Social and economic dimensions of carrageenan seaweed farming in the United Republic of Tanzania

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Msuya, F.E. 2013. Social and economic dimensions of carrageenan seaweed farming in the United Republic of Tanzania. *In* D. Valderrama, J. Cai, N. Hishamunda & N. Ridler, eds. *Social and economic dimensions of carrageenan seaweed farming*, pp. 115–146 . Fisheries and Aquaculture Technical Paper No. 580. Rome, FAO. 204 pp.

ACKNOWLEDGEMENTS

Thanks are expressed to the people from Zanzibar, Pemba, Mtwara, Lindi, Kilwa, Tanga, Bagamoyo and Dar es Salaam who participated in the interviews and filled in questionnaires. The author is also grateful to Dr Amelia Buriyo and I. Sware Semesi for providing literature. Thanks are also given to Mr Hamad Said Khatib who provided export statistics of marine products from Zanzibar.

1. INTRODUCTION

Although the farming of red seaweeds in Tanzania began more than 20 years ago, exploitation of the natural stocks of seaweeds has a longer history in the country. Seaweed exports from Tanzania to Europe trace back to the 1930s (Mshigeni, 1998). Seaweeds were then exported under the species name of *Eucheuma*, which included the currently farmed *Eucheuma denticulatum* and *Kappaphycus alvarezii*.

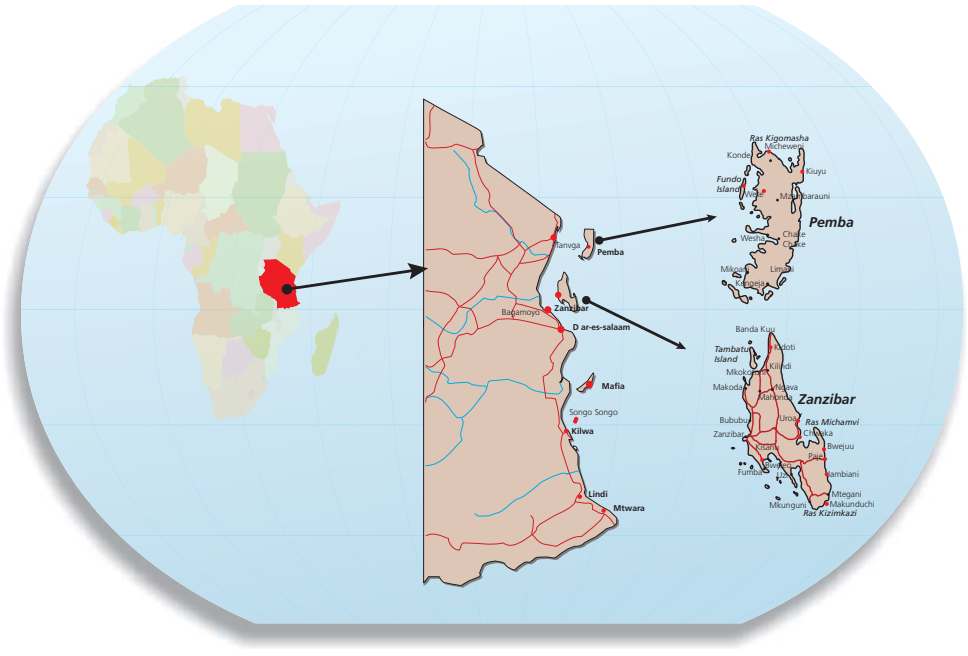
From the two seaweed species farmed in Tanzania, a gel called "carrageenan" is extracted and used in a number of industries, including food, pharmaceutical, cosmetic, and textile. Seaweed is thus valued on the quality of the carrageenan. The gel extracted from *E. denticulatum* is called *iota* carrageenan while that from *K. alvarezii* is called *kappa* carrageenan. Generally, the stronger (or thicker) the carrageenan is, the higher its quality is. *Kappa* carrageenan is normally thicker than *iota* carrageenan.

This study takes a look at the entire spectrum of seaweed farming in Tanzania, from farming to exportation, with a special focus on the socio-economic impacts of the activity. It updates the findings from earlier studies, in particular Shechambo *et al.* (1996) and Semesi (2002).

The information for this study was collected through literature and questionnaire surveys, focus group discussions and interviews with key informants, including on-farm discussions and observations. Questionnaires were developed for seaweed farmers, government departments, exporters and NGOs. In some cases, the questionnaires elicited information directly from the respondents; in some other cases, respondents filled out the questionnaires following discussions with the author. Key informants were selected from government departments, NGOs, and groups of seaweed buyers and experienced farmers. The questionnaire for farmers was translated into Kiswahili to facilitate interviews. Field visits covered four areas in Zanzibar (Unguja Island[1]), three areas in Pemba (the sister island of Zanzibar), Kigamboni in Dar es Salaam, Bagamoyo in Pwani, Tanga; Mtwara; and Lindi (Figure 1).

FIGURE 1

Map of Tanzania illustrating the seaweed farming areas



[1] Unguja is the biggest island within the Zanzibar archipelago.

2. CARRAGEENAN SEAWEED PRODUCTION AND VALUE CHAIN

2.1 History

Documentation of Tanzania seaweed resources began in the late years of the nineteenth century with Sonder (1879) – who reported around 40 seaweed taxa – and Schmitz (1895), who recorded 68 taxa including the commercial genus *Eucheuma*. These initial surveys were followed by the comprehensive work of Jaasund (1976), which in turn stimulated interest on the economic potential of seaweed farming. It has also been demonstrated that the Tanzanian coastal inhabitants have traditionally used seaweeds for medical purposes (*e.g.* wound treatment) and as fish bait (Mshigeni, 1983a). During the late 1960s and early 1970s, coastal villagers in Zanzibar (Unguja), Pemba, and Mafia Islands were harvesting and exporting the red seaweed *Eucheuma* (Mshigeni, 1998). Reportedly, this trade had been taking place since as early as 1935 in Zanzibar and Mafia Islands. According to Shechambo *et al.* (1996), about 387 tonnes of seaweed were exported in 1951. The main export destinations were Denmark, France and the United Kingdom (Mshigeni, 1973; 1976). However, this trade collapsed between 1973 and 1975 as Tanzanian exports based on natural crops (and containing a considerable amount of admixtures) were outcompeted by the copious, clean and semi-processed farmed crop products from the Philippines and other Southeast Asian suppliers (Mshigeni, 1992). It became apparent that the seaweed trade could only be maintained if a controlled production process through farming was put in place.

The farming concept was implemented in Tanzania at different stages. Initially, a couple of papers on the potential of seaweed farming were published in the Tanzania Notes and Records journal (Mshigeni, 1973; 1976). These articles were followed by a book written in Kiswahili, also by Mshigeni (Mshigeni, 1983b). In 1985, Mshigeni conducted the first farming experiments in three localities in Tanzania: Tanga (northern Tanzania), Fumba in Unguja (Zanzibar) Island, and Fundo Island in Pemba (Figure 1). Only until 1989 did commercial farming develop as a result from these experiments (Eklund and Petterson, 1992; Msuya *et al.,* 1996; Shechambo *et al.,* 1996; Msuya, 2005).

FIGURE 2

Species of cultured seaweed in Tanzania



Eucheuma denticulatum



Kappaphycus alvarezii



Kappaphycus striatum locally known as ***kikarafuu***



A variety of K. alvarezii locally known as ***Bulabula***

Experimental commercial farms were established in two villages on the east coast of Zanzibar (Paje and Jambiani).

From Zanzibar, commercial seaweed farming expanded to the mainland in 1992–1996 in the Tanga (Zuberi *et al.*, 2007) and Bagamoyo areas, followed by Mafia Island (Msuya, 2009a). In southern Tanzania, farming expanded to Mtwara, Lindi and Kilwa Districts (Msuya, 1995; 1996).

