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Deep-Sea Farming of *Kappaphycus* Using the Multiple Raft, Long-Line Method

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Farming practices of *Kappaphycus* seaweed planters using the multiple raft, long-line method were assessed in three major cultivation areas of Zamboanga del Sur, Mindanao. Results show that this cultivation method is appropriate in deeper waters (> 10 m deep). Family labor (6–70 years old) is usually used in the selection and preparation of 'cuttings', unloading of newly harvested crops and drying of seaweeds, while preparation and installation of the raft, tying of 'cuttings' and harvesting, hired labor is needed. Though the multiple raft, long-line method of cultivating *Kappaphycus* is expensive (PhP 45,742 to PhP 49,785) based on a 500 m^2 raft, return on investment (ROI) is high and the payback period is short. Of the three areas assessed, Maasin had the highest ROI (218 %), followed by Tictauan Island (212 %), and finally Taluksangay (79 %). Consequently, the payback period followed the same order. Seaweed farming in these areas showed a tremendous impact on the quality life of the fisher folk and contributed a high revenue to the national economy.

Introduction

Farming of the tropical seaweed *Kappaphycus* outside the Philippines has been successful only in a few countries such as Indonesia (Adnan and Porse 1987), Tanzania (Lirasan and Twide 1993), Fiji (Luxton *et al.* 1987) and Kiribati (Luxton and Luxton 1999). The ever increasing demand of carrageenan in the world market makes seaweed farming a worthwhile livelihood among coastal fisher folk.

Seaweed cultivation in the Philippines is predominantly of the 'cottonii' type which comes mainly from *Kappaphycus alvarezii* (Doty) Doty and *Kappaphycus striatum* (Schmitz) Doty. Almost 80 % of the total seaweed production of the country comes from southern Philippines, western Mindanao and the Autonomous Region for Muslim Mindanao, in particular. In western Mindanao, Zamboanga City is the highest producing area amongst the three provinces (Zamboanga del Sur, Zamboanga del Norte and Basilan) with a total production of 386,202 MT from 1995 to 1999 [Seaweed Industry Association of the Philippines (SIAP), pers. com.].

After the successful experimental cultivation of *Kappaphycus,* previously called *Eucheuma,* in Tapaan Island, Siasi Sulu in 1967 (Doty 1973), simultaneous demonstration farms were established in Mindanao, Visayas and southern Luzon. Sacol Island, Zamboanga City was one of the demonstration farms in 1970 that originally used the fixed off-bottom method in shallower waters (Doty 1973, Parker 1974). However, modifications have been made so that the multiple raft, long-line method may be adopted in deeper waters. This study was undertaken to determine the farming practices of seaweed planters in deeper waters using the multiple raft, long-line method and to assess the economics of the culture system.

Material and Methods

A survey was conducted among seaweed planters of *Kappaphycus* in three major producing areas (e.g. Tictauan Island, Taluksangay and Maasin) of Zamboanga City (Fig. 1). A total of 30 respondents using the multiple raft, long-line method were interviewed based on the following variables: (1) personal background, (2) farming practices, (3) marketing system, (4) problems, and (5) economics (initial investment, cost and returns and sensitivity analyses) and (6) socioeconomic impact. The economic analysis was based on actual input and output data of the seaweed planter. Initial investment included non-motorized and motorized boat, flat binder, polypropylene rope, monofilament nylon cord, steel bars, styrofoam floats and bull hammer. Operating costs consisted of: (1) cash expenses such as 'cuttings', soft 'tie-tie', bamboos, gasoline, oil and engine maintenance, hired labor, miscellaneous expenses, and (2) non-cash expenses such as family labor and depreciation. The actual family labor was valued at the opportunity cost for the labor of a seaweed planter. Depreciation was computed using the straight-line method based on the estimated useful life of the asset (Meade 1989). Economic indicators (Shang 1981) like return on investment (ROI) and payback period were computed to evaluate the viability or performance of multiple raft, long-line cultivation of *Kappaphycus*. Thus:

