SOCIAL AND ECONOMIC DIMENSIONS OF SEAWEED FARMING: A GLOBAL REVIEW

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ABSTRACT

Seaweed farming based primarily on the culture of *Kappaphycus* and *Eucheuma* species has grown significantly in the Philippines and Indonesia over the last two decades, with growth also taking place at a smaller scale in Tanzania, India and a few other developing countries. Unlike other forms of aquaculture, seaweed farming foregoes the use of feed and fertilizers and has minimum technological and capital requirements. In addition, growout cycles are short, normally lasting less than two months. Given these unique characteristics, seaweed farming has generated substantial socio-economic benefits to marginalized coastal communities in developing countries, most of which have reduced access to alternative economic activities. In some communities, seaweed farming has emerged as the most relevant livelihood strategy. This paper summarizes the findings of a recent FAO review on the social and economic dimensions of seaweed farming in six countries in Asia (the Philippines, Indonesia, India), Africa (Tanzania), Oceania (Solomon Islands), and Latin America (Mexico). Each case study documented the evolution of the farming sector and examined the mix of public sector policies and private sector involvement leading to growth of the activity. Given the rising global demand for seaweed-derived products, seaweed farming has the potential to generate further socio-economic benefits to coastal communities in tropical regions; however, a number of challenges and constraints (some of which are country-specific) will need to be addressed to fully take advantage of these opportunities.

INTRODUCTION

Seaweeds are harvested throughout the world (either collected from the wild or cultivated in farms) and used in a large number of applications, including food for human consumption and as a source of hydrocolloids of commercial importance: agar, alginate and carrageenan. The latter is a gelling agent extracted from red seaweeds that is used as an emulsifier, a binder, or for suspension and stabilization in a remarkably wide range of products in the food processing, pharmaceutical and cosmetic industries. Demand for carrageenan rose substantially after World War II, with supplies limited by the availability of natural stocks of *Chondrus crispus* (also known as Irish moss) from Canada, Ireland, Portugal, Spain and France and *Gigartina*/*Iridaea* from South America and Southern Europe. By the late 1960s, dwindling wild stocks led carrageenan producers to scout the world seas in order to diversify seaweed supplies; at the same time, seaweed ecology research was intensified as the possibility of cultivation offered a solution to the instability of raw material supply [1]. These efforts finally found success in southern Philippines, where a native *Eucheuma* seaweed was found to produce high-quality carrageenan and ecological conditions made cultivation possible. The first seaweed farm was established jointly in 1969 by U.S.-based Marine Colloids Inc. (MCI) and University of Hawaii Professor Maxwell Doty in the southern Philippines province of Tawi-Tawi [2].

Production of *Eucheuma* spread rapidly in the Philippines, which soon displaced Canada as the top world supplier of carrageenan-yielding seaweed. The lower cost of labor in the Philippines relative to Canada further incentivized companies to source supplies from the Asian nation. Although the same corporations that dominated the Canadian market tried to control production in the Philippines through plantation-style seaweed farms, they soon realized they could not compete with small, family-run farms. The reasons were two-fold: 1) the labor for seaweed cultivation must be highly flexible to work on the cyclical time scales of tides and the moon, making it difficult to pay workers stable wages; and 2) seaweed farming has low capital and technological requirements for entry.

The success of seaweed aquaculture in the Philippines was rapidly replicated in Indonesia. Farm production came to be dominated by two species: *Kappaphycus alvarezii* (commonly known as 'cottonii') and *Eucheuma denticulatum* ('spinosum'), which currently account for approximately 80 and 10 percent of the world production of carrageenan seaweeds, respectively [3]. Outside the Philippines and Indonesia, culture of *K. alvarezii* and *E. denticulatum* has been attempted in a number of tropical countries around the world. However, significant production for export markets has only been achieved in Malaysia and Tanzania. The Philippines remained as the world's top producer of *K. alvarezii* until 2007, when it was surpassed by Indonesia. Indonesia's production was estimated at 85 thousand tonnes (dry seaweed) in 2009 while Philippine production was 61 thousand tonnes (by comparison, Tanzania's production barely exceeded 10 thousand tonnes, consisting mostly of *E. denticulatum*). Philippines' farm output has been consistently declining over the last 10-15 years due to unfavorable weather conditions and political unrest in farming areas. It is currently not clear whether this trend can be reversed; as a result, further increases in the global supply of seaweeds are expected to come primarily from Indonesia.

