Seaweed farming as a sustainable livelihood option for northern coastal communities in Sri Lanka

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Sea Weed Farming, Sustainable livelihood, Financial feasibility, Coastal communities, Constraints

Abstract

Sri Lanka has recently contributed to the growing significance of seaweed farming in the globe. This study attempted to assess the financial feasibility, employment generation, perceived importance, social acceptability and major constraints associated with seaweed farming in the Northern part of Sri Lanka. The study sample included 160 seaweed farmers from the area. A questionnaire survey, in-depth interviews and focus group discussions were conducted to collect data and information. Descriptive analytical, investment evaluation and constraint analysis techniques were employed in data analysis. Both the economic viability indicators and employment generation were estimated for an average of 25 seaweed rafts. The estimated net present value (at a 20% discount rate) was US $ 253 (implying an Internal rate of return [IRR] = 43%), while the benefit-cost ratio was 1.19. The employment generation of seaweed farming at the study area has been estimated at 3,392 man days (1,280 man days plus 2,112 woman days) per annum. Among the prevailing livelihood activities, seaweed farming received the second highest perceived importance of the farmers followed by fishing. The constraint analysis disclosed poor quality of planting materials, distortions in the market, improper aquatic environments, and poor post-harvest handling as major constraints of seaweed farming. The results established considerable financial feasibility and social acceptance of seaweed farming, allowing it to identify as a sustainable livelihood option for Northern coastal communities. Furthermore, the study leads to recommend seaweed farming as a system to replicate in other potential areas in the country. It also suggests making adjustments in the cultivation season, offering problem related extension and training programs, introducing a flexible purchasing mechanism, and establishing more collaborative actions among key stakeholders as solutions for the identified constraints.

Introduction

The coastline of Sri Lanka measures approximately 1700 km, which contains many different varieties of seaweeds. About 320 seaweed species belonging to different families have been identified by different scientists (Durairatnam, 1961; Barton, 1903; Boergensen, 1936). Two species of seaweed, namely Gracilaria edulis and G. verrucosa, commonly known as 'Ceylon moss' are found in coastal areas of Kalpitiya, Trincomalee, and Mannar areas (Duraitarnam and Medcof, 1955). Since 1800s, naturally collected Gracilaria spp have been exported from Sri Lanka (Duraitarnam, 1963), and a growing export market was identified thereafter. Furthermore, a small percentage of dried seaweeds is sold locally, while a good demand for packed Gracilaria spp can be identified in Islamic festive season in Sri Lanka. In 1987, Jayasuriya reported Gracilaria spp as a popular food item among fishermen, especially in producing areas, and was domestically consumed as porridge and a jelly drink.

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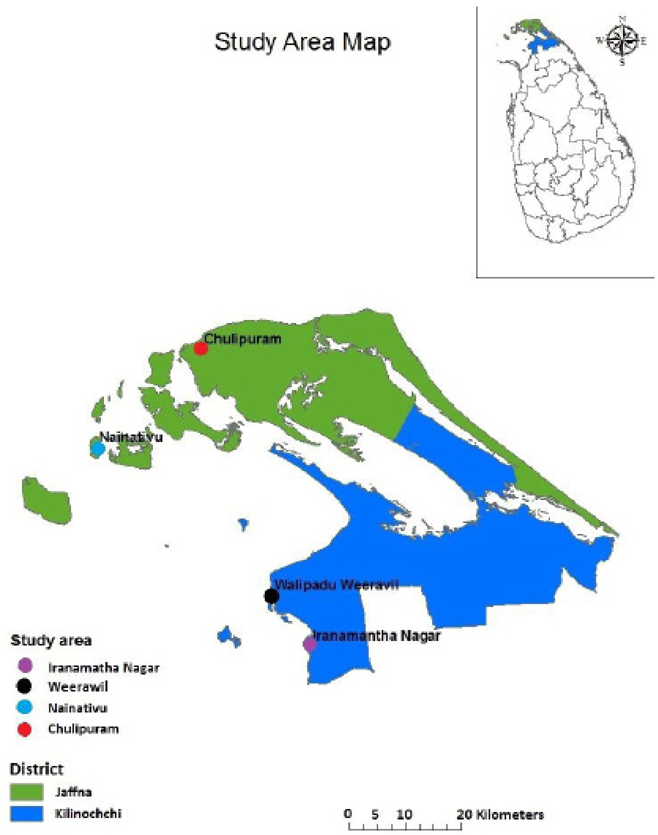

Figure 01: Map of the study area (Source: Authors' illustration)

More recently, seaweed farming in Sri Lanka has seen significant growth and continues to expand globally, thanks to its relatively higher productivity led by a variety of coastal resources (Nayanananda, 2007). In the coastal belt, fishery is the conventional economic activity of the majority, surpassing all other agricultural aspects. The fishing escalates on a daily basis due to the involvement of a heavily populated coastal community. However, such operations are becoming more unsustainable with destructive fishing practices coupled with illegal fishery issues (Madanayaka, 2015) and communal clashes.