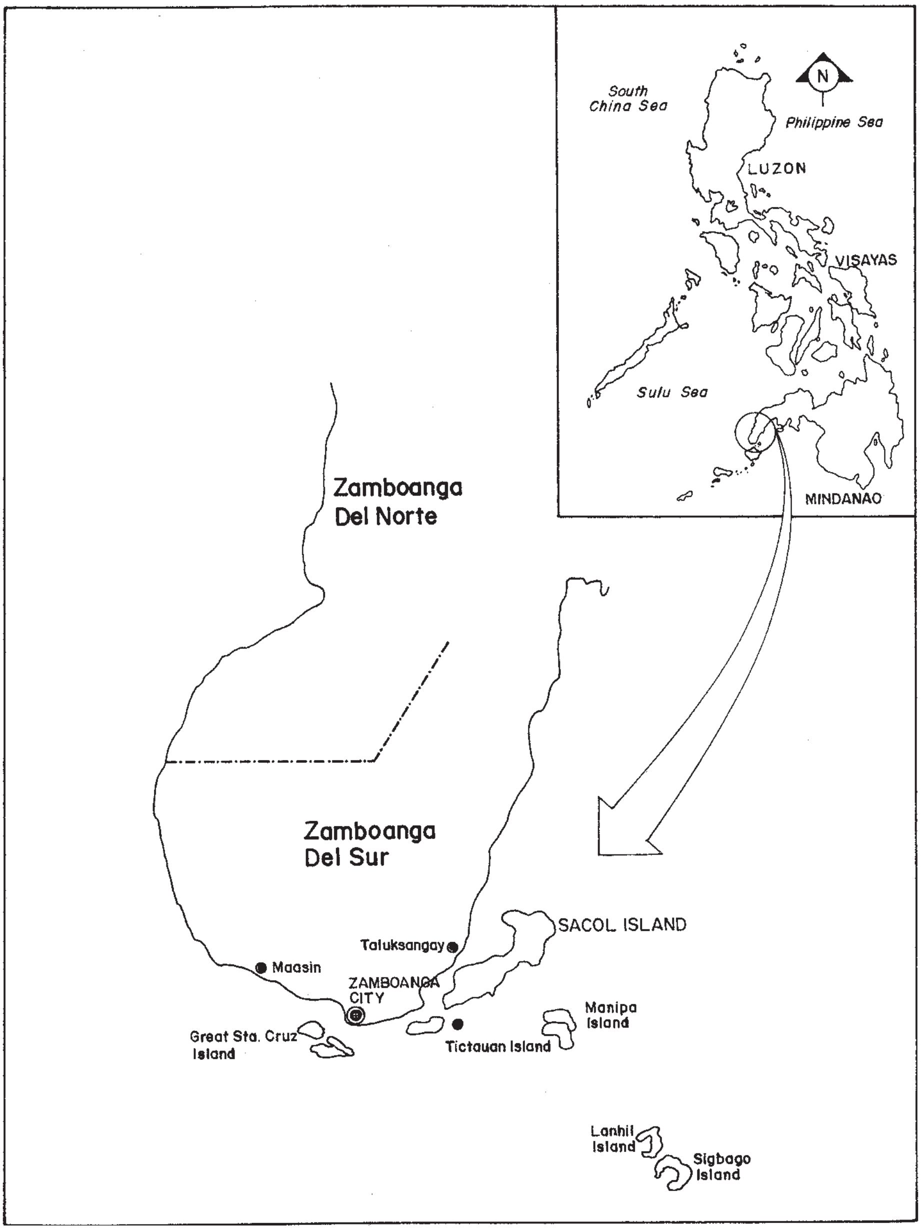

Fig. 1. Survey sites around Zamboanga City used in the study.

ROI = annual net income/initial investment
Payback period = (initial investment)/(annual net income + annual depreciation)

Cost and return analysis was used to determine ROI and payback period. Payback period estimates the time required to recover initial investment out of the expected earnings from the project. This method is used as an indicator of the investment feasibility when risks involved are relatively high.