From its beginnings, seaweed farming proved to be a profitable commercial proposition for many coastal communities. For example, Naylor (1976) demonstrated that for plots of approximately one hectare, net income from seaweed farming was five to six times the minimum average wage of an agricultural worker [1]. Recognizing its potential to uplift the socio-economic status of marginalized coastal populations, international development agencies began promoting seaweed farming in Indonesia and neighboring countries since the 1980s [4]. Seaweed farming is a relatively simple technology and it requires low initial capital investment; in addition, with growout cycles as short as six weeks and favorable prices, it provides a rapid and high return on investment. A number of studies have corroborated the positive impact of seaweed farming on the socio-economic conditions of coastal villages in countries as diverse as the Philippines, Indonesia, Tanzania, India, Vietnam and Kiribati [5, 6, 7, 8, 9].

Despite its many attributes, seaweed farming is not without its own set of challenges. As a commodity traded in the international market, farm gate prices are subject to volatility. This was particularly evident during the "seaweed price bubble" of 2008, when farm prices reached exorbitant levels and then collapsed in the course of a few months. In Indonesia, for example, *K. alvarezii* prices more than tripled, from about USD 0.50/kg to as much as USD 1.80/kg. Given the sudden price increase, many farmers rushed to harvest immature or low-quality seaweed, flooding the market and precipitating the subsequent price crash [10]. In addition to fluctuating prices, farmers face a myriad of other challenges such as incidence of tropical storms, predation by herbivorous fish and lack of access to capital. In particular, a disease condition named 'ice-ice'(a) has caused devastating outbreaks in the Philippines, Indonesia and Tanzania.

Given the economic benefits and challenges associated with seaweed farming, the Food and Agriculture Organization (FAO) recently conducted a comprehensive evaluation of the socio-economic impacts of this activity in different farming locations throughout the world: Indonesia, Philippines, Tanzania, India (Tamil Nadu), Solomon Islands and Mexico (Yucatan Peninsula) [11]. The goal of each case study was to provide a review of seaweed farming development and identify the impacts that the sector has had on the socio-economic status of farmers in each country. The review covered countries with established commercial production (Indonesia, Philippines, Tanzania) and with nascent farming sectors (India, Solomon Islands). Even though no commercial aquaculture production is currently taking place in Mexico, the associated case study described the context and outcomes of experimental trials implemented in the community of Dzilam de Bravo (Yucatan) in the early 2000s. The review also provided useful policy recommendations addressing the most pressing constraints to further development in each country. This paper summarizes the most important findings and draws global conclusions from the FAO review.

COMPARATIVE ECONOMIC ANALYSIS

The FAO review covered a number of production systems used throughout the world, most of which are variants of the two most popular cultivation methods: the fixed, off-bottom line and the floating lines methods. In the off-bottom method, monofilament nylon lines or polypropylene ropes are stretched (usually one m apart) between wooden stakes pounded into the substrate. Small pieces of seaweed (50-100 g) are then tied to the lines. If the site is suitable and proper maintenance is provided, the seaweed should reach 10 times its original size in six-eight weeks, when it can be harvested. The seaweed is then sun dried away from sand and dirt, then packed into bales ready for shipping. The floating lines method is suitable in protected areas where water current is weak or the water is too deep for fixed bottom lines. Normally, a floating construction or raft (typically a 3×3 m square timber frame with polypropylene ropes stretched parallel in one direction between the timbers) is used to suspend the seaweed about 50-cm below the surface. The seedlings are tied to the ropes and the raft is anchored to the bottom. Plastic bottles attached to the lines can also be used as floatation devices instead of a wooden raft. The off-bottom line method allows easier access since the farmer can walk around the lines at low tide, but the floating lines have the advantage that they can be easily moved to another position if necessary, and removed from the water altogether in bad weather [3].