In order to create a sustainable coastal community, especially at geographically isolated, marginalized, and vulnerable locations, the creation of alternative (Thilepan and Thiruchelvam, 2011; Crawford, 2002) or sustainable livelihood options capable of unlocking the potential of oceans seems vital. Accordingly, resettled coastal communities, including Kilinochchi, Mannar, Jaffna, and Mullaitivu of Northern Sri Lanka have been actively involved in seaweed farming. In some countries, seaweed has already identified as a catalyst of social progression (Prado et al., 2012) in coastal communities providing substantial income while rendering extensive employment opportunities (Krishnan & Narayanakumar, 2010) to the farming households. Though major constraints, such as unfavorable weather and uncertain market condition (Valderrama et al., 2013) have negatively affected the progression of seaweed cultivation, yet majority has illustrated the potential of seaweed farming as a profitable commercial enterprise adding opportunities for value addition, integration, and earning much needed foreign exchange through exporting (Prado et al., 2012; Abowei & Ezekiel, 2013).

Previous studies have investigated the socio-economic impacts of seaweed farming at different levels of economic outcomes (Rebours et al., 2014). With reference to the Brazilian context, seaweed farming is identified as a significant source of income for individual households. Beyond the favorable economic effects on individual farm families, seaweed cultivation has extended beneficial effects on the entire economy of certain countries. For instance, it has contributed significantly to the economy of the Zanzibar Islands of Tanzania by becoming a leading foreign exchange earner that accounts for above 90 percent of Zanzibar's marine export products (Msuya, 2006). On the contrary, poor levels of economic performance of seaweed farming (Eklöf et al., 2012) has also been reported in some other locations. In Mexico, Seaweed farming is not attractive when compared to other fisheries, like sea urchin, which is not assuring a good livelihood for the growers (Rebours et al., 2014). In addition to income generation, previous studies (Crawford, 2002; Narayanakumar & Krishnan, 2011) have also identified the employment potential of seaweed farming, especially as a means of women empowerment in coastal

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Table 1: Sample Distribution

District	DS Division	GN Division	Sample Size
Kilinochchi	Poonakary	Walipadu Weeravil	40
		Iranamathanagar	30
Jaffna	Velanai	Chulipuram	40
	Islands South	Nainathivu	50
Total			160

(Source: Field survey, 2016)

communities (Msuya, 2006).

Though the basic technological package is similar across countries, the prevailing uneven development of the industry is largely owing to variations in farm prices and the scale of operations (Valderrama et al., 2015). As indicated by Eklöf et al. (2012), which refers to the seaweed farming in Chwaka Bay, such uneven developments coupled with various challenges, including varying environmental conditions (Msuya, 2012), uncertain markets (Valderrama et al., 2013), and poor institutional structures (Kim et al., 2017; Msuya, 2012) have negatively affected the social acceptability as well as the socio-economic sustainability of seaweed farming.

Still, it is vital to have a sound basis of information related to the performances, including economic viability in terms of financial feasibility, employment generation, and social acceptability of seaweed cultivation in coastal localities in order to identify it as a sustainable livelihood option and other potential expansion of coastal areas in Sri Lanka. Thus, this investigation was conducted to explore the socio-economic feasibility and viability of small-scale seaweed farming along Northern coasts of Sri Lanka.

Methodology

Study Area and Sample Selection

Two districts, namely Jaffna and Kilinochchi, which are located in the Northern Province of Sri Lanka, were intentionally selected for the study considering the presence of seaweed farmers (Figure 1). Afterwards, four Grama Niladhari (GN) divisions were selected called Walipadu Weerawil and Iranamathanagar from Kilinochchi district; and, Chulipuram and Nainathivu from Jaffna district. 160 seaweed farmers were randomly selected, representing different operational scales, such as small-scale (<25 rafts), medium-scale (25-50 rafts) and large-scale (>50 rafts). A raft is a flat buoyant structure of timber or other materials fastened together and is used as a floating platform. The scales were proportionality selected from each GN division that represents 40% of the total seaweed farmers (Table 1).

Data Collection

Data collection was carried out during the months of May to July 2016. Both primary and secondary data were collected in the study. Primary data were collected from the sample respondents, mainly through a questionnaire survey. Moreover, key personnel interviews, focus group discussions, and field observations were performed to acquire detailed information on measured aspects. Data were collected concerning the production process, cost of production, marketing aspects, farmer perceptions, and constraints of seaweed cultivation. A multidisciplinary team of researchers, including a sociologist, economist, and biologist were involved in the data collection process. Secondary data required for the study were extracted from both published and unpublished sources.

Data analysis

The conventional tabular analysis was completed by working out item-wise expenditure and revenue to assess the returns from the representative seaweed farms, which consist of a habitat system of 25 floating bamboo-rafts (12×12). The calculation took into account all the costs of production, including cash and non-cash costs. Cash costs included direct expenses needed in the production of seaweed, whilst non-cash items included depreciation, interest on investment, and unpaid family labour occupied in the seaweed farm. Depreciation costs were computed using the straight-line method and assumed no residual value at the end of the useful life of 03 years for the initial investment. Still, interest on investment was charged at 7 % per annum, parallel to the rates adopted by commercial banks. Total revenue was worked out by multiplying the total production by the average farm-gate price. Net return was solved as the difference between total revenue and the total cost of production.