The first documented production and export activity took place in 1990, when 808 tonnes were exported. Production increased over the years, reaching nearly 11 thousand tonnes by 2008 (Msuya 2006a; 2009a). Most production is from Zanzibar while mainland Tanzania's output is less than 1 000 tonnes, consisting mostly of *K. alvarezii* (MNRT, 2005). The Aquaculture Department of the Ministry of Livestock and Fisheries recently reported a total production of 887 tonnes for the mainland in 2008/2009.

2.2 Production and trade

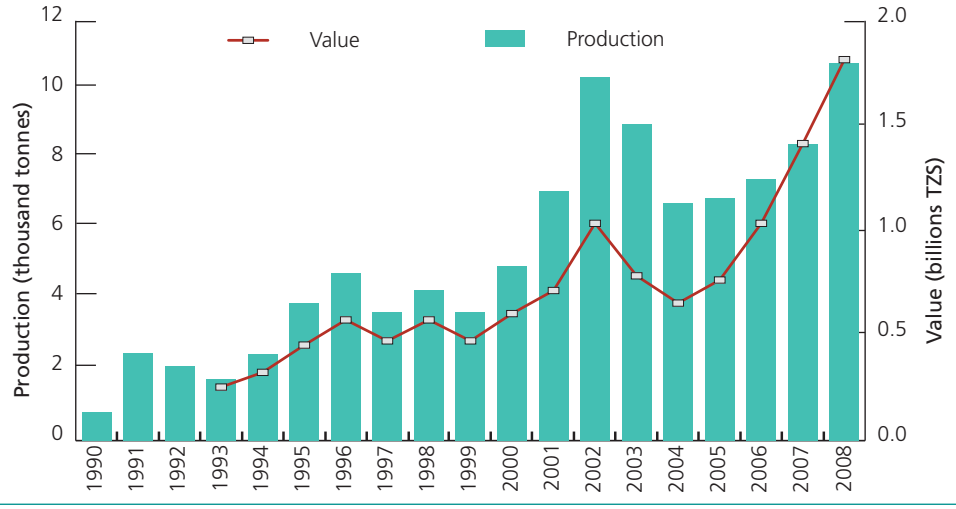
As mentioned above, the idea of farming seaweed in Tanzania was introduced in the early 1970s by Professor Keto Mshigeni of the University of Dar es Salaam (Mshigeni, 1973; 1976), who also conducted the first culture trials (Mshigeni, 1985). These experiments encouraged private entrepreneurs in the late 1980s to engage in commercial seaweed farming. By the early 1990s seaweed was commercially exported from Tanzania. The industry grew significantly in the Zanzibar islands, where it is the second most important industry after tourism. Seaweeds also represent the largest marine export product from Zanzibar, contributing over 97 percent in most years[2].

Species

Several cultured seaweed species in Tanzania are illustrated in Figure 2. *Eucheuma denticulatum* and *K. alvarezii* continue to be the most widely farmed species. Recently, serious problems have been caused by widespread die-offs of *K. alvarezii* experienced in many areas in Tanzania. This situation has created negative impacts for farmers, exporters, and the country at large. Unfortunately, the world market has a preference for *K. alvarezii* over *E. denticulatum* because of its thicker carrageenan. Farmers

FIGURE 3

Seaweed production and value in Zanzibar, 1990–2008



Source: DFMR, Zanzibar (2009).

[2] Other export products include lobsters, fish fins, squids, anchovies, oysters, octopus, crabs and fish offal.

have tried to grow *K. alvarezii* for a number of years in the hope of achieving greater incomes, but these attempts have failed repeatedly. Many farmers have thus resorted to the lower priced species. These problems have discouraged some farmers, particularly men, who have returned to low-paying activities and to fishing, in some cases using environmentally unfriendly gear such as beach seines.

Alternatives to *K. alvarezii* – e.g. *K. striatumn*, locally known as *kikarafuu*, and a variety of *K. alvarezii* known as *kikorosho*, have been tried but did not perform well in culture trials and are not farmed anymore.

Recently a variety of *K. alvarezii* known as *Bulabula* has been introduced in Tanga since 2007. Commercial culture of this species is still at experimental stages as only a few "risk-tolerant" farmers are planting it. It must be noted that all these species and varieties have been introduced in compliance with the regulations stipulated by the government.

The potential for farming two agarophyte[3] species, *Gracilaria salicornia* and *G. Edulis*, is also being evaluated by scientists at the UDSM (Kivaisi and Buriyo, 2005). Both species occur naturally in Tanzanian waters. Methods for farming *Gracilaria* include the traditional off-bottom technique and the cage farming technology employed in South Africa. Market outlets in Tanzania would include universities, hospitals (for microbiological purposes), and food processing industries (Msuya, 2009c).

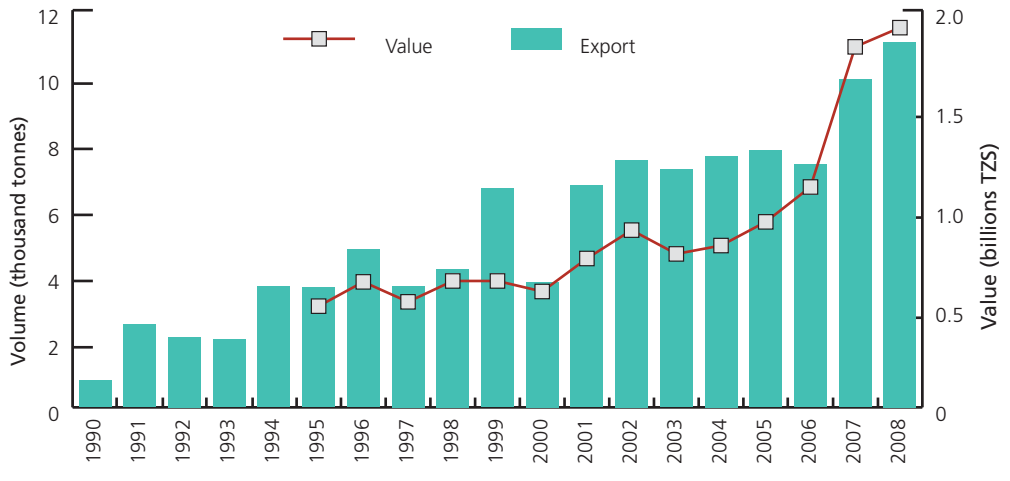
Production and trade

Commercial seaweed production in Zanzibar grew rapidly throughout the 1990s (Figure 3). Output fell drastically between 2002 and 2004 from 11.2 to 7.2 thousand tonnes but increased again from 2005 onwards, reaching nearly 11 thousand tonnes in 2008. Seaweed produced in Zanzibar is mostly exported. Seaweed exports from Zanzibar reached 11 thousand tonnes worth TZS 1.7 billion in 2008 (Figure 4).