To make meaningful comparisons across the case studies reported in the review, representative systems based on the culture of *K. alvarezii* were selected from each of them. Because these systems varied in scale and farming method, standardized metrics such as productivity per m of line and production cost per kg of dry seaweed were computed. In order to account for the contribution of unpaid family labor (which is used in many seaweed farms around the world), farming systems using hired labor were selected for the analysis. The opportunity cost of family labor was computed in those cases for which data on labor costs were not available. Below follows a brief description of the farming systems selected for each country.

Indonesia: The representative farm consisted of a floating lines habitat system using sandbags as anchors and plastic bottles as floaters (a system commonly found in South Sulawesi). The total length of planted lines was 30 km. Eight 45-day cycles per year were assumed, resulting in an annual production of 33 tons of dry seaweed. All labor was paid on a piecework basis [12].

Philippines: Given that information on labor costs was more readily available as compared to other farming methods, the selected system was a multiple raft long line farm (MRLL) occupying an area of 10×50 m (around 2 km of planted lines). The MRLL is one of the innovative approaches to seaweed farming being used in deeper waters (>5 m) in Zamboanga City (southern Philippines), requiring a substantially higher capital investment relative to the simpler fixed off-bottom method [13].

Tanzania: Two systems were considered in Tanzania: a 30×10 off-bottom plot and a 27×12 floating lines plot. Because seaweed die-offs tend to be avoided in the deeper floating-line system, it is assumed that eight production cycles per year are completed in the floating-line plot as compared to only seven in the off-bottom farm. The representative budgets assumed a price of TZS 350 (USD 0.27), which is normally paid to independent farmers in the country (i.e., farmers who do not depend on exporters/traders to be supplied farming materials) [14].

India: Off-bottom and floating lines systems were also considered for India (Tamil Nadu province). The off-bottom farm consisted of 45 60-m ropes while the floating lines system used 45 3×3 m rafts. Each system assumes six 45-day production cycles for a total of 270 production days per year (farms do not operate during the northeast monsoon, which lasts approximately 95 days). These farms tend to rely heavily on family labor; as such an opportunity cost was computed based on the average wages earned by fishermen in the region [15].

Solomon Islands: the representative farm in Wagina, Solomon Islands, assumes an annual yield of 21,700 kg produced in 4 km of lines. All labor is hired [16].

Mexico: the Mexican case study reports the results of experimental trials led by CINVESTAV (Research and Advanced Studies Center of the National Polytechnic Institute, acronym in Spanish) in the community of Dzilam de Bravo, Yucatan. Both off-bottom and floating lines systems were explored. Each system consisted of 10 × 20 m modules scaled up to one hectare. The analysis considered only four two-month cultivation cycles as climatological conditions are unsuitable for farming during the late and early months of the year [17].

The structure of costs is discussed in greater detail for the Indonesian system only.(b) Table I presents the initial investment per km of line along with the cost of equipment and facilities required by the 30-km floating lines farm (2009 prices). Based on this information, Table II presents an annual amortization schedule for the farm. The item "Biomass for initial planting" refers to the acquisition of seedlings for the first operating cycle in Year 1. Starting with the first cycle, a portion of the harvest is allocated as replanting biomass for the ensuing cycle, circumventing the need for outside purchases of seedlings. For the purposes of this analysis, the cost of the initial purchase of seedlings is spread over the span of 10 years. Annual labor costs for this farm are itemized in Table III.