Productivity was computed based on the equation used by DeBoer and Ryther (1977):

Productivity (g dwt m^{-2} day^{-1}) = $\{(N_t - N_o) / t * (dwt/fwt)\} / A$
where: N_t – final weight (Kg); N_o – initial weight (Kg); t – no. of culture days; dwt – dry weight (Kg); fwt – fresh weight (Kg); A – total area.

Yield was also computed based on a modified equation of Doty 1986:
Yield (Kg fwt, m^{-1} $line^{-1}$) = $(N_t - N_o) / L_t$
where: N_t – final weight (Kg); N_o – initial weight (Kg); L_t – total length of cultivation line (m).

Due to uncertainties, the investment decision does not only rest on the economic choice implied by the best estimate of costs and benefits, but also on whether a change in one or more elements in the economic analysis will affect the decision. Sensitivity analysis on ROI and payback period was performed to determine the effects on the profitability of the culture system under unfavorable conditions such as: (1) 20 % reduction in farm gate price; and/or (2) a reduction in the number of harvests to 3 crops $year^{-1}$ due to a typhoon disturbance and/ or 'ice-ice' disease infestation. The currency used in the computations is the Philippine peso (PhP 40 = US$ 1).

Results and Discussion

Personnel background

The ages of seaweed farmers in Tictauan Island, Taluksangay and Maasin, Zamboanga City ranged from 20–70 years. All the members of the family whose ages were above 6 years were found to assist in seaweed farming. The seaweed farmers either had no education, or had reached/ or finished elementary, secondary or college level. Females, both young and old were predominantly involved in the tying of individual 'cuttings' while the older males were involved in the selection of 'cuttings', drying and trading. The small children usually helped in unloading and carrying harvested seaweed especially during weekends and the summer vacations. All the interviewed respondents in the three study areas were full-time seaweed planters.

Structure of the set up

All seaweed planters in the three areas used the multiple raft, long-line method (Fig. 2) of cultivating *Kappaphycus*. This consisted of six to eight whole bamboos measuring 7–10 m long, arranged in parallel design at 10-m intervals, connected to one another by tying 2–4 pieces of flat binders using monofilament nylon cord (#110 test lbs.). The flat binders served as cultivation line, tied to the bamboo poles at 25-cm intervals which made a total of 20–28 lines. The peripheral cultivation lines consisted of 3–4 pieces of flat binders while the rest was made up of 2 pieces each. The total length of the raft ranged from 50–70 m. The whole structure was anchored to the bottom by a 0.80–1.5 m ringed-steel bar using a bull hammer to which a #14 polypropylene rope was tied at 45º to the water column. Usually, one anchor rope was tied to 2 ringed-steel bars. All sides of the raft were anchored to the bottom to maintain stability and adjust depth in the water. After 2–3 weeks of culture, 4–5 styrofoam floats (30 cm in diameter) were tied to bamboo poles; one styrofoam float was tied at the center of each cultivation line to provide additional floatation effect. This maintained the whole raft buoyant, 25–30 cm below the water surface, after the seaweeds had gained biomass. Construction of the structure was made on land and installation assisted by improvised SCUBA diving equipment by skilled laborers.

Farming practices

Seaweed farming practices in the three areas had the following common characteristics: (1) family entrepreneurship, (2) hiring of labor, and (3) capital sharing. The average raft area of a family ranged from 500–720 m^2. A single family could only operate and manage a maximum of 5 rafts with an equivalent to-