In terms of species, while the production of *E. denticulatum* in Zanzibar *has been on an upward trend since 2004, the production of K. alvarezii* has been decreasing over the years, from 1 048 tonnes in 2001 to 16.5 tonnes in 2008 (Figure 5). The decline is mostly

FIGURE 4

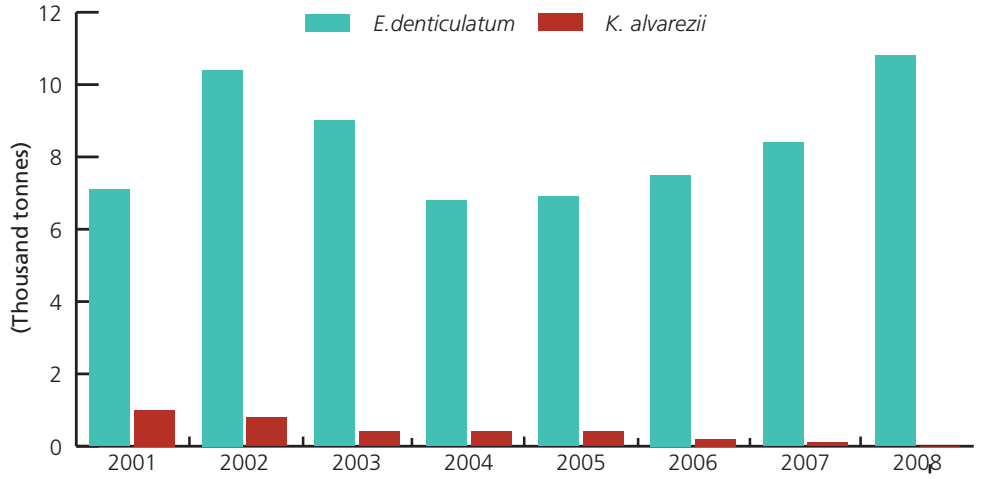
Seaweed exports from Zanzibar, 1990 – 2008



Source: DFMR, Zanzibar (2009).

[3] An agarophyte is seaweed producing the hydrocolloid agar as part of the makeup of their cell wall. This agar can be harvested commercially for use in biological experiments, among other applications.

FIGURE 5
Seaweed production per species in Zanzibar, 2001 – 2008



Source: DFMR, Zanzibar (2009).

due to the die-off episodes[4] caused by diseases (e.g. ice-ice). Production of *K. alvarezii* has also decreased in the mainland Tanzania in recent years, from 1 222 tonnes in 2002 to 887 tonnes in 2008/2009.

The value chain

Post-harvest processing

Seaweed is harvested after 4 to 6 weeks depending on the growth rates at the farming site. Harvesting involves untying the lines from the anchorage pegs and then removing the seaweed. This is followed by selecting new branches from the harvest as re-planting material, and tying the lines back to the pegs. The tying-in of new branches can be performed at the farming site by sitting in the shallow water (Figure 6) or at home following daytime activities at sea. The remaining portion of the harvest is taken home for drying and selling.

Farmers dry the seaweed by spreading it on mats, coconut branches, grass or sand. Seaweed takes from two to three days to dry on sunny weather, but drying may take up to seven days on rainy seasons. Upon drying, seaweed is sorted and shaken to remove dirt and sand. It is then stored at home or sold directly depending on the harvest volume.

Sales are negotiated in the farming villages. Buyers usually have storage rooms in the villages and employ a local agent to buy the seaweed from the farmers. Seaweed is collected and stored and then transported by trucks to warehouses for baling and shipping. If for any reason funds are not sent to the village on time, farmers' routine selling may be delayed for up to three months. Buyers usually make efforts to avoid this situation.

Exportation

Seaweed is purchased from the farmers and stored in the village until sufficient quantities have been accumulated to make a truck trip to Zanzibar Town worthwhile. From Zanzibar Town seaweed is exported by local companies to multinational sister

[4] Interviews with farmers have also revealed that continuous production for two consecutive years is normally followed by die-off episodes, which can last for more than a year.

FIGURE 6
Seaweed farmers tying seed at sea in Uroa, Zanzibar



companies abroad. Besides major export companies[5], anecdotic evidence indicates that local entrepreneurs have started joining seaweed collecting and exporting businesses and hence provide alternative market channels.

Main export markets of seaweed from Tanzania used to be the United States of America, France, Denmark and Spain. Chile and China have also started importing seaweed from Tanzania because of a worldwide shortage of carageenan seaweed raw materials. Such emerging markets tend to provide more opportunities for local entrepreneurs to thrive.

Value-added products

During 1983–84, researchers used extracts from *Gracilaria* as a fertilizer for bean plants[6]. These initial trials paved the way for further examination of the fertilizing properties of seaweeds (e.g. the Zero Emissions Research and Initiatives [ZERI]).[7]

Under the guidance of the Zanzibar Seaweed Cluster Initiative (ZaSCI), value-added products such as seaweed-based soaps, body creams, and puddings were developed and manufactured in Zanzibar (Msuya, 2005; 2006b). ZaSCI produced four types of seaweed soaps in Kidoti and Bweleo during 2008 and 2009: regular soaps and soaps containing cinnamon, lemon grass, and lime (Msuya, 2008; Msuya and Kyewalyanga, 2008; Msuya, 2009c; 2009d). Farmers have also been trained in Jambiani (Zanzibar) and Wete (Pemba). ZaSCI has also produced a variety of seaweed-based body creams containing cinnamon, clove, lemon grass and eucalyptus (Msuya, 2009c; 2009d). Other value-added products such as crackers, candies, biscuits, juice, cakes and salad could potentially be commercialized in the future (Msuya, 2006b; 2009c; 2009d).

[5] Major companies exporting seaweed from Tanzania include C-weed Co., Zanzibar Agro-Seaweed Company Limited (ZASCOL), Zanzibar East African Seaweed Company (ZANEA), Birr, Mwani Mariculture, ZanQue and Zanzibar Shell.

[6] Mshigeni and Msuya were among the first scientists undertaking efforts to develop value-added seaweed products.

[7] ZERI is a global network of scientists and entrepreneurs working on a range of projects and case studies that emphasize the use of waste as raw materials for the development of new production systems.

Carrageenan gel has been extracted at experimental levels by CoET/UDSM in association with MUCHS/UDSM and also by the Sokoine University of Agriculture (SUA), mostly for medical purposes, including its potential use in HIV/AIDS control programmes. The gel is also being extracted by TIRDO to establish the potential of a semi-processing industry in the country.

3. CARRAGEENAN SEAWEED FARMING: ECONOMIC AND SOCIAL PERFORMANCE

3.1 Farming techniques

Seaweeds in Tanzania are farmed using primarily the peg and line (off-bottom) method, which is the most common farming method worldwide. Some farmers use 4-m long lines with one peg at each end (Figure 7) while other farmers use from 10- to 20-m long lines with buoys and one peg at each end as well (Figure 8).

Nylon ropes with seaweed are tied between two wooden pegs obtained from mangroves or land-based plants. The seed, typically from the same stock initially imported from the Philippines, is sourced from other farmers or from a buyer. In addition to seed, buyers also provide materials (ropes and tie-ties[8]) to the growers,

FIGURE 7
Off-bottom method: 4-m long lines with two pegs at each end. Uroa, Zanzibar



FIGURE 8
Off-bottom method: 10-20-m long lines. Mwambani, Tanga



[8] A tie-tie is a type of thin nylon rope.

who then must sell the seaweed product to the buyer if materials were provided free of charge.

Seeds are usually obtained from older plants although farmers are sometimes forced to use younger branches if seeds are scarce. Branches of about 100 g are tied in the 4-mm-diameter nylon ropes. The branches (usually from 11 to 15 in a 4-m line) are tied at 20-cm intervals (using tie ties); the line is then tied to the wooden pegs (about 60 cm long) that have been rooted into the sediment (Figure 7).

A farm (or plot) consists of 50 lines approximately, but this number may vary depending on the farmer's preferences. Some farmers maintain between 100 and 300 lines and some reportedly manage up to 1 000 lines.

Low tides occur two times a month and each low tide takes seven days, thus farmers work on their farms for 14 days during each month. The time between ebbing and flooding during low tides is 4 hours; this is the time interval used by farmers to tend their plots. Farm management primarily consists of removing sand and debris from the lines (including wild seaweeds), tying new branches to replace those broken by the action of the winds or grazed upon by sea urchins, and re-attaching the loose and uprooted pegs.