Table I: Initial Investment per km of Line and Equipment and Facilities Reported for a 30-km Floating Lines Seaweed Farm in Indonesia, 2009

Item	Number	Units	USD/unit	Total cost (USD)
Investment per km of line				
1 km (13.6 kg) of 5-mm PP line	1	km	34.00	34.00
0.2 km (11 kg) of 10-mm PP line	0.2	km	136.00	27.20
0.2 km (9 kg) of 8-mm PP line	0.2	km	114.00	22.80
1 km of 1-mm PP line (for loops)	1	km	1.00	1.00
Sandbag anchors	50	pieces	0.15	7.50
Plastic bottles as floats	500	pieces	0.03	15.00
Total investment for one km of line				**107.50**
Farm equipment and facilities				
9-m canoe with 5.5-hp motor	2	unit	500.00	1,000.00
6-m canoe with no motor	2	unit	150.00	300.00
Miscellaneous tools and equipment	2	set	150.00	300.00
Drying structures	4	set	150.00	600.00
Shelters for shade	2	set	800.00	1,600.00
Sacks	800	pieces	0.08	64.00
Total				**3,864.00**

Source: [12].

Table II: Annual Amortization Schedule for a 30-km Floating Lines Seaweed Farm in Indonesia, 2009

Item	Number	Years	Total cost	USD/year
Km of farm system	30	2	3,225	1,613
9-m canoe with 5.5-hp motor	2	5	1,000	200
6-m canoe with no motor	2	5	300	60
Miscellaneous tools and equipment	2	5	300	60
Drying structures	4	5	600	120
Shelters for shade	2	5	1,600	320
Sacks	800	2	64	32
Biomass for initial planting		10	960	96
Total				**2,501**

Source: [12].

Table III: Annual Labor Costs for a 30-km Floating Lines Seaweed Farm in Indonesia, 2009

Item	USD/km/cycle	USD/km/year
Attachment of cuttings to lines	6	48
Placement of lines	4	32
Harvesting of lines	4	32
Seaweed drying	4	32
Annual total per km		**144**
Annual total per farm		**4,320**

Source: [12].

Table IV presents the abridged enterprise budgets developed for the selected farming systems in each country.(c) Annual productivity of dry seaweed ranged from 1.10 (Indonesia) through 5.43 (Solomon Islands) kg per m of cultivation line. The relatively low productivity reported for the Indonesian system may be related to the large size of the farm (30 km), meaning that higher yields (per m of line) are easier to achieve in smaller operations such as those reported in Tanzania and India. A remarkable result is the high productivity of *K. alvarezii* reported in the Mexican case study: annual productivity reached 5.38 kg/m (the second highest in the review), overcoming the impact of a relatively short growout season (240 days).

Average farm-gate prices varied widely across studies, from USD 0.27/kg (Tanzania) to USD 1.09/kg (Philippines). The median price was USD 0.62/kg. Distance to processing centers seems to be the key factor influencing the prices received by farmers: the lowest prices were reported in relatively remote locations such as Tanzania and the Solomon Islands while Indonesian and Philippine farmers (located not too far from processing plants) were paid higher prices. It should be noted that Indian farmers reported relatively low prices (USD 0.29) despite the presence of processing plants in Tamil Nadu and neighboring regions.

Labor accounts for the greatest share of variable costs across budgets and represents around 50 percent of total costs of production. Investment costs incurred in the construction of farming systems were annualized in amortization schedules (see Table II) and charged as depreciation expenses in Table IV. The budgets assume that biomass for replanting is self-generated within the farms (i.e., a portion of the harvest is used to generate seedlings for the next production cycle) with the exception of Mexico, where seedlings for each production cycle are purchased from a hatchery. For simplicity, financial expenses (interest on operating capital and long-term loans) were ignored in Table IV.