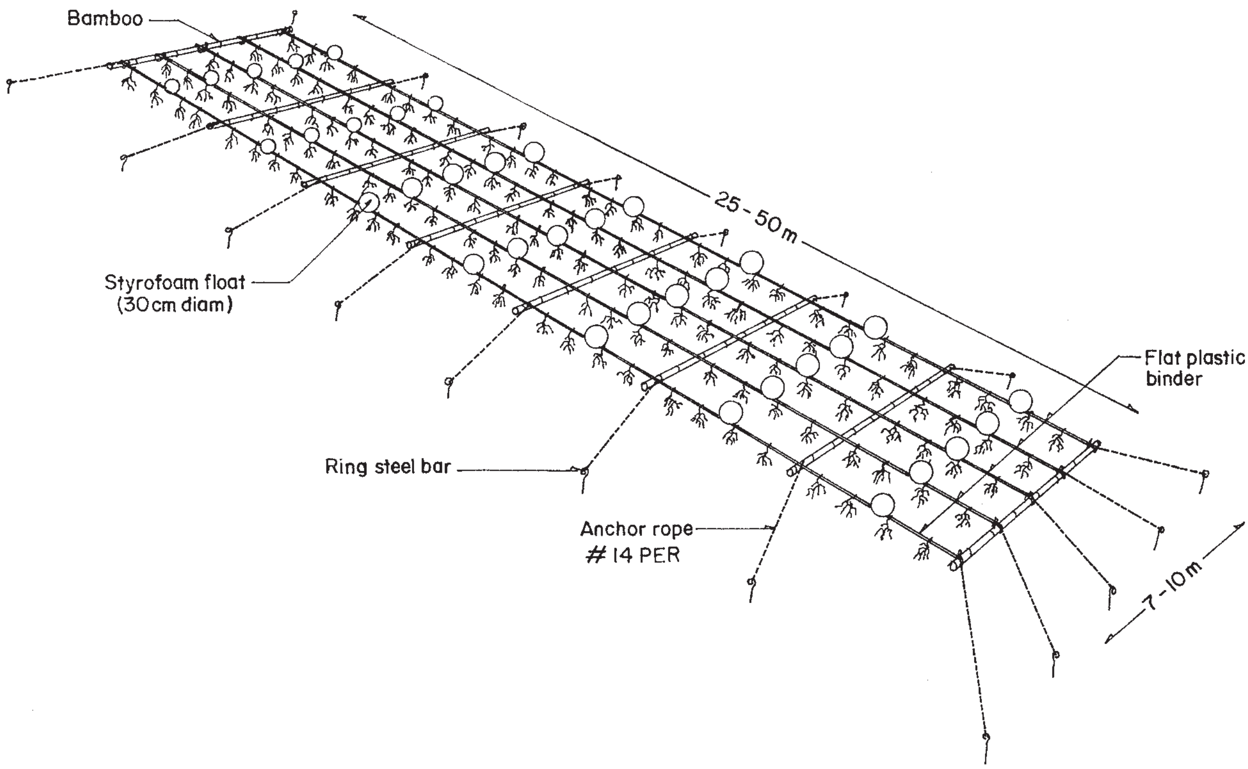

Fig. 2. Multiple raft, long-line design.

tal area of 0.31–0.36 ha. The preparation of ‘cuttings’ was done at the farmhouse by the older male members of the family, whilst the tying of individual ‘cuttings’ was undertaken by the females. Final tying of the ‘cuttings’ to the cultivation lines with a spacing of 20–25 cm apart was made by hiring skilled laborers whose ages ranged from 18–23 years. Both motorized and non-motorized boats were used by the planters. All the seaweed planters in Tictauan Island used motorized boats, while in Taluksangay and Maasin, both kinds of boats were used.

Generally, those who lacked initial capital to start seaweed farming borrowed money from relatives, friends or exporters, payable after harvest on an installment basis. Those who borrowed from the exporter were expected to sell their harvest to the latter. Farmers never borrowed from the traditional banks because of high interest rates and the lack of qualifying collateral. The initial capital was used for the purchase of tying and support materials such as ropes, flat binders, plastic soft ‘tie-tie’, bamboo, styrofoam floats and ringed-steel bars. Initial ‘cuttings’ (200–300 Kg) were given free by the established seaweed farmer with the belief that this practice is passed on to all beginners who are incapable of purchasing big volumes of ‘cuttings’.

For a new comer to the industry whose raft was < 500 m^2, seaweeds were harvested after 30 days of culture in order to expand their seed-stock. However, those farmers who had > 500 m^2 of rafts, all seaweeds were harvested after a 45–60-day culture period. This can be compared to the Indonesian practice where the seaweeds were pruned alternately with full harvesting (Adnan and Porse 1987). Young branches were selected from the harvest and served as seedstock for the next culture and the rest were sun dried. Since the seaweed is a cash crop, sometimes even young seaweeds (< 45 days old) were harvested for drying. However, the yield of colloid obtained from young seaweed was much lower than the mature material when processed (SIAP pers. comm.).