Investment evaluation techniques were used to assess the financial feasibility of seaweed cultivation. Payback period and rate of return on investment were used as undiscounted measures, whilst net present value (NPV), internal rate of return (IRR), and benefit cost ratio (BCR) were used as discounted measures of investment worthiness (Engle, 2010; Gittinger, 1982; Firdausy & Tisdell, 1991; Narayankumar & Krishnan, 2011). Since undiscounted measures fail to take the timing of the benefit stream into account adequately, it is recommended to use a mix of both discounted and undiscounted measures to cover every aspect of the investment (Engle, 2010; Gittinger, 1982).

Investment options with shorter payback periods were preferred as it quickly identifies investment options with immediate cash returns. The rate of return on investment indicates what percentage of the investment is received from the average annual net returns, but fails to consider the size and timing of the annual earnings (Engle, 2010). Net present value, as a discounted cash flow technique, measures the present worth of the income stream generated by an investment, therefore, investments with a positive NPV would be accepted. The internal rate of return indicates the discount rate that makes incremental cash flow equal to zero, and investments with an IRR greater than the discount rate is considered as profitable. The benefit-cost ratio was obtained by dividing the present worth of the benefit stream by the present worth of the cost stream. The BCR of one or greater at the opportunity cost of capital was preferred. The discount rate, which represents the rate of return that the investor could have earned by investing on other available options, is important for a reasonable evaluation. Accordingly, a 20% discount rate was adopted for the analysis. Furthermore, the study considered that each cultivation cycle remains for 45 days, with four cultivation cycles for the first and third-year, and five cycles for the second year. The equations used in the analysis are given below.

$$\text{Pay} - \text{back period (years)} = \frac{\text{Investment}}{\text{Average annual net revenue}} \quad (1)$$

$$\text{Rate of return on investment} = \frac{\text{Average annual net revenue} \times 100}{\text{Investment}} \quad (2)$$

$$\text{NPV} = \sum_{t=1}^{t=n} \frac{B_t - C_t}{(1+i)^t} \quad (3)$$

IRR: the discount rate (i) such that,

$$\sum_{t=1}^{t=n} \frac{B_t - C_t}{(1+i)^t} = 0 \quad (4)$$

$$\text{BCR} = \frac{\sum_{t=1}^{t=n} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{t=n} \frac{C_t}{(1+i)^t}} \quad (5)$$

Where,
B_t= benefit in each year, C_t= cost in each year, t = terminal year, n = number of years, i = discount rate

The additional employment generation from seaweed farming was estimated by adapting the procedure proposed by Satyanarayana and Rao (2013) for Groundnut cultivation. The package of practices undertaken in seaweed farming was identified through a review of literature and discussion with experts. The response of each interviewee was recorded in terms of approximate time spent in hours for each practice within the package, which was then summed up separately and converted into man days. The study assumed that one woman-day

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$$\text{Percent Position} = \frac{100 \times (R_{ij} - 0.5)}{N_j}$$

Where,
R_{ij} = Rank given to i^{th} constraint by the j^{th} individual
N_j = Number of constraints ranked by the j^{th} individual

equals 0.6 man-days and considered 08 hours as the standard working hours per day.

The Garrett's ranking technique (Christy, 2014; Zalkuwi *et al*., 2015; Dhanavandan, 2016) was exercised to detect the judgment of the farmers about the constraints faced by them in seaweed cultivation. Consequently, respondents were inquired to assign the rank for all the constraints and the outcome of ranking was converted into percent position by using the formula 6.

The percent position estimated was switched into scores by using Garrett's Table (Garrett, 1926). Then for every constraint, the scores of each individual were inputted and total value of scores and respective mean values of scores were computed. The constraint having the highest mean value was considered as the most significant factor.

The perceived importance of farmers towards different production activities was measured by assigning a perceived ordinal rank (Crawford & Shalli, 2007) and farmers

Table 2: Annual cost and returns of seaweed farming (per average of 25 rafts)

Initial investment	Unit	Quantity	Per unit price (US $)	Total Value (US $)	Share (%)
Planting materials	kg	1500	0.03	44.34	6.93
Seaweed growing structures	raft	25	213.70	534.26	83.55
Miscellaneous	-	-	-	2.96	0.46
Labour for installation	md*	5	5.91	29.56	4.62
	wd**	8	3.55	28.38	4.44
A. Total initial investment				639.48	
Fixed cost					
Depreciation				178.09	81.39
Interest on investment (7%)				40.71	18.61
B. Total fixed cost				218.79	
Operating cost					
Maintenance Labour	wd**	12	3.55	42.56	47.37
Harvesting and drying Labour	md*	2	5.91	11.82	13.16
	wd**	6	3.55	21.28	23.68
Miscellaneous labour	wd**	4	3.55	14.19	15.79
C. Total operating cost				75.67	
D. Total cost of production(B+C)				308.65	
E. Gross revenue				638.45	
F. Net income (E - D)				329.80	

md* - man-days, wd** - woman-days

were requested to provide their view on each perceived rank.