Based on the preceding assumptions, production costs per kg of dry seaweed were estimated for each system (last row in Table IV), ranging from USD 0.06/kg in Tanzania (floating lines system) to USD 0.68/kg in the Philippines (MRRL system). In general terms, most countries report production costs under USD 0.30/kg with the exception of Mexico and the Philippines. Tanzania is the lowest cost producer, regardless of the production method (the floating farm is the most profitable alternative as the case study assumes that die-offs are avoided in this system). Production costs are also relatively low in India, with the off-bottom method generating slightly greater profits than the floating rafts.(d) The relatively high costs in the Philippines are driven by the low productivity reported for the MRLL system (1.43 kg/m/year) whereas high costs in Mexico resulted from the purchases of seedlings from an outside source.(e) Despite a productivity of only 1.10 kg/m/year, the Indonesian floating system has the largest profitability margin (68 percent) due to the relatively high farm-gate prices. The lowest profit margins were computed for the floating rafts in India (21 percent), which resulted from the low prices reported for the country (USD 0.29/kg) and the high opportunity cost of labor.

It is also instructive to compare net returns to operator's labor and management across the selected seaweed farming operations. Figure 1 displays the net returns estimated in Table IV relative to the International Poverty Line (IPL) computed for a four-person household (assuming a daily income of USD 1.25 per person). Given the low productivity of seaweed farming in general (the most productive system [Solomon Islands] generated only 5.43 kg/m/year) relative to prices received, it becomes clear that the scale of operations matter greatly in seaweed farming. Despite low production costs, the small Tanzanian systems (279 m of line on average) fail to generate substantial net returns (USD 147), falling much short of the IPL (USD 1,825). The Indian (2,633 m) and Philippine systems (2,000 m) also fall below the IPL. In contrast, the Indonesian and Mexican farms' net revenue far exceeds the IPL: USD 19,160 produced by 30,000 m of line in Indonesia and USD 1,682 produced by 10,000 m of line in Mexico.

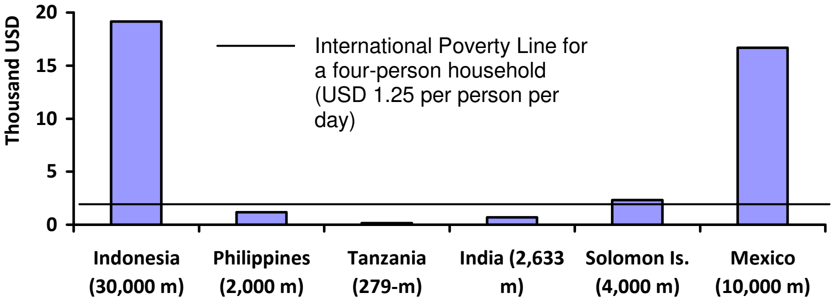

Figure 1. Net Returns to Operator's Labor and Management in Selected Seaweed Farming Operations, 2009

Table IV: Comparative Enterprise Budgets for Seaweed Farming Systems (Currency Shown is 2009 USD)

Item	Indonesia	Philippines	Tanzania		India		Solomon Islands	Mexico	
	Floating	Floating	Off-bottom	Floating	Off-bottom	Floating	Floating	Off-bottom	Floating
Production Parameters									
Total length of lines (m)	30,000	2,000	270	288	2,700	2,565	4,000	10,000	10,000
Number of cycles per year	8	5	7	8	6	6		4	4
Length of a cycle (days)	45	63	45	45	45	45		60	60
Annual yield of dry seaweed (kg)	33,000	2,850	662	806	7,560	6,480	21,700	53,778	53,778
Annual productivity (kg/m/year)	1.10	1.43	2.45	2.80	2.80	2.53	5.43	5.38	5.38
Cycle productivity (kg/m/cycle)	0.14	0.29	0.35	0.35	0.47	0.42		1.34	1.34
Farm-gate price (USD/kg)	0.85	1.09	0.27	0.27	0.29	0.29	0.38	0.96	0.96
Gross Receipts	**28,050**	**3,107**	**179**	**218**	**2,192**	**1,879**	**8,246**	**51,627**	**51,627**
Variable Costs									
Seed								13,264	13,264
Labor	4,320	759	26	28	1,168	1,043	3,717	8,853	8,853
Fuel	29	332					1,117		
Maintenance and repairs	420								
Sales and marketing	600							7,115	7,115
Total Variable Costs	**5,369**	**1,091**	**26**	**28**	**1,168**	**1,043**	**4,833**	**29,232**	**29,232**
Fixed Costs									
Depreciation	2,501	841	26	24		434	1,077	2,274	2,934
Administrative costs	900				45				
Utilities	120								
Insurance						8			
Fees for coastal land usage								3,109	3,109
Total Fixed Costs	**3,521**	**841**	**26**	**24**	**45**	**441**	**1,077**	**5,383**	**6,043**
Total Costs	**8,890**	**1,932**	**52**	**52**	**1,213**	**1,484**	**5,910**	**34,615**	**35,275**
Net Returns to Operator's Labor and Management	**19,160**	**1,174**	**127**	**166**	**979**	**395**	**2,336**	**17,012**	**16,352**
Production cost per kg of dry seaweed	**0.27**	**0.68**	**0.08**	**0.06**	**0.16**	**0.23**	**0.27**	**0.64**	**0.66**