Seaweed farmers of Tictauan Island sold their harvest as fresh biomass at PhP 2–3 Kg^{-1} directly to the exporter whose drying platform was a part of the farmhouse located at the site. The farmhouse had an approximate total area of 1000 m^2 located off-shore and it was the center of all activities of the seaweed planters in Tictauan Island, e.g. selection and preparation of ‘cuttings’, drying, trading and more importantly, as a resting place. There was a large advantage on the part of the exporter in buying fresh seaweed since the desired moisture content was controlled and thus the quality of the dried seaweed was ensured.

In contrast, seaweed planters in Taluksangay and Maasin, dried their harvest on land, either on the ground or on plastic liners. Seaweed drying takes only a day or two with the addition of table salt, this malpractice adversely affects the quality of the seaweed. Seemingly, the outer portion of the seaweed is dry, however, the inner part of the thallus remains moist and the seaweed was vulnerable to bacterial decomposition during storage and transit time. Moreover, the carrageenan yield could decrease by 20–40 % leading to serious product cost implications (Balicuatro pers. comm.).

Production

The estimated production of *Kappaphycus* using the multiple raft, long-line method ranged from 1.5–2.3 t dwt crop^{-1} raft^{-1} or an equivalent of 38.5–67.5 t dwt year^{-1} family^{-1} with 5–7 rafts. Maasin produced the highest yield (2.3 t) followed by Tictauan Island (1.9 t) and the least from Taluksangay (1.5 t). Similarly, estimated productivity (d wt m^{-2} day^{-1}) was highest in Tictauan Island (47.6), with Maasin (45.3) and Taluksangay (26.5) in descending order.

The multiple raft, long-line method of *Kappaphycus* cultivation was expensive when compared to fixed off-bottom, raft monoline (Samonte *et al.* 1993) or hanging long-line methods (Hurtado-Ponce *et al.* 1996). However, productivity was greater and the corresponding revenue was higher. Dried *Kappaphycus* is an export market driven commodity, therefore, its economic value can be greatly affected by the fluctuating dollar exchange rate and the supply and demand.

Marketing system

The proximity of the three farming areas to Zamboanga City (the center of trade and commerce in the province), makes trading and marketing seaweeds very advantageous. It only takes 30–45 minutes to travel to the buying station as compared to a much longer period for those farmers located on more remote islands. There was a direct access among the seaweed planters and traders, exporters and processors in Zamboanga City which made marketing activities easy and convenient. Sometimes traders were found to go directly to the planters and purchase dried seaweed at lower prices. Since some farmers did not have the capacity to bring their crops to the city, the sale of products to the trader could be less cumbersome. The largest bulk of dried seaweed was sold to exporters and processors while smaller volumes were sold to traders.

Problems

The major problems facing the seaweed industry in these areas were the bad farming and post-harvest practices of certain operators. Premature harvesting, addition of table salt during the drying process and drying newly harvested seaweeds directly on the ground have resulted in low productivity and low quality seaweeds that are contaminated by sand, dirt, plastic and other debris. In some cases, unwanted (fouling) seaweeds are found in the harvested stock. These practices have resulted in a lowering of the price of harvested seaweeds and ultimately to financial losses. The seasonal occurrence of 'ice-ice' is a minor problem in comparison to other areas. Theft is rampant, not only of seaweed stocks but also of the operational and planting implements such as boats, engines and harvesting baskets. In addition, there is lack of scientific research and technology that will address the problem of the deteriorating quality of 'seed-stocks'. The farmers claim that the stock seaweeds are becoming shorter, sparser in branches and slower in growth, thus there is also a perceived biomass reduction. Continuing education among seaweed planters especially on post-harvest management will greatly improve crop productivity, reduce production cost and improve the ability to compete globally.