Results and Discussion

Costs and returns of seaweed farming

Table 2 presents the annual costs and returns incurred by seaweed farming with respect to an average of 25 bamboo-rafts (12×12). Accordingly, the initial investment was estimated at US $ 639.50, mainly comprising the investment cost incurred in the construction of farming systems (84%) or rafts, which do not need to be replaced yearly. Generally, seedlings were sourced from the harvest of the earlier crop and a portion of the harvest is allocated as replanting biomass for the subsequent cycle. The total cost of production was estimated at US $ 308.65, comprising a fixed cost of US $ 218.80 (75% of the total cost of production), and an operating cost of US $ 89.86 (25 %). The non-cash expense of depreciation is high as the study assumes that the productive lifespan of a bamboo-raft is 03 years. Labour is the most common, or rather the only operating cost, for the majority of farmers involved in seaweed farming within the study area. With the exception of labour requirement for initial preparation, the operating cost covers labour for weeding, harvesting, drying, and maintenance. Though the present analysis considered the imputed value of unpaid family labour, in practice, labour expenses are low since farmers employ their own family members. Additionally, the opportunity cost of their employment may also be lower due to the scarcity of productive jobs at the coastal communities.

The average level of total production after a grown out period of 45 days equals to 250 kg of fresh seaweeds. Thus, a 10:1 ratio of fresh to dry weight generates 25 kg of dry seaweed. After removing all the impurities, the gross revenue was estimated as a yield of 24 kg of dried seaweed per raft and a farm-gate price of US $ 0.27 for the first-year and thereafter US $ 0.29. Consequently, the annual gross revenue was estimated at US $ 638.45 leading to an annual net income of US $ 329.80.

Financial feasibility of seaweed farming

Financial feasibility indicators were measured and are presented in Table 3. Accordingly, the net income for the first and second years were US $ 329.80 and US $ 555.62 respectively, leading to a payback period of 1.55 years, indicating moderate cash returns to the investment. Moreover, 67% of the initial investment (US $ 639.48) is covered by a Net Present Value (at 20% discount rate) of US $ 253.10 (implying an IRR of 43 %), while the benefit-cost ratio (BCR) was 1.19. Additionally, the financial feasibility of seaweed farming within Jaffna district (BCR=1.12) was relatively low compared to Kilinochchi district (BCR=1.43). This difference may be attributed to the more established nature of seaweed farming in Kilinochchi district. However, these indicators are less attractive compared to the previously reported studies of Padilla and Lampe (1989) and Narayankumar and Krishnan (2011), who refer to the seaweed industries of Philippine and India, respectively. This discrepancy could be explained by the difference in scale of production, where those countries are practicing large-scale production systems compared to the condition in Sri Lanka. Some scientists (Hurtado *et al*., 2001; Alin *et al*., 2015) have noted that the seasonality of cultivation affects the positivity of these indicators, where positive indicators are received during peak months, whilst negative values are obtained during lean periods. Therefore, under small-scale production, caution must be applied as the findings might not be transferable to already established, large-scale weed production systems. It could be argued that the present investigation considered all of the cash and non-cash expenses, such as unpaid family labour for calculations, however, in practice, most of the farmers fulfill labour requirements from the available family labour and the existing contract growing system which assists farmers in constructing seaweed growing structures. Therefore, seaweed growers may receive more benefits that are not interpreted from these theoretical estimations. Together, these results provide important insights to the improvement of the Sri Lankan seaweed industry as a financially profitable livelihood option for coastal communities.

The average level of total production after a grown out period of 45 days equals to 250 kg of fresh seaweeds. Thus, a 10:1 ratio of fresh to dry weight generates 25 kg of dry seaweed. After removing all the impurities, the gross revenue was estimated as a yield of 24 kg of dried seaweed per raft and a farm-gate price of US $ 0.25 (for the first-year and thereafter US $ 0.29). Consequently, the annual gross revenue was estimated at US $ 638.29 leading to an annual net income of US $ 329.72.

Financial feasibility of seaweed farming

Financial feasibility indicators were measured and are presented in Table 3. Accordingly, the net income for the first and second years were US $ 329.72 and US $555.49respectively, leading to a payback period of 1.55 years, indicating moderate cash returns to the investment. Moreover, 67% of the initial investment (US $ 639.33) is covered by a Net Present Value (at 20% discount rate) of US $ 253.04 (implying an IRR of 43 %), while the benefit-cost ratio (BCR) was 1.19. Additionally, the financial feasibility of seaweed farming within Jaffna district (BCR=1.12) was relatively low compared to

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Table 3: Financial feasibility indicators for seaweed farming (per average of 25 rafts)

Indicators	Unit	Year 1	Year 2	Year 3
Initial investment	US $	639.48	N/A	N/A
Total cost of production	US $	308.65	331.03	308.57
Gross returns	US $	638.45	886.52	709.21
Net income	US $	329.80	555.49	400.63
Payback period	Years	1.55		
Return on investment	Percent	67		
Net Present Value (20% discount rate)	US $	253.10		
Benefit Cost Ratio (20% discount rate)	Ratio	1.19		
IRR	Percent	43		