SOCIO-ECONOMIC IMPACTS

The evidence collected throughout the case studies indicates that the socio-economic impacts of seaweed farming on coastal communities have been positive to a very significant extent. Because the production model favors small-scale, family operations over corporate, plantation-style farms, seaweed farming generates substantial employment relative to other forms of aquaculture. In addition, seaweed farming is often undertaken in remote areas where coastal communities face a reduced number of economic alternatives. Many of these communities have traditionally been reliant on coastal fisheries and are currently being affected by overexploitation of these resources. In these cases, the impact of seaweed farming goes beyond its economic benefits to communities as it reduces the incentives for overfishing. The FAO study [11] explains how the economic fortunes of many villages have been transformed by seaweed farming. Many of these communities routinely lived at or below poverty levels prior to engaging in aquaculture; with their incomes earned from the sale of seaweeds, many farmers have experienced substantial improvements in their standards of living as they are able to send their children to school, introduce improvements to their dwellings, enhance their diets, increase their purchasing power of material goods, etc. In particular, seaweed farming has had a remarkably positive effect on the socio-economic status of female farmers as it allows them to engage in an income-earning activity that can be undertaken without neglecting traditional household chores.

The FAO study also revealed a number of challenges that may constrain development of seaweed farming in the future:

- Low prices: low prices seriously hamper the revenue-generating potential of seaweed farming, particularly in places such as Tanzania and the Solomon Islands. Reported prices in the Indonesian, Philippine and Mexican case studies ranged from USD 0.60 through USD 1.40/kg. In contrast, prices reported in Tanzania, India and the Solomon Islands never exceeded USD 0.38/kg. As explained previously, higher shipping costs seem to account (at least partially) for the lower prices paid to farmers in Tanzania and the Solomon Islands. Low prices in Tanzania have led some farmers (mostly males) to quit seaweed farming altogether in recent years.
- Ability of farmers to supply their own farming materials: in places such as Tanzania farmers are highly dependent on processors/traders for the sourcing of farming materials (stakes, culture lines, etc.). The cost of these materials is discounted from the price paid to farmers at the end of the production cycle, which also explains the low prices paid in this country. As long as farmers continue to depend on processors for the procurement of their farming materials, their leverage to negotiate higher prices will be compromised.
- The impact of diseases: *ice-ice* disease has seriously impacted the farming of *K. alvarezii* in places such as Tanzania and the Philippines. Many farmers in Tanzania have turned to the farming of the more resistant *E. denticulatum* in an attempt to maintain farm yields; however, farm revenues have nevertheless declined as *E. denticulatum* normally fetch lower prices than *K. alvarezii*.
- The managerial capability of farmers: the success of seaweed farming in places such as Tanzania and the Solomon Islands will depend to a great extent on the farm management capabilities acquired by coastal villagers. In order to increase profitability, farmers may have to resort to new farming methods (e.g., deeper-water farming) and scale up the size of operations, all of which will require enhanced farm management skills. The ability of farmers to work effectively in producer cooperatives will also be essential in order to reduce production costs and improve price-negotiating capabilities.