Economics

Total investment per 500 m^2 farm at these sites ranged from PhP 45,742 in Tictauan and PhP 49,785 in Taluksangay. Working capital (equivalent to the operating expenses for one crop) was greatest in Maasin (PhP 29,183) due to the cost of 'cuttings' there, followed by Taluksangay (PhP 24,893) and Tictauan Island (PhP 22,264) (Table I).

In the cost and return analysis (Table II), revenue was highest in Maasin (PhP 266,110) due to the high quantity of the raw material produced (2,314 Kg) from a 500 m^2 farm when compared to Tictauan (PhP 221,835 from 1,929 Kg produced) and Taluksangay (PhP 177,445.00 from 1,543 Kg produced). The operating cost per crop was also highest in Maasin due to the higher cost of 'cuttings'. All other operating costs were similar in all the farming areas. In the non-cash expenses representing family labor and depreciation, all areas registered approximately the same amounts (PhP 2,747 – PhP 2,578) except for some minor differences in depreciation costs.

As a result of the higher productivity, Maasin garnered the highest annual income, which amounted to PhP 107,395, followed closely by Tictauan at PhP 96,781. Taluksangay was far behind at PhP 39,372. The ROI showed similar trends at Maasin (218 %), Tictauan (212 %), and Taluksangay (79 %). Consistently, Maasin and Tictauan had a shorter payback period of less than one year or approximately after two crops. Overall, however, the three sites registered high and acceptable profitability levels.

In the sensitivity analysis (Table III), two scenarios were tested: (1) only three out of five crops survived either due to typhoon and/or disease; and (2) a decrease of farm-gate prices by 20 %. In the first scenario, all sites registered low rates of return of 2 % in Maasin, and 18 % in Tictauan, and –63 % in Taluksangay. In the second scenario when the farm-gate price was reduced from PhP 23 to 18 Kg^{-1}, Tictauan Island showed the highest ROI (106 %) followed by Maasin (100 %) and Taluksangay (2 %) with a corresponding lower payback period. Apparently, reduction in farm-gate price by 20 % is more tolerable than a reduction in the number of crops $year^{-1}$ except in the case of Taluksangay.

Seaweed farming, like any agriculture enterprise, can be exposed to nature's fury such as typhoon and disease caused by environmental degradation. One

Table I. Initial investment in the cultivation of *Kappaphycus* using the multiple raft, long-line method (per 500 m^2) (1 US$ = 40 PhP).

Item	Tictauan Island			Taluksangay			Maasin		
	Value	Economic life (yrs)	Depreciation*	Value	Economic life (yrs)	Depreciation	Value	Economic life (yrs)	Depreciation
A. Capital outlay									
Motorized boat	8,750.00	7	1,250.00	9,720.00	7	1,388.60	5,000.00	7	714.30
Non-motorized boat	–	–	–	2,880.00	5	576.00	2,880.00	5	576.00
Flat binder	3,750.00	3	1,250.00	4,000.00	3	1,333.30	4,400.00	3	1,466.70
Polypropylene rope	4,350.00	3	1,450.00	3,750.00	3	1,250.00	3,375.00	3	1,125.00
Monofilamnet cord	1,500.00	3	500.00	1,750.00	3	583.30	1,750.00	3	583.30
Steel bars	2,400.00	5	480.00	1,200.00	5	240.00	1,200.00	5	240.00
Float	2,528.00	2	1,264.00	1,392.00	2	696.00	1,288.00	2	644.00
Bull hammer	200.00	5	40.00	200.00	5	40.00	200.00	5	40.00
Total	**23,478.00**		**6,234.00**	**24,892.00**		**6,107.20**	**20,093.00**		**5,389.30**
B. Working capital	22,264.00			24,893.00			29,183.00		
C. Total investment	45,742.00			49,785.00			49,276.00		

* Meade 1989

Motorized boat costs PhP 25,000.00. For a 500 m^2 farm, PhP 1,250.00 is the allocated cost. Non-motorized boat costs PhP 8,000.00. For a 500 m^2 raft, PhP 400.00 is the allocated cost.

Table II. Costs and return analysis in the cultivation of *Kappaphycus* using the multiple raft, long-line method (PhP raft^{-1}).