Table 4: Additional employment generation from seaweed farming (per average 25 rafts)

Management practice	Man/male-days	Woman-days
Site preparation	5	2
Seedlings selection and preparation	-	1
Hauling of seedlings	-	1
Planting	-	4
Care of crops	-	12
Harvesting	1.5	4
Hauling of produce	0.5	2
Drying	-	2
Packing	-	2
Total	7	30

Kilinochchi district (BCR=1.43). This difference may be attributed to the more established nature of seaweed farming in Kilinochchi district. However, these indicators are less attractive compared to the previously reported studies of Padilla and Lampe (1989) and Narayankumar and Krishnan (2011), who refer to the seaweed industries of Philippine and India, respectively. This discrepancy could be explained by the difference in scale of production, where those countries are practicing large-scale production systems compared to the condition in Sri Lanka. Some scientists (Hurtado *et al*., 2001; Alin *et al*., 2015) have noted that the seasonality of cultivation affects the positivity of these indicators, where positive indicators are received during peak months, whilst negative values are obtained during lean periods. Therefore, under small-scale production, caution must be applied as the findings might not be transferable to already established, large-scale weed production systems. It could be argued that the present investigation considered all of the cash and non-cash expenses, such as unpaid family labour for calculations, however, in practice, most of the farmers fulfill labour requirements from the available family labour and the existing contract growing system which assists farmers in constructing seaweed growing structures. Therefore, seaweed growers may receive more benefits that are not interpreted from these theoretical estimations. Together, these results provide important insights to the improvement of the Sri Lankan seaweed industry as a financially profitable livelihood option for coastal communities.

Table 5: Percent rank distribution of livelihood activities

Livelihood activity	Percentage of respondents(N=160)					Total
	Perceived ordinal rank					
	1	2	3	4	5	
Fishing	65.6	12.5	7.5	0.0	0.0	85.6
Seaweed	25	68.8	6.2	0.0	0.0	100.0
Hired labour	5	12.5	51.2	6.3	0.0	75.0
Livestock	0.0	3.1	18.8	26.3	3.1	51.3
Trading	2.5	3.1	10.0	10.6	6.3	32.5
Terrestrial farming	0.0	0.0	6.3	15.6	9.4	31.3
Government Employment	1.9	0.0	0.0	0.0	0.0	1.9
Total	100.0	100.0	100.0	58.8	18.8	

Source: Primary data processed, 2016

Employment generation

The results, as shown in Table 4, indicates that 25 man-days (07 man-days + 30 woman-days, assuming one woman-day equals 0.6 man-days) of additional employment opportunities are generated from an average of 25 seaweed rafts. This implies that approximately 100 man-days; 0.33 full-time equivalent jobs per year (assuming 300 working days per year) could be generated from well-managed 100 seaweed rafts. In this situation, a large-scale seaweed industry would generate abundant employment opportunities for the coastal communities. This employment potential of seaweed farming was observed in earlier studies of Hurtado (2013); Krishnan and Narayanakumar (2010); and, Narayankumar & Krishnan (2011).

It is obvious that the most labourious portions of seaweed farming are initial site preparation and the crop maintenance. In a family operation, all of the family members, including spouse and children, are working together on the farm. Therefore, only a small number of respondents were identified using hired labour only for the labourious activities. These findings may help us to understand the fact that the seaweed farming offers reasonable employment opportunities, particularly for the female farmers that can be effortlessly managed with their household activities.

Perceived importance towards seaweed farming

Among the prevailing livelihood activities, fishing received the highest perceived importance of the respondents. However, 94% of the respondents perceived seaweed as either first or second in importance (Table 5). A variety of perspectives were expressed when the respondents were requested to suggest reasons for their perceived importance towards seaweed farming. Accordingly, eight causative responses emerged from the study are the favorable income (95% respondents) and employment generation (87%), the ability to readily integrate with fishing (72%), instrumental in empowering women (65%), the existence of a contract farming system (60%), rapid return on investment (58%), requiring simple farming techniques (55%), and an alternative for deprivation of terrestrial lands for cultivation (52%).

The seaweed farming, as a favorable source of livelihood option, has provided relatively high and continuous income for the respondents. The additional income from outside of fisheries helps highly fishing-dependent communities to manage income losses during extended periods of declining fish catch. This livelihood diversification has reduced the risk of over-reliance on one income source. As an economically viable alternative and livelihood option (Narayankumar & Krishnan, 2011), seaweed farming has delivered a stable annual average income, ensuring a stable way of life for farmers of those who mainly depend on it. Altogether, the beneficial impact of income generation from seaweed farming improves household economic resilience and enables a sustainable way of life which uplifts the overall living standard of the farming communities (Crawford, 2002). Those who responded felt that they are more food secure after engaging in seaweed farming. Investments indicated other beneficial spin-offs on facilitating extra educational options, like tuition for the children, purchasing new housing, material assets (Crawford & Shalli, 2007), and other essential consumer goods. As indicated by Krishnan and Narayanakumar (2013), there is a beneficial influence

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of extra income generation from seaweed farming that facilitates more participation in social functions by the respondents. These findings confirm with Zacharia *et al*. (2015) and Tobisson (2013) on the role of seaweed farming in coastal livelihood improvement. According to Thilepan and Thiruchelvam (2011), to improve livelihoods of poor coastal communities in Sri Lanka, alternative non-traditional livelihoods are vital and it can, therefore, be assumed that the present study raises the possibility of seaweed farming in fulfilling these requirements.