RECOMMENDATIONS

One of the major lessons of the FAO review is that the success and impact of seaweed farming is highly dependent on the level of farm-gate prices. The potential of seaweed farming to lift the socio-economic status of coastal communities is compromised when prices go below USD 0.40/kg. In order to counteract the effect of low prices, farmers in Tanzania are engaging in deep-water methods (which reduce the impact of diseases on the higher-priced *K. alvarezii*) and value-added processes leading to the production of seaweed-based soaps, lotions, powder, etc. These strategies provide at least a partial solution to the predicament of low prices and as such must be pursued further. Research needs also to be conducted on disease-resistant strains of *K. alvarezii* in order to reduce the impact of *ice-ice* and other diseases.

It is also clear that farmers must strive to procure their own farming supplies to avoid falling in dependent relationships with traders/processors. The microfinance schemes that have proved to be so successful in places such as Bangladesh and India may provide a viable means for dependent farmers to break free from disadvantageous arrangements with suppliers of farming materials. Given that the initial capital requirements of seaweed farming are not excessively high, microfinance might be available from banking institutions or through organizations such as Kiva.org.(f) Seaweed farmers in the Philippines are already taking advantage of Kiva to raise investment capital to fund their operations [18].

The review also revealed that despite low prices, seaweed farming is a profitable venture for coastal communities with little access to other income opportunities. Nevertheless, farmers must attempt to scale up operations in order to generate sizable income levels. For example, an Indonesian farmer tending 10 thousand meters of lines with an average annual productivity of 1.10 kg/m of line will produce 33 thousand kg of dry seaweed per year. Assuming a selling price of USD 0.85/kg and a production cost of USD 0.27/kg, this farmer will attain an income level (net returns to operator's labor and management) of USD 19,140, which far exceeds the per capita GDP in the country (estimated at USD 4,144 [Purchasing Power Parity adjusted] in 2009 [19]). In contrast, a Tanzanian farmer managing a 270-m off-bottom plot with an average annual productivity of 2.45 kg/m will generate only USD 127 in net returns (assuming a price of USD 0.27/kg and a production cost of USD 0.08/kg), which falls short of the 2009 per capita GDP (PPP-adjusted) of USD 1,257. Assuming the same technical and economic parameters, the Tanzanian farmer could generate an income level of USD 1,397 by increasing his operation from 270 to 3,000 m of lines. Needless to say, such an increase in production levels would require substantial improvements in farm management skills.

In conclusion, seaweed farming of *K. alvarezii* and *Eucheuma* species has generated positive socio-economic impacts in many coastal communities around the world due to unique characteristics such as low capital and technological requirements and short growout cycles. However, these positive contributions have been diminished in some places due to the effect of low prices and diseases. As long as strategies are implemented to address these issues, seaweed farming will continue to enhance the standards of living of some of the poorest coastal communities in the world.

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ENDNOTES

(a) Ice-ice is caused when changes in salinity, ocean temperature, and light intensity inflict stress on seaweeds, making them produce a moist organic substance that attracts bacteria in the water and induces the characteristic whitening and hardening of the seaweed's tissues.

(b) The overall structure of costs is similar for other farming systems used throughout the world.

(c) Local currency values were converted to USD (2009 exchange rates).

(d) Nevertheless, grazing by fish is typically more difficult to control in off-bottom plots. If grazing is excessive, Indian farmers may be driven to work with rafts in deeper waters despite the slightly greater production costs.

(e) Assuming that replanting biomass is generated within the farm, production costs in Mexico would decline to around USD 0.45/kg.

(f) Kiva.org is a non-profit organization that allows people to lend money via the internet to people in developing countries through partner microfinance institutions