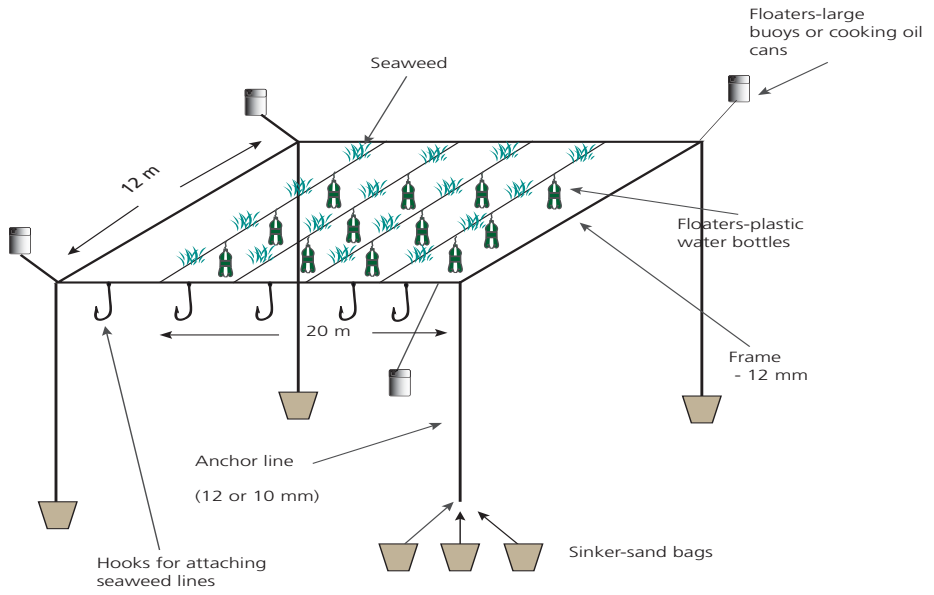
Trials have also been conducted on deep-water farming with bamboo rafts (Zuberi, 2000; Msuya and Kyewalyanga, 2006; Msuya and Salum, 2006). However, this technique has not been adopted primarily because of the limited availability of bamboos along the coast and the fact that bamboo rafts are not durable.

In a recent initiative, a new technique based on deep-water floating lines (Figure 9) has been tried and adopted in about five villages in Zanzibar (Msuya, 2006b; Msuya *et al.*, 2007a; Msuya, 2009a). The new technique has been shown to yield greater harvests per unit area (Msuya *et al.*, 2007a) than the off-bottom method. In addition, the floating systems consist of recycled plastic water bottles and oil cans as opposed to wooden pegs, which reduce reliance on forest resources. For this reason, some have dubbed the technique as "forest friendly".

Other innovative seaweed farming methods being tested or considered in Tanzania include 1) the "cast method" which involves tying seed in stones with a rubber band

FIGURE 9

The deep-water floating lines method



Source: Msuya (2006b).

and letting the seaweed attach itself to the rock and grow and 2) the "broadcast method" which involves placing seaweed in fences made of netting materials.

3.2 Economic performance

The economic performance of two seaweed (*K. alvarezii*) farming methods used in Tanzania are examined below. One is the traditional off-bottom method; the other is deep-water floating lines method. Comparison of costs was achieved using data from Zuberi (2000), Msuya *et al.* (2007a), Msuya (2006b), Msuya (2009b), and the current study through interviews with seaweed buying companies and a number of NGOs.

Capital cost

The traditional off-bottom method remains the most widely used technique in Tanzania. This method uses 4-mm diameter lines with varying lengths between 4 and 20 m, depending on the characteristics of the site and the ability of farmers. In Zanzibar and in some mainland areas, farmers only use 4- or 5-m lines. However, in areas such as Bagamoyo, Tanga, Mtwara and Lindi, farmers use long lines (10–20 m, see Figure 7) to which buoys are sometimes attached.

Table 1 summarizes the investment requirements and the corresponding amortized annual capital costs (i.e., depreciation) of an off-bottom farm. The farming system comprises ropes, tie-tie, floaters and stakes. Thirty pieces of 10-m ropes are needed. One roll of tie-tie is required for every three lines of 10-m rope. Floaters are made of recycled plastic water bottles. Two floaters per line are required for a total of 60 floaters (one floater per 5-m length of line). Floaters normally need to be replaced after three months; hence totally 180 floaters are needed for one year of operation. Two stakes per line are required, which normally need to be replaced after 6 months; hence 120 stakes in total are needed for one year of operation.

TABLE 1
Initial investment and amortized annual capital costs for an off-bottom farm

Items	Quantity	Unit cost (TZS)	Total investment cost (TZS)	Lifespan (years)	Annual amortized capital cost(TZS)
Farming system			**19 490**		**19 490**
Ropes (m)	300	27.8	8 340	1	8 340
Tie-tie (roll)	10	275.0	2 750	1	2 750
Floaters	180	30	5 400	1	5 400
Stakes (pegs)	120	25	3 000	1	3 000
Boat and equipment			**20 500**		**7 328**
Boat construction	1	7 413.8	7 414	10	741
Boat maintenance	1	86.2	86	1	86
Diving masks	1	10 000.0	10 000	2	5 000
Knife	1	1 000.0	1 000	2	500
Machete	1	2 000.0	2 000	2	1 000
Post-harvest facilities			**20 000**		**6 900**
Drying rack frame	1	7 000.0	7 000	5	1 400
Palm fronds for rack	30	50.0	1 500	1	1 500
Tarps (m)	10	1 000.0	10 000	4	2 500
Plastic bags	10	150.0	1 500	1	1 500
Total			**54 890**		**33 718**

Source: Modified from Msuya *et al.* (2007).

Non-motorized boats are routinely used by farmers; the cost of constructing one boat is TZS 430 000. In the case of the 58-member cooperative, each farmer would contribute TZS 7 413.80. The useful life of the boat is about 10 years and boat maintenance is performed once a year at a cost of TZS 5 000 (each cooperative member contributes TZS 86.21 per year).

Equipment and tools include knives and machetes for cutting and sharpening the stakes, snorkelling masks for inspecting the plots during high tide, and gloves and rubber shoes to prevent scratches in hands and legs.

Traditionally, seaweeds are dried on palm fronds and cloth materials placed directly on the ground (Figure 10). To improve quality, drying racks made of wooden stakes and palm fronds that elevate the drying surface off the ground are recommended (Ask, 1999; MNRT, 2005; Msuya, 2006b). Farmers have begun constructing racks as they learn the importance of thorough drying. Thus the cost of constructing a drying rack is included in this analysis. A drying rack frame is built using two bundles of wooden stakes, each costing TZS 2 000, 15 palm fronds at a cost of TZS 50 per frond (the palm fronds are normally changed every three harvests, thus a total of 30 palm fronds are required), and two rolls of rope, each costing TZS 500. The labour cost for the construction of one rack is approximately TZS 2 000. In the rainy season, plastic materials (i.e., tarps) are needed to cover the seaweed while it is drying. Plastic bags (10 pieces) are used for transporting the wet seaweed from the farm to the drying area and for storage of the dry seaweed.

FIGURE 10

Drying seaweed in Kiuyu (Pemba Island), with storage sheds shown at the background



Table 2 summaries the investment requirements and the corresponding amortized annual capital costs of a deep-water floating-lines farm with 30 pieces of 12-meter lines. The raft frames require one roll of 12-mm lines for the frame, one roll of 10-mm anchor lines, one roll of 8-mm lines for tying anchors, and three rolls of 4-mm lines for tying seaweed. Anchors consist of fertilizer bags filled with sand or stones depending on the availability of sand and the nature of the tidal flat environment (muddy bottoms would demand more frequent replacement of the sand bags). Recycled oil cans are used both as large buoys and markers while the plastic water bottles are used as floaters. A commercially profitable floating system should be at least 20×10m.