The participants highlighted that the seaweed farming renders extensive employment opportunities (Rajasree & Gayathri, 2014; Crawford & Shalli, 2007), especially during initial preparation and harvesting stages, whilst there were some cases where all household members entered the workforce. This result is in agreement with the findings of Rajasree and Gayathri (2014), and Crawford and Shalli (2007), which showed the employment potential of seaweed farming. The possibility to develop diversified seaweed products locally will be an implication to generate more employment opportunities during post-harvest processing of seaweed. This view is supported by Abowei and Ezekiel (2013), who noted that seaweed farming is a solution for social problems, such as the high rate of under and unemployment, youth restiveness, and militancy in the Niger Delta. Similarly, considering the employment potential of seaweed farming, Narayankumar and Krishnan (2011) suggest that the government policy measures should encourage fishers, especially fisherwomen, to form self-help groups. Altogether, this finding has important implications for developing higher levels of employment-income-consumption relationships as indicated by Krishnan and Narayanakumar (2010) referring to the coastal communities in India.

The key personnel interviews and focus group discussions revealed that seaweed farming requires lesser time for its maintenance after planting and allows farmers to engage in other activities. Therefore, the farmers can easily integrate seaweed farming with conventional fishing (Abowei & Ezekiel, 2013). However, and consistent with Zamroni and Yamao (2011), there were some cases where fishing, the primary economic livelihood of fishermen, has already been replaced by seaweed farming as the main income source. As noted by Prado *et al*. (2012), integrated mariculture farming systems boost family productivity in the coastal environments. Thus, this finding has important implications for developing other possible integrated farming systems of seaweed at the local conditions.

Another common view amongst interviewees was that the seaweed farming is instrumental in empowering women in the coastal communities (Tobisson, 2013; Abowei & Ezekiel, 2013). This finding corroborates the ideas of Tobisson (2013), and Abowei and Ezekiel (2013), who emphasized the significance of seaweed farming in empowering women in the coastal communities. In addition, Rajasree and Gayathri (2014) noted that the seaweed farming is an economically sustainable livelihood option for fisherwomen, especially widowed fisherwomen. Generally, the shallow water seaweed farming, particularly planting, maintenance, and harvesting stages tend to be dominated among female farmers. The contribution of female farmers to the regular labour force reduces the cost of production, whilst the cash income is viewed to be mainly invested for tuition and purchasing modern housing materials (Rajasree & Gayathri, 2014).

The existing contract farming scheme builds up a contractual relationship among the buyer and seaweed farmers. Accordingly, the buyer initially provides extension facilities and planting materials, and commits to purchase seaweed at a pre-determined price, whilst the contracted farmer is liable to supply dried seaweed at a satisfactory quality. The participants assume that the product is purchased at a discounted price to cover-up the cost of materials provided and further argue that the existing payments are not properly compensating the efforts. In a study conducted by Zamroni and Yamao (2011), it was noted that the seaweed price fluctuates within the year. Consequently, the price decreased by 10% during the peak production period compared to the annual average price for seaweed, which increased by 20% during the lean production period, and remained stable during medium production periods. Though the existing contact growing system is not fully encouraging, it has reduced the financial risk for farmers by minimizing the price fluctuation of dried seaweed and avoids longer market chains. It can, therefore, be suggested to improve the prevailing contract growing system by concerning more on farmer satisfaction, rearranging basic seaweed price based on effort, and using non-price arrangements for farmers in meeting social obligations. These recommendations are in line with Krishnan and Narayanakumar (2013) who refer to the contract farming system in Indian seaweed industry. However, there is abundant room to effectively utilize the contract farming scheme to facilitate rapid expansion of seaweed farming in Sri Lanka.

The in-depth interviews indicated that rapid return on investment and employing simple farming techniques generate perceived importance for seaweed farming. Generally, the seaweed farming demands minimal com-

Table 6: Results of the constraint analysis

Constraint	Total Score	Rank	Percentage
Unfavorable weather	12536	1	19.59
Poor quality of planting materials	10673	2	16.68
Distortions in purchasing system	9408	3	14.70
Improper aquatic environments	8794	4	13.74
Poor post-harvest handling	7381	5	11.53
Occupational health hazards	6463	6	10.10
Damaged by predators	5033	7	7.86
Theft problem	3712	8	5.80

pulsory agro-inputs and easy maintenance. In comparison to other aquaculture industries, the technical aspect of the seaweed farming is easier to grasp. Thus, farmers can adapt learning by doing practice to improve the husbandry. Moreover, additional training and extension schedules can cause an immediate impact on the performance of seaweed farming. Altogether, these findings suggest a role for farmer groups or producer associations (Neish, 2013), which allows members to share labour and other material inputs towards the more effective functioning of individual seaweed farms.

