October 2023.

Norway is the largest producer in Europe, mainly producing North European kelp, North Atlantic rockweed, and brown seaweeds (FAO, 2023). In 2020 it produced 153,000 tons (live weight) (FAO, 2022) exported \$5.5 million, and imported \$8 million (UNCTADStat, 2023). The second largest European producer is France, at 52,200 tons in 2020. Its top species, mainly produced in Brittany, include tangle and North European kelp. Production is via inland and offshore farming and wild collection, for multiple end-uses including human food and abalone feed. Portugal reported 2020 production of 1,175 tons (live weight), exports of \$4.1 million, and imports of \$1.6 million.

Due to its unique environmental conditions, Portugal hosts a highly diverse range of seaweeds. It mainly produces red seaweed. Despite its long history of seaweed harvesting, the economic potential and environmental value of Portuguese seaweed farming remain to be fully understood. Kelp reforestation efforts are underway off the coast of Lisbon. Most Portuguese higher education institutions have research groups dedicated to seaweed-related studies (Gaspar et al., 2019).

The United Kingdom has a small but important seaweed industry in Scotland, historically focused on wild collection. The Scottish government has identified seaweed cultivation as an industry that can contribute to the blue economy with potential for rural, island and coastal communities (The Scottish Government, 2017).

- North America

Although North America is a relatively small seaweed producer, seaweed has long been an integral part of the culture of coastal Indigenous populations (Chopin and Ugarte, 2006). Seaweed is cultivated and collected on both the Pacific and Atlantic coasts. North American seaweed production was 17,246 tons (live weight) in 2020 (FAO, 2023). The main species cultivated include North Atlantic rockweed and brown seaweed. A large importer of seaweed, mostly from Asia's top producers, North America exported \$38.4 million and imported \$101.9 million in 2020 (UNCTADStat, 2023). In the continental United States of America, the largest source of cultivated seaweed is Atlantic Sea Farms, a woman-owned and -run seaweed processing firm based near Portland, Maine.

Canada's seaweed sector is also bicoastal. For centuries on the east coast the Mi'kmaq people have harvested *Palmaria palmata* (dulse) for use as a dietary staple and as medicine (Cascadia Seaweed, 2022). From about 1950 to 1970, Canada was the top producer of the red seaweed *Chondrus crispus* (Irish moss), used to extract carrageenan (Chopin and Ugarte, 2006). In the Pacific Northwest, many First Nations have harvested Pacific dulse among other red algae species, eating it both cooked and raw and using it to relieve indigestion. More recently, seaweed aquaculture has been successfully adopted in British Columbia (Foulkes, 2022).

Endnotes

- 1 See: <https://unctad.org/meeting/4th-oceans-forum-trade-related-aspects-sustainable-development-goal-14>.
- 2 See: <https://unctad.org/ter2023>.
- 3 Based on the interview conducted by the authors virtually on February 15, 2023, with Fiona Houston, Mara Seaweed.
- 4 Based on the interviews conducted by the authors virtually on February 2, 2023, with Flower Msuya, Zanzibar Seaweed Cluster Initiative, Scientific Council, Global Seaweed Coalition; and on February 16, 2023, with Anicia Hurtado, Consultant, Integrated Services for the Development of Aquaculture and Fisheries.
- 5 See information available at: <https://unctadstat.unctad.org/wds/TableViewer/tableView.aspx?ReportId=208023>.
- 6 See information available at [https://unctadstat.unctad.org/en/Biotrade.html#:~:text=The%20Trade%20and%20Biodiversity%20\(TraBio,products%20and%20other%20relevant%20indicators](https://unctadstat.unctad.org/en/Biotrade.html#:~:text=The%20Trade%20and%20Biodiversity%20(TraBio,products%20and%20other%20relevant%20indicators).
- 7 Carrageenan is derived from Kappaphycus / Eucheuma, Sarcothalia crispate, Gigartina skottsbergii, Mazzaella laminarioides, Gymnogongrus furcellatus, and Chondracanthus chamissoi; agar-agar, from Gracilaria spp, Gelidium spp, Gelidium corneum, and Pterocladia lucida; and alginate, from brown seaweeds in general. Abalone, a large, high value-added mollusk that is considered a culinary delicacy, is fed with kelp, Gracilaria, and other seaweeds in Eastern Asia, and Ulva in South Africa and France (Cai et al., 2021).
- 8 Based on the interview conducted by the authors virtually on February 15, 2023, with Philippe Potin, French National Centre for Scientific Research (CNRS).
- 9 Based on the interview conducted by the authors virtually on February 15, 2023, with Philippe Potin, French National Centre for Scientific Research (CNRS).
- 10 For example, Running Tide Technologies (United States); SINTEF, DNV, Equinor and Aker BP (Norway); SOS Carbon (Dominican Republic) and Seaweed Generation (United Kingdom) (World Bank, 2023).
- 11 An area classified according to the species that live in that location on the planet.
- 12 Based on the interview conducted by the authors virtually on February 9, 2023, with Runa Ray, Mojo Design Studios.
- 13 Based on the interviews conducted by the authors virtually on February 2, 2023 with Flower Msuya, Zanzibar Seaweed Cluster Initiative; Scientific Council, Global Seaweed Coalition; and virtually on January 31, 2023 with Anoushka Concepcion, Connecticut Sea Grant; Strategic Advisory Council, Global Seaweed Coalition.
- 14 Marine special planning is usually understood as a public and political process of analyzing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives. See: <https://www.ioc.unesco.org/en/marine-spatial-planning>.
- 15 Based on the interview conducted by the authors virtually on February 15, 2023, with Philippe Potin, French National Centre for Scientific Research (CNRS).
- 16 Ibid.
- 17 Based on the interviews conducted by the authors virtually on February 16, 2023, with Anicia Hurtado, Consultant, Integrated Services for the Development of Aquaculture and Fisheries; and virtually on February 13, 2023, with Philippine seaweed producers, PAKISAMA; and virtually on February 14, 2023, with Gabriella D'Cruz, Founder, The Good Ocean.
- 18 Based on the interviews conducted by the authors virtually on February 2, 2023, with Flower Msuya, Zanzibar Seaweed Cluster Initiative; Scientific Council, Global Seaweed Coalition; virtually on February 16, 2023, with Anicia Hurtado, Consultant, Integrated Services for the Development of Aquaculture and Fisheries; virtually on February 14, 2023, with Gabriella D'Cruz, Founder, The Good Ocean; and virtually on February 9, 2023, with Runa Ray, Mojo Design Studios.