The boat, equipment and post-harvest facilities used in the floating-lines system are assumed to be the same as the off-bottom farm.

TABLE 2
Initial investment and amortized annual capital costs for a floating-lines farm

Items	Quantity	Unit cost (TZS)	Total investment cost (TZS)	Lifespan (years)	Annual amortized capital cost (TZS)
Farming system			**58 925**		**21 565**
Ropes for raft (27×12 m):					
- 12 mm (frame line)	1	18 500	18 500	5	3 700
- 10 mm (anchor line)	1	14 000	14 000	5	2 800
- 8 mm (for tying anchor bags)	1	8 000	8 000	5	1 600
- 4 mm (seaweed lines)	3	2 500	7 500	1	7 500
Tie-tie (roll)	11	275	3 025	1	3 025
Anchors (stones)	16	200	3 200	4	800
Floaters (empty plastic bottles)	50	30	1 500	1	1 500
Frame construction	1	3 200	3 200	5	640
Boat and equipment			**20 500**		**7 328**
Boat construction	1	7 414	7 414	10.0	741
Boat maintenance	1	86	86	1.0	86
Knife	1	1 000	1 000	2.0	500
Machete	1	2 000	2 000	2.0	1 000
Diving masks	1	10 000	10 000	2.0	5 000
Post-harvest facilities			**20 000**		**6 900**
Drying rack frame	1	7 000	7 000	5.0	1 400
Palm fronds for rack	30	50	1 500	1.0	1 500
Tarps (m)	10	1 000	10 000	4.0	2 500
Storage containers	10	150	1 500	1.0	1 500
Total			**99 425**		**35 793**

Source: Modified from Msuya *et al.* (2007).

TABLE 3
Initial investments and amortized annual capital costs: off-bottom vs. floating lines

Items of capital investments	Total investment cost		Amortized annual capital cost		Capital cost per km	
	Total cost (USD)	Share of total cost (%)	Annual cost (USD/year)	Share of Annual cost (%)	Total (USD/km)	Annual (USD/year/km)
Off-bottom (30×10 m)						
- Farming system	15.5	32	15.5	58	51.8	51.8
- Vehicle and equipment	16.3	34	5.8	22	54.4	19.5
- Post-harvest facilities	15.9	33	5.5	20	53.1	18.3
Total	**47.8**	**100**	**26.9**	**100**	**159.3**	**89.6**
Floating lines (27×12 m)						
- Farming system	47.0	59	17.2	60	144.9	53.0
- Vehicle and equipment	16.3	21	5.8	20	50.4	18.0
- Post-harvest facilities	15.9	20	5.5	19	49.2	17.0
Total	**79.2**	**100**	**28.5**	**100**	**244.5**	**88.0**

USD 1 = TZS 1255 (2007) Numbers may not add up due to rounding

Based on Tables 1 and 2, Table 3 compares the investment and annual capital costs of the off-bottom and floating-lines systems. The unit is converted from TZS to USD based on the exchange rate in 2007, USD 1 = TZS 1255.[9] The results indicate that although the floating-lines system (USD 144.9/km) is much more expensive to build initially than the off-bottom system (USD 51.8/km), its amortized annual capital cost (USD 53.0/per km) is almost the same as the off-bottom system (USD 51.8/km) because of the durability of the materials it uses[10].

Variable cost

After initial periods, the variable cost of seaweed farming primarily comprises the cost of labour; the cost of seed is negligible because farmers usually propagate seeds from previous harvests. Labour requirements per production cycle are assumed to be the same for the off-bottom and floating-lines farms, which include seed tying, planting, farm management, tie-tie/rope separation, harvesting, drying, packaging, and transportation.

Most of these works (except transportation) are done by family labours who are not paid directly but do incur an opportunity cost, which in this case is the hourly wage paid to hired seed-tying labour, i.e. TZS 37.5 per hour. Transportations of fresh seaweed to the drying sites and dried seaweed to the market are accomplished by hired labours. The details are summarized in Table 4 and briefly explained as follows:

- Four family members spend eight hours each to complete the tying process.
- It is estimated that two family members participate in the planting process and spend half an hour each in planting a total of 15 lines. Planting is completed over two days in each production cycle; therefore, each of the two family members devotes one hour per production cycle to plant a total of 30 lines.
- One family member devotes half an hour per day for management tasks during six days in each production cycle, leading to a total of three man-hours per production cycle.
- Four family members assist in the harvesting process. It takes one hour for four people to harvest 10 lines of 10 meters each. Both farms harvest up to 10 lines per

TABLE 4
Labour costs per cycle for the off-bottom and floating-lines farm

Labour requirement per production cycle	No. of workers	Hours per worker	Labour (hours)	Wage (TZS/hr)	Annual cost (TZS/cycle)
Family labour			**64.25**		**2 409**
- Typing seed	4	8	32	37.5	1 200
- Planting	2	1	2	37.5	75
- Farm management	1	3	3	37.5	113
- Tie-tie separation	4	3.75	15	37.5	563
- Harvesting	4	3	12	37.5	450
- Packing	1	0.25	0.25	37.5	9
Hired labour			**2.5**		**2 150**
- Transportation to drying place	1	2	2	1 000	2 000
- Transportation to market	1	0.5	0.5	300	150
Total labour					**4 559**

Source: Modified from Msuya et al. (2007)

[9] Source: The United States Central Intelligence Agency: World Fact Book.

[10] Msuya (2006b) explained that the useful life of frames in the floating systems could reach 10 years because under more stable conditions in deep waters, abrasion of the lines is less prevalent and thus lines need to be replaced less frequently. However, to be conservative and consistent with the experience in other countries, the depreciation period of the frame is assumed to be 5 years.

day, thus the 30 lines in each production cycle are harvested in three days. This gives a total of 12 man-hours per cycle.

- Farmers routinely work to separate tie-ties and ropes that are entangled together at sea. It is estimated that four family members perform this task. It takes one hour to disentangle eight 10-m lines, thus 3.75 hours will be required for the 30 10-m lines.
- A hired cart is used to carry the fresh seaweed to the drying place. The cost of hiring a device such as a cart is the same as that of hiring one person: in most cases the hired person will bring his own cart. Therefore, the cost of carrying seaweed is included in the labour costs in this analysis. It takes about two hours to carry 30 lines of 10 m; the cost is TZS 1 000 per hour.
- After drying, one family member packs the dried seaweed into sacks. It takes 15 minutes to pack one sack of 100 kg.
- A person or a carrying device is hired to carry the dry seaweed from storage to the market. The cost of hiring a device (or one person) to carry one sack of 100 kg to the market is TZS 300 per hour. One sack is required in each production cycle and the process of carrying it to the market takes about half an hour.

Revenue, cost and profit

On both off-bottom and floating lines farms, three seaweed lines are not harvested at the end of the cycle; instead, they are used to generate seed for the ensuing cycle. This means that 27 and 24 lines are harvested per production cycle on the off-bottom (270 m in total) and floating lines farms (288 m in total), respectively.