	Tictauan Island	Taluksangay	Maasin
Quantity (Kg, 7:1, dwt crop^{-1})	1,929.00	1,543.00	2,314.00
Revenue (PhP, 23 Kg^{-1}, 5 crops year^{-1})	221,835.00	177,445.00	266,110.00
Operating expenses			
Cash			
'Cuttings' (PhP 2–3 Kg^{-1})	10,000.00	12,000.00	16,000.00
Soft tie-tie	200.00	270.00	250.00
Bamboos	440.00	360.00	280.00
Gasoline, oil and engine maintenance	4,600.00	4,600.00	4,600.00
Labour			
Tying of seedlings	2,000.00	2,000.00	2,000.00
Installation of raft	2,000.00	2,400.00	2,400.00
Harvesting	1,000.00	1,000.00	1,000.00
Miscellaneous expenses (12 % of seedlings, soft tie-tie, bamboos, gas, oil and engine maintenance and labor)	2,024.00	2,263.00	2,653.00
Sub-total	**22,264.00**	**24,893.00**	**29,183.00**
Non-cash			
Family labor-preparation of seedling/drying	1,500.00	1,500.00	1,500.00
Depreciation	1,246.80	1,221.45	1,077.86
Sub-total	**2,746.80**	**2,721.45**	**2,577.86**
Total cost run^{-1}	25,010.80	27,614.45	31,760.86
Total cost year^{-1}	125,054.00	138,072.24	158,804.29
Net income before tax (5 crops)	96,781.00	39,372.76	107,305.71
Return on investment (ROI %)	212	79	218
Payback period (year)	0.444	1.095	0.437

Table III. Sensitivity analysis in the cultivation of *Kappaphycus* using the multiple raft, long-line method.

Scenarios	ROI (%)	Payback period (year)
1. Reduction in the no. of crops year^{-1} (3 crops only)		
Tictauan Island	18	3.20
Taluksangay	–6	–1.95
Maasin	2	7.80
2. Reduction in farm-gate price by 20 % (PhP 18 Kg^{-1})		
Tictauan Island	106	0.84
Taluksangay	2	7.21
Maasin	100	0.90

of the biggest advantages of seaweed farming in southern Mindanao as compared to other parts of the country is the low rainfall and the fact that it is out of the normal path of typhoons that influence the Philippines every year. The clean and clear water, as well as the moderate to strong water movement have contributed to the high productivity of seaweeds in southern Mindanao comprising 70–80 % of the total production of the country (SIAP pers. comm.)

Socio-economic impact

One of the most significant things that influenced the lives of these seaweed planters since *Kappaphycus* farming was introduced, has been the improvement in their standard of living. The basic needs of the family, e.g. food, shelter and clothing were improved as a result of higher cash income. Additionally, education for the children has been upgraded. Supplementary income ensured that children were sent to school, as far as the collegiate level. Consequently, there were professionals in the community who are now leaders. Vehicles for commercial purposes, consumers' electrical appliances such as television, stereo, refrigerator, modest furniture set and dining table have been purchased. Semi-permanent to permanent houses have been built especially by those farmers in Taluksangay and Maasin. All of these material possessions were non-existent prior to the introduction of seaweed farming in 1971 in the farming areas. As a whole, export of dried seaweed (US$ 5.9 M) and the local production of carrageenan (US$ 40 M) have generated a significant revenue for the national economy (National Statistics Office [NSO] pers. comm) and more importantly to individual families. This has positively promoted the self-esteem of each family, as has also been observed with other seaweed farmers in other parts of the Philippines (Smith and Pestano-Smith 1983, Alih 1990, Hurtado-Ponce *et al.* 1996) and also outside the country (Luxton and Luxton 1999, Luxton *et al.* 1987).

In spite of the success of seaweed farming using the multiple raft, long-line method, production rates could still be improved. Materials such as PVC pipe filled with polyurethane foam and plastic buoys that have longer economic life could be used. Mechanical harvesting could be introduced to reduce harvesting time and cost which is similar to the commercial harvesting of *Laminaria* and *Undaria* (pers. obs.) in Japan.

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