Constraints for seaweed farming

The results, as shown in Table 6, indicate that the unfavorable weather pattern (19.6%), poor quality of planting materials (16.7%), distortions in the purchasing system (14.7%), improper aquatic environments (13.7%), poor post-harvest handling (11.5%), and predator damages (10.1%) are the major issues and challenges for the seaweed farming.

Seaweed farming, within the study area, is critically affected by the prevailing unfavorable weather condition that is mainly due to the seasonal changes accompanied by monsoonal weather pattern. As indicated by Zamroni and Yamao (2011), the monsoonal weather pattern is the most critical challenge faced by the Indonesian seaweed industry. Furthermore, both Hurtado *et al.* (2001) and Neish (2013) put forward that the seasonality impact is the major issue for sustained seaweed cultivation. The environmental condition is always changing due to this seasonal variation leading to heavy rains and other severe weather, like prolonged higher temperature periods. On average, the seaweed cultivation limits to four cultivation seasons per year, beginning from mid-May in every year and continuing to February in the following year totaling nine months. Cultivation during rest of the period is not possible due to prevailing high-temperature conditions and severe rainfalls. These unfavorable changes in the environmental conditions lead to variations in the harvesting time. Consequently, in many cases farmers have harvested seaweed before reaching harvestable size and age. Both the quality and measure of seaweed are highly affected by missing the best maturity stage of the plant. A comparative study on Indonesian seaweed farming by Valderrama *et al.* (2013) found that the monthly seaweed harvest of the best season is 2.8 times greater than the average, while it is only 42% during the worst periods. The growth and quality of seaweed can also be affected by the changes of water and salinity levels during dilution of seawater with rainwater. The strong waves and currents prevailing within the study area have also affected the seaweed farming. Over half of those surveyed reported that such strong waves have carried away the plots causing detachments to the seaweed growing structures and floating debris entangled with the existing crop. For these reasons, the seaweed production within the studied area fluctuates throughout the year.

In case of severe damages, farmers have terminated seaweed cultivation prematurely. This finding has implications for developing strategies to lower the adverse effects of environmental changes on seaweed farming. To promptly adapt to such changes, establishing an early warning system of sudden environmental changes and improving the awareness on the link between seaweed growth and environmental conditions seem vital. Addi-

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tionally, Neish (2013) suggested shifting the cultivation sites and cultivating appropriate seaweed cultivars as strategies to keep up a much seaweed production during unfavorable environmental conditions. In a study on Philippine seaweed farming conducted by Hurtado (2013), it was recommended encouraging farmers to buy a crop insurance to cope with the associated risk, despite the cost incurred on it. As Krishnan and Narayanakumar (2013) pointed out, a weather damage relief from government, providing floating rafts to tsunami-affected Indian seaweed farmers can be more beneficial under adverse environmental impacts. However, further studies that consider account site-specific mitigation strategies will need to be undertaken.

The poor quality of existing planting materials was ranked next to unfavorable weather condition as a major constraint faced by the seaweed growers (Zamroni & Yamao, 2011). Farmers usually practice self-propagation of seaweed by using cuttings that were set aside from the previous harvest. This continuous application of long-established knowledge in seaweed propagation, in terms of utilizing the old seaweed stock, it might have created inferior strains over the years. A possible explanation for this might be that the self-propagation may affect the growth rate and quality of seaweed. A further decline in the existing seed stock makes it, so the farmers are unable to optimize the yield. Additionally, rather than practicing self-propagation as individual farmers, a specialized and collective seed production system would become more economically efficient by means of attaining the advantage of economies of scale. Thus, it can be suggested that establishing commercial seaweed nurseries, as previously described by Neish (2013) and Hurtado (2013) for respective Indonesian and Philippine seaweed industries, requires the creation of improved seaweed strains. However, the technological complexities attached to such a process will not enable farmers to start commercial nurseries. Therefore, the intervention of the government and other related parties is a determining factor in this regard.

Distortions prevailing in the existing seaweed purchasing mechanism or the contract growing system (Krishnan & Narayanakumar, 2013) that creates a pre-determined purchasing arrangement in between the buyer and the grower have discouraged the seaweed farmers. In this study, lower farm gate price (Zamroni & Yamao, 2011; Hurdato, 2013) that does not rise as the cost of living made the average price paid to the farmer stagnated at a lower level over the years. Therefore, the farmers feel that their efforts are not properly compensated. The dependence of the Sri Lankan seaweed industry entirely on overseas processors and non-existence of benchmarking international prices at the local seaweed market could be well responsible for this relatively lower farm gate price. The majority of respondents viewed that the buyers regularly justify these low prices, highlighting the importance of technical provisions, like raw materials and advisory support, which are mainly provided by them. As there are no other marketing channels available, the growers are forced to accept the price dictated by the available buyers. Generally, under a limited number of buyers, a monopsony situation or else oligopsonistic pricing (Hurdato, 2013) tends to occur, repressing the price paid to growers while weakening the bargaining power of the farmers. Approximately two-thirds of the participants commented that sporadic payment (Tobisson, 2013) and defective weighing were also distorted qualities of the existing purchasing system. Although the performance of the existing purchasing system is not ideal, the farmers still believe that the protection from price volatility occurred due to periodic disequilibrium in supply and demand. Additionally, the nonexistence of layers of intermediaries create a favorable environment to engage in the cultivation. This would appear to indicate that corrective actions on the identified limitations would turn the contract growing system more beneficial for the seaweed farmers.