Assuming 0.35-kg/m/cycle productivity (Msuya *et al.*, 2007), the off-bottom farm would generate 94.5 kg of dry seaweed per cycle for sales; the floating-lines farm 100.8 kg per cycle. Because of the die-offs caused by diseases, seven production cycles per year are completed in off-bottom farms instead of the usual eight. Die-offs are averted in the floating lines method (Msuya *et al.*, 2007a). Therefore, the total dry

TABLE 5
Annual revenue, cost and profit of seaweed farming in Tanzania

Item No.	Items	Off-bottom	Floating-lines
(0)	**Initial investment (USD)**	**47.8**	**79.2**
(1)	**Total length of lines (m)**	**300**	**324**
(2)	**Dried seaweed produced (kg)**	**662**	**806**
(3)	- Productivity (tonne/km of lines)	2.2	2.5
(4)	**Price of dried seaweed (USD/tonne)**	**207**	**207**
(5)	**Revenue (USD)**	**137**	**167**
(6)	- Productivity (USD/km of lines)	457	516
(7)	**Cost (USD)**	**54**	**58**
(8)	- Fixed cost (USD)	27	29
(9)	- Variable cost (USD)	27	29
(10)	Operational cost (USD)	15	15
(11)	Transportation cost (USD)	12	14
(12)	**Net profit (USD)**	**83**	**109**
(13)	- Profit margin (%)	61	66
(14)	- Break-even price (USD/tonne)	81	71
(15)	- Pay-back period (year)	0.43	0.57

Notes: USD 1= TZS 1255 (2009). (3)=(2)/(1). (5)=(2)*(4)/1000. (6)=(5)/(1)*1000. (7)=(8)+(9). (9)=(10)+(11). (10): Imputed family labour cost detailed in Table 4. Harvesting and packing are 7 cycles for off-bottom; others are 8 cycles for both farms. (11): 7 cycles for off-bottom; 8 cycles for floating-line. (12)=(5)-(7). (13)=(12)/(5)*100. (14)=(7)/(2)*1000. (15)=(0)/[(12)+(8)]. Numbers may not add up due to rounding.

seaweed production is 661.5 kg per year (7 cycles) for the off-bottom farm and 806.4 kg per year (8 cycles) for the floating-lines farm[11].

The revenues, costs and net profits of the two farms are summarized in Table 5. The results indicate that:

- Both farms are profitable with high profit margins, 61 and 66 percent for the off-bottom and floating-line systems, respectively.
- Because of the loss of one crop due to die-offs, the off-bottom farm has lower profit than the floating-line farm, even though its cost is slightly lower.
- The off-bottom farm would have positive net profit as long as the price of dried seaweed is above USD 81/tonne. The break-even price for the floating-lines system is USD 71/tonne.
- It would take 0.43 year to recover the initial investment of the off-bottom farm. The pay-back period for the floating-line farm is 0.57 year.

The higher productivity of the floating lines system (Table 5, item 3) reflects the extra one crop it harvests because of avoidance of die-offs, while the productivity per cycle is assumed to be identical for both systems (i.e. 0.35kg/m/cycle).

However, evidence indicates that the floating-lines system may tend to have higher yield than the off-bottom system[12]. In addition, the deep-water farming sites of floating-lines system allows it to have relatively less environmental impacts and greater potential to be integrated with the farming of other species (e.g. molluscs and finfish). However, the deep-water farming site would also be less accessible, more difficult to manage (e.g. requiring swimming skill), and may cause conflicts with other activities such as fisheries and navigation (Msuya et al., 2007b).

3.3 Social performance

Livelihoods

In most areas in Tanzania, seaweed farming is still perceived by farming communities, exporting companies and government officials as an economic activity that yields great benefits to the nation. Some people, however, complain that seaweed is not contributing to economic welfare as much as they had expected or as it used to do in the past. Most of these feelings are being voiced in Zanzibar (Unguja). Whether this is linked to how much effort a farmer needs to put into seaweed farming or not will be discussed under this section. Generally, a number of studies (Eklund and Pettersson, 1992; Mshigeni, 1998; Shechambo *et al.,* 1996; Semesi, 2002) suggest that seaweed farming is indeed helpful to coastal people in Tanzania.

There are two important aspects to seaweed farming in Tanzania that greatly influence perceptions of the activity. One aspect deals with the price differences between *E. denticulatum* and *K. alvarezii* whereas the second issue revolves around the differences in the intensity of work and the availability of buyers between mainland Tanzania and Zanzibar islands. In most areas where the higher priced *K. alvarezii* is cultured, farmers perceived seaweed farming as a beneficial activity whereas growers tend to complain more in areas where the lower priced *E. denticulatum* species is cultured. However, farmers generally deemed seaweed aquaculture a beneficial economic activity for the following reasons:

[11] Harvests from the floating lines farms could potentially be much higher as demonstrated in previous tests of floating systems (Hurtado and Agbayani, 2002; Zuberi, 2000)

[12] Field evaluations have showed that the floating-line method achieves higher growth rates (6–15 percent per day) than those attained with the traditional off-bottom method (3–5 percent per day). In Pemba, a company currently farming both *K. alvarezii* and *E. denticulatum* in 42 floating rafts reported that the wet weight of both species increased nearly ten times in 45 days, from 2.5 kg to 20-22 kg for *K. alvarezii* and 22-28 kg for *E. denticulatum* (Msuya, 2009b).

- Incomes from seaweed farming have enhanced the food security of people who have been relying on food aids from government (e.g. Shuka village in Lindi district).
- Seaweed farming provides farmers with a means to tackle a range of problems that could not be solved without seaweed money, such as improving household diets, sending children to school, buying clothing and books, opening bank accounts, improving houses (e.g. cement for wall, iron sheets for roof, toilet, kerosene lamps, etc.), buying assets (e.g., beds, cupboards, bicycles, radios, mobile phones, etc.), among others.
- Seaweed aquaculture yields positive returns to able and hard-working farmers. As a part-time activity with a relatively short cycle, seaweed farming provided great economic opportunities in areas without much arable land and has become a diversified livelihood source for fishing households in coastal villages. Seaweed farming yields returns greater than the wages normally paid to field (land cultivation labourers) workers. Farmers also felt that seaweed farming compares in favourable terms to traditional agriculture. A villager in Shuka explained that he had been a fisherman for many years but decided to engage in seaweed farming because fish prices are low; and the fishing area is remote. Seaweed farming has given housewives a source of extra household incomes. A senior villager who was over 80 years old stated that although he was unable to farm seaweed anymore, he could still help transport the seaweed from the sea to the drying places or put seaweed in sacks and get paid.
- Seaweed farming not only enabled farmers to satisfy day-to-day needs but also allowed them to borrow money or items from a shop knowing that they could pay back upon selling the seaweed harvest.
- Seaweed farming has become more pivotal livelihood sources for farmers whose land-based farming space has been threatened by urban development (e.g. villagers in Mwambani and Mchukuuni).

Employment

Farmers hire other villagers for performing tasks such as tying seed, harvesting, carrying seaweed to the drying and selling locations, etc. Given that tasks need to be carried out at every low tide, this type of employment is more or less permanent. It is estimated that seaweed is farmed in Zanzibar Islands and mainland Tanzania in around 60 villages (personal communication from exporters). Assuming that at least five villagers are employed in each village during low tides, employment is created for more than 300 people at each low tide and thus 600 people each month.

In addition, export companies employ local individuals who buy seaweed and provide extension services on behalf of the companies[13]. These agents operate in buying stations operating in every district on the mainland and in almost every other village in Zanzibar.

Age and education

An analysis of the ages of the interviewed farmers (n=43) in Zanzibar showed that only two farmers were younger than 20 and only one farmer was older than 60. Most farmers were within the 40–50 year-old bracket (24 farmers) or within 51–60 (9 farmers). A similar situation was observed in mainland Tanzania. Very young people are not getting involved with seaweed farming, in part because educational levels are rising in the country and youngsters are looking to get employed in other sectors of the economy upon graduation.

[13] All agents employed by export companies are nationals, with the exception of the Mwani Mariculture Company, which has hired an individual from the Philippines.

More than half of the interviewed farmers in Zanzibar (25 out of 43) had secondary school education. This is in contrast to Shechambo *et al.* (1996), who had reported that most farmers in 1996 only had primary-school education. This trend may reflect the current inability of secondary-school graders to find employment with the central government system. During the 1990s, most individuals with a secondary-grade education could potentially aspire to positions with the government.

Gender

Seaweed farming in Tanzania is more a female-oriented activity because men were often discouraged by the labour-intensiveness and relatively low profitability of seaweed farming[14] and hence prefer other activities such as fishing, tourism, shell polishing trade, etc. Women, on the other hand, had limited alternatives and thus put more effort into farming.

In contrast to Eklund and Pettersson (1992) and Shechambo *et al.* (1996), who found that money-power conflicts sometimes emerged between women seaweed farmers and their husbands, no such situations were observed in this study. On the contrary, men were supportive of their wives and even provided some help during harvesting. Women explained that husbands are content because they see that some of the family needs can be covered by their wives, even though they often remark that returns from the activity do not fully compensate for the amount of work invested.

In Zanzibar most men do not engage in seaweed aquaculture but they do not prevent women from farming. In Kidoti, women explained that pro-seaweed husbands provide assistance with seaweed line tying and transportation tasks. Children also help with minor chores during the evenings, weekends and school holidays. Kidoti women also explained that men sometimes complain about the smell of dry seaweed that is stored at home.

Zanzibar is an Islamic society and as such men are polygamous, marrying up to four wives. A few women explained during the interviews that, because they can provide for some of the basic household needs, men are able to save more money but instead of helping at home they use the money as dowry to marry yet more wives. With all its negativities to the first household, general household income will increase if the new wives also engage in a revenue earning activity such as seaweed farming. Similar results were reported by Eklund and Pettersson (1992).

The interviews also revealed that most children needs, especially school expenses, are covered by women using seaweed income. In Tanga, a female villager mentioned that "when a child asks for books or even a pen for school, the father tells him/her to go to the mother".

Msuya (2009a) mentions the case of a woman in Bweleo, Zanzibar, who has been in the seaweed trade business for a number of years. The woman explained that her aim is not only to gain a profit but also to help her fellow farmers increase their income. She also explained that she buys seaweed from needy farmers when the export companies fail to do so. She then re-sells the seaweed to the exporters in Zanzibar Town.

4. GOVERNANCE AND INSTITUTIONS

4.1 Legal and institutional framework

Seaweed farming in mainland Tanzania is governed under the Fisheries Act, Fisheries Policy and other fisheries regulations. At the time of this writing, the government is implementing modifications to the Fisheries Act and Fisheries Policy to clearly outline the sections on mariculture and seaweed farming.

[14] In Tanga, one young male farmer ceased operating his farm of 700 lines allegedly because the price of seaweed is "a female price", meaning that it can be tolerated by women but not by men like him.

Entry to seaweed farming is unrestricted. Any inhabitant from a coastal village can establish a farming location wherever space is available. As long as this person continues to farm its selected space, the area will belong to him. Protection of property is based purely on "rural modesty" (Msuya, 1996; 2009a), whereby farmers protect each other's farming areas against any external intruder. People usually farm in the same areas where they live and a villager can grant a farming space to a fellow villager from the same village/area. For villagers from other areas, entry is achieved simply by requesting space from local farmers. No licenses or purchase of land are involved in seaweed farming.

4.2 Contract farming scheme

The system for purchasing and exporting seaweed from Tanzania can be characterized as a monopsony (MNRT, 2005) whereby farmers are provided with the farming materials (i.e. ropes) by the buying companies; in turn, they are obliged to sell the seaweed product to the company. Under this "contract farming" scheme, companies may also provide extension services. Each company has a buying office in each village operated by a native or foreign agent (depending on the company and location).

If more than one exporter is operating in a village and no agreements with farmers have been signed, conflicts between companies are likely to arise. An example of this situation occurred in Mtwara where one company routinely provided farming materials but then a new company visited the area offering to buy the seaweed. The first company reacted by interrupting the supply of farming materials while the second company turned out to have no means of supplying these materials. The end result was that farmers were left without farming materials and without production to sell.

Conflicts between companies can also emerge when they operate in areas with limited farming sites. This was observed in Pemba, where two companies conflicted over access to the farming area of Fundo Island. In this case, one company moved away from the area because of die-offs of *K. alvarezii*; later on, a new company arrived as the die-off situation improved, just to find out that the first company was returning to the same area. Under such situations, government departments normally intervene and the farming sites are divided between the companies.

Growers who are provided farming materials and extension services by the export companies normally settle for relatively low prices. For example, independent farmers in Lindi receive TZS 400/kg of dried *K. alvarezii* while dependent farmers under contracts get only TZS 300/kg. Whether such price discounts are worthwhile for dependent farmers depends on many factors such as the value of farming materials, extension services and credits provided by the contractor, the reliability of the contractor honoring the contract[15], restrictive terms in the contract on the quantity and quality of seaweed acceptable by the contractor, among others. It should be noted that independent farmers do not always get a price premium. For example, some farmers who procured their own culture materials have discovered that they were offered the same prices received by dependent farmers, as has been reported in Bweleo (Zanzibar).

A few farming villages have managed to become independent, procuring their own materials and selling to buyers of their choice, e.g. Bagamoyo since the early 2000s. Msuya *et al.* (2007a) explains that Bagamoyo farmers were assisted in this process by organizations such as FINCA, WIOMSA and the Tanzania Coastal Management Partnership (TCMP). Although they are still independent, production has declined in recent years because of a lack of buyers. However, it was learnt during a recent visit

[15] It was also learnt from the interviews that when market demands are weak and prices low, the exporter who had promised to provide extension services and purchase the seaweed was doing little for the farmers; the purchase of seaweed eventually became slow and unpredictable.

that the problem had to do less with the availability of buyers than with leadership issues in the community of farmers.

Some younger members of the group have started farming independently from the large group in the hope of increasing seaweed production. The young farmers have recently approached ZaSCI for assistance in the farming and marketing of seaweed. ZaSCI and this group of farmers are currently planning to carry out exports possibly via Calmax Exporters and other companies under ZaSCI, bypassing the major export companies. Tanga is the only other area where farmers in most villages procure their own materials through credit systems or other mechanisms; in addition, they only sell to companies that purchase seaweed in a manner that they consider consistent. Thus, the general observation is that whereas most farmers in Zanzibar are still deeply involved in the monopsony system, those on the mainland are gradually moving away from this system.

4.3 Government

The governments of mainland Tanzania and Zanzibar have played a significant role in the development of seaweed farming through their departments in the ministries of natural resources and trade and industry. The governments provide a link between farmers and exporters.[16] Their role is to negotiate prices with buyers and to control taxes, revenue, and the importation of seaweed strains for cultivation. They also assist farmers with procurement of farming materials, marketing of the harvest, etc. The government of mainland Tanzania has produced a Seaweed Development Strategic Plan (SDSP) (MNRT, 2005) which provides information on aspects such as the minimum production levels considered to be commercially profitable.[17] The aim of the SDSP is to promote the production of *K. alvarezii* in order to increase farmers' income as well as government revenue from the seaweed industry.

In addition to the SDSP, the governments of Tanzania and Zanzibar are implementing efforts to promote free trade in order to release farmers from the monopsony system (MNRT, 2005; Msuya, 2006b; Msuya *et al.,* 2007a; ACDI/VOCA, 2005). Efforts have been made to provide farmers with seed money for the purchase of farming materials. These initiatives, however, should be implemented strategically through negotiations with the buyers who will eventually purchase and export the seaweed. Because seaweed is not consumed within the country and there are no industrial processing facilities, farmers still rely on the exporting companies for the purchase and export of seaweeds. In other words, the country cannot afford to lose the buyers and therefore free trade must be approached as a process rather than an action. The governments' efforts have been implemented through programmes such as the Marine and Coastal Environment Management Project (MACEMP) and the establishment of small credit systems such as Savings and Credit Cooperative Societies (SACCOS) and Village Corporative Banks (VICOBA).

The Aquaculture Department under the Ministry of Livestock Development and Fisheries has been promoting the farming of *K. alvarezii* through the SDSP. The plan was developed in 2005 but has been mostly ineffective as little has been done to implement its recommendations. In the Mtwara and Lindi regions (southern Tanzania), fisheries officers are using the SDSP to encourage farmers to produce more seaweed. Development has been thwarted in these regions because of the conflicts between farmers and buyers. The SDSP was translated into the local language and distributed to farmers by dedicated fisheries officers in order to let famers and buyers/exporters

[16] The word "exporters" is used here as a synonym to the terms "developers" and "buyers" used in other studies; exporters are also called developers because they provide extension services and farming materials.

[17] According to the SDSP, each farmer needs to produce 500 kg of dry seaweed per month to stay profitable.

understand their rights and responsibilities in the seaweed business; e.g., farmers should produce at least 500 kg per month; and buyers should obtain a signed agreement from the farmers before purchasing seaweed.

According to officials in the department, field visits funded through MACEMP have been conducted to a number of areas to oversee the status of the industry and outline strategies to support future development. Farming materials have been provided by government to farmers as a result of these visits. However, the lack of extension officers in mariculture is a problem that the Department is attempting to solve by training new officers. In addition to the funds allocated through MACEMP, the Department also has access to a Development Fund from the government. Both funds will be used by the Department to make seed banks available to farmers and to promote the adoption of the deep-water farming method.

Through the TCMP (which is supervised by the National Environment Management Council [NEMC]), the government has assisted villagers in Bagamoyo in becoming independent from buyers by helping them procure their own farming materials. The TCMP has also helped to bring in credit organizations such as FINCA to provide support to farmers.[18]

Through its Department of Fisheries and Marine Resources (ZDFMR), the government of Zanzibar advises farmers to work jointly with the companies and agree on the mode of conducting business prior to engaging in production. Farmers must sign agreements to confirm that the seaweed will be purchased by the exporters. The ZDFMR can provide guidance to farmers for the signing of agreements. Fisheries officers at the ZDFMR cited the example of Kidoti village, where farmers have developed agreements with an exporting company which stipulate the selling price at TZS 160 per kg, regardless of the fact that the company also procured farming materials (normally, the company would have applied a discount of TZS 20). The ZDFMR provided essential advice to farmers in Kidoti during the negotiation process.

Through MACEMP, the government of Zanzibar is also assisting villagers with the testing of new methods of farming, the acquisition of boats for the transport of seaweed, and the construction of a warehouse in Chwaka village. Through PADEP, the government has contributed to the renovation of seaweed storage rooms and the opening of shops for seaweed farming materials (Bweleo village).

4.4 International organizations and NGOs

Support to seaweed farmers is also being provided by various development agencies and NGOs, including:

- ACDI/VOCA (Agricultural Cooperative Development International/Volunteers in Overseas Cooperative Assistance) under programmes such as Smallholder Empowerment and Economic Growth through Agribusiness and Association Development (SEEGAAD) and Sustainable Environmental Management through Mariculture Activities (SEMMA). These programs provide farmers with seed money to purchase farming materials with the ultimate goal of making them independent from buyers. Not only is ACDI/VOCA involved in eliminating the monopsony system but it is also helping farmers to increase yields and income levels.
- The Seaweed Cluster Initiative (ZaSCI) established in 2006 is also involved in efforts to increase seaweed production and add value to the process (Msuya, 2006b). The ZaSCI is one of about 30 innovative clusters in Tanzania created under the Innovation Systems and Cluster Programmes (ISCP) coordinated by the College of Engineering and Technology of the University of Dar es

[18] Seaweed production in Bagamoyo has nevertheless decreased because of the problems described in Section 5.4.

Salaam (CoET/UDSM) and funded by the Swedish International Development Cooperation Agency (Sida). The aim of ZaSCI is catalyzing innovation within the seaweed industry through modification of farming techniques and value-adding processes. Under the vision of becoming "the best producers and sellers of quality seaweed and seaweed value-added products by 2015", ZaSCI has adopted the deep-water floating system technique and has made progress towards the manufacturing of value-added products. ZaSCI has also plans for the construction of drying racks in a number of villages to prevent impurities from attaching to the seaweed during the drying process.

- The Tanzania Industrial Research and Development Organization (TIRDO), established in 1979 as an NGO under the Ministry of Industry and Trade, has the main task of conducting applied research and providing technical services to a number of industries in the country. In cooperation with Taurus, a South African processor and exporter of seaweed, and the Muhimbili College of Health Sciences of UDSM (MUCHS/UDSM), TIRDO has begun to engage in seaweed value addition by conducting experiments on extracting the gel from seaweed and using seaweed for mushroom cultivation (Mamiro and Mnege, 2001).
- As a way of implementing the recommendations outlined in the SDSP, the U.S. Ambassador in Tanzania provided funding to seaweed farmers in Bagamoyo in 2005. The funds were routed through a local NGO (Kiromo Development Foundation) based in Bagamoyo using the "Self Help Programme" of the Ambassador's office. The funds were used to construct boats and purchase farming materials.
- A recent initiative is being led by the Regional Programme for the Sustainable Management of the Coastal Zones of Indian Ocean Countries (ReCoMaP). The ReCoMaP released funds to the Department of Environment in Zanzibar (ZDoE) to explore new, more productive methods of farming seaweed such as the "cast method" being tested in Uzi village, Zanzibar [19].
- The Western Indian Ocean Marine Science Association (WIOMSA) under its programme Sustainable Coastal Communities and Ecosystems (SUCCESS) and working jointly with the Institute of Marine Sciences of the University of Dar es Salaam (IMS/UDSM), developed the deep-water floating lines technique mentioned previously in Bagamoyo. This programme received funding from USAID through the Coastal Resources Centre of the University of Rhode Island (CRC-URI). During 2005–2007, SUCCESS managed to develop the system, test for its efficiency and demonstrate that the technique is more productive than the off-bottom method, yielding an additional 0.35 kg per meter of line per year (Msuya *et al.,* 2007a).
- International micro-credit organizations such as the Foundation for International Community Assistance (FINCA) have provided seaweed farmers with micro loans for the acquisition of farming materials (Msuya *et al.,* 2007a).
- The Chalmers School of Entrepreneurship (Sweden) has joined efforts with ZaSCI to assist producers in Paje village with the construction of a Seaweed Centre where farmers can dry seaweed (especially during the rainy season) and develop value-added products. By 2009, land had been acquired, drawings of the centre had been developed, and soap-making machines were being constructed.
- The United Nations Industrial Development Organization (UNIDO) has recently provided assistance to increase production in seaweed farms and to establish value-added processes. Along with ZDFMR, three Tanzanian ministries are involved in this cooperative effort: the Ministry of Labour, Youth, Women

[19] The cast method involves tying seed in stones with a rubber band and letting the seaweed attach itself to the rock and grow.

and Children Development (MLYWCD); the Ministry of Agriculture, Livestock, and Environment (MALE); and the Ministry of Tourism, Trade and Investment (MTTI). Whereas MLYWCD is involved in promoting farming cooperatives, MTTI is partnering with ZaSCI to advance the value-added technologies (initial trials were conducted in November 2009, which will be followed by training programs for farmers).

4.5 Producer associations

Most farmers – especially in Zanzibar – have organized themselves into associations. These usually congregate a large number of farmers under the label "Seaweed Farmers Association" with the name of the respective village attached to it, e.g. Jambiani Seaweed Farmers Association. These large associations act as umbrella organizations for all farmers in an area or village. In addition, there may be smaller associations (which may be registered or not) with members ranging from as few as five to as many as 35. The same situation was observed in the mainland; the major difference is that large associations are more common in Zanzibar.

This study revealed that most of these associations were formed around 2005 under special programmes such as MACEMP and PADEP (Participatory Agricultural Development Empowerment Project) rather than