- 19 Ibid.
- 20 Based on the interviews conducted by the authors virtually on February 2, 2023, with Flower Msuya, Zanzibar Seaweed Cluster Initiative; Scientific Council, Global Seaweed Coalition; virtually on February 16, 2023, with Anicia Hurtado, Consultant, Integrated Services for the Development of Aquaculture and Fisheries; virtually on February 14, 2023, with Gabriella D'Cruz, Founder, The Good Ocean; and virtually on February 9, 2023, with Runa Ray, Mojo Design Studios.
- 21 Based on the interview conducted by the authors virtually on February 10, 2023, with Helena Abreu, ALGApplus, Strategic Advisory Council, Global Seaweed Coalition.
- 22 Based on interviews conducted by the authors virtually on: February 17, 2023, with Elizabeth Cottier-Cook, Scottish Association for Marine Science (SAMS), Scientific Council, Global Seaweed Coalition; February 17, 2023, with Ndeye Coumba Bousso, PhD candidate at the Dakar Polytechnic School; and February 2, 2023 with Flower Msuya, Zanzibar Seaweed Cluster Initiative, Scientific Council, Global Seaweed Coalition.
- 23 Based on interviews conducted by the authors virtually on: February 14, 2023, with Gabriella D'Cruz, Founder, The Good Ocean; February 17, 2023, with Elizabeth Cottier-Cook, Scottish Association for Marine Science (SAMS), Scientific Council, Global Seaweed Coalition; February 8, 2023, with Anga Mbeyiya, BFA Global TECA Fellow; and February 17, 2023, with Ndeye Coumba Bousso, PhD candidate at the Dakar Polytechnic School.
- 24 Based on talk by Dr. Bernice McLean, Head of Blue Economy, African Senior Program Officer, Industrialisation Division at Africa Union Development Agency-NEPAD. Panelist during "Seaweed and Sustainability, Through an African Lens" session at the Safe Seaweed Coalition Seaweed Day, UN Ocean Conference 2022, Lisbon, June 29.
- 25 Interview conducted by the authors virtually on February 2, 2023, with Flower Msuya, Zanzibar Seaweed Cluster Initiative; Scientific Council, Global Seaweed Coalition.
- 26 Interview conducted by the authors virtually on February 10, 2023, with Helena Abreu, CEO, ALGApplus and presentation by ALGApplus at the 4th United Nations Oceans Forum on Trade related aspects of SDG 14, April 2022.
- 27 Based on Dyer phone conversation on August 26, 2021, with Neha Jain, Founder Zerocircle.
- 28 Based on talk by Dr. Bernice McLean, Head of Blue Economy, African Senior Program Officer, Industrialisation Division at Africa Union Development Agency-NEPAD. Panelist during "Seaweed & Sustainability, Through an African Lens" session at the Safe Seaweed Coalition Seaweed Day, UN Ocean Conference 2022, Lisbon, June 29.