Thanks to the increasing number of plots and farms, the near-shore areas that are generally accepted as ideal aquatic environments for seaweed cultivation are limited and subjected to competition. Therefore, in absence of rich farm locations, farmers have shifted the seaweed cultivation to less fertile aquatic environments. Among the causative factors behind this, the legal cut-offs imposed by the government in addressing special local conditions, like national security, conservation, and coastal management were prominent. Within the permitted area, seaweed-farming locations are co-managed by coastal villagers and a considerable proportion of the existing farms are represented by idling seaweed farms. Seaweed farmers, those who are willing to expand their cultivation by increasing the number of seaweed rafts, have undergone serious issues in managing these idling farms. Moreover, the plots that are abandoned for a long time create a dirty and more disorganized system. Very few participants of those surveyed (10%) indicated that depriving near-shore areas has added extra transportation cost and thereby the overall production cost escalated proportionately. This is hardly distinguishable from Zamroni and Yamao (2011), where the production costs of seaweed farms located at the deeper waters are much greater compared to those in shallow waters. Findings so far eventually lead to consider the reordering of existing seaweed farms supported by a proper spatial planning program, and the need to set up a more defined legal policy framework of marine farm tenure (Zamroni and Yamao, 2011). These policies could support the issue of licenses, especially when expanding across the country, to avoid social conflicts while maximizing productivity and identifying promising farm sites for further development of the seaweed cultivation.

The existing post-harvest processing of seaweed confines to purifying and drying them under sunshine to produce dried seaweed as a raw material for international processors. Apart from few respondents (15%), those who are utilizing at least bamboo racks for drying seaweed, dried seaweed on the sand. Consequently, during the rainy seasons, seaweed growers face difficulties in managing time for getting a quietly dried harvest. Additionally, the present drying technology does not support increasing production, particularly during extended rainy periods. It was revealed that the farmers and buyers equally do not consider much about the quality of dried seaweed. Therefore, quality standards for dried seaweed are not customary within the system. Currently, buyers pay a uniform price for dried seaweed regardless of quality. However, it would be beneficial for the market mechanism to motivate growers to consider the quality of seaweed by the reward of elevated prices. Another issue that emerges from these findings is lacking post-harvest processing or value-added products (Valderrama *et al*., 2013; Zamroni & Yamao, 2011). Commonly, value-added seaweed products receive a higher price in the international market compared to unrefined products that eventually results in low-profit margins. Therefore, it will bring in more entrepreneurial qualities to the growers if they could consider producing value-added seaweed products. This view is supported by Prado *et al*. (2012) who state that value-added initiatives are effortlessly achievable with available family labour, mainly more women, and female children. However, technical complications and desired capital inflows would be restrictive factors in this regard. This combination of findings suggests the need of establishing best practices (Rebours *et al*., 2014) and quality standards (Hurtado, 2013) by respective standard-setting agencies for dried seaweed. To facilitate investigating prospects for processing seaweed, more multidisciplinary research will be needed linking the affiliated research institutes (Abowei & Ezekkie, 2013).

It can be seen from the study that unlimited exposure to burning sun, wind, and saline water under poor working conditions cause occupational health hazards (Valderrama *et al*., 2013; Tobisson, 2013) similar to general fatigue, eye soreness, skin problems, and allergies. A common view amongst interviewees was that activities, like initial establishment and hauling harvest, demand physical stamina and are repeatedly causing musculoskeletal pains and aching backs. It is difficult to explain the consequence of such health hazards on the performance of seaweed farming, but it might be related to poor health conditions, which diminish the overall labour productivity.

Though fish grazing (Valderrama *et al*., 2013) has taken place within the study area, it is interesting to note that most of the respondents did not name it as a main constraint. There was a sense of invading certain areas by exotic fish species among the interviewees. However, farmers did not leave out fish threatening periods or alter the cultivation season in response to this problem. Issues related to disease outbreaks also were not particularly prominent within the study area.

Conclusions and recommendations

The study concludes that the present seaweed farming system in the Northern coastal part of Sri Lanka is reasonably profitable and generates considerable additional employment opportunities, thus finically profitable venture. The perceived importance of seaweed as a vital livelihood option proves that the system is socially acceptable among the coastal communities in Northern Sri Lanka. These findings disclose the distinct possibility of the venture to further improve as a commercial enterprise in order to harness its full potential. However, further investigations are needed to identify the biological sustainability of the system for recommending it for further replication to other coastal areas in Sri Lanka. Furthermore, there is a definite need for an open interaction between government, farmers, traders, and representatives of related sectors to further promote the seaweed farming as a commercial venture in coasts of Sri Lanka.

Conflict of Interests

The authors hereby declare that there are no conflicts of interests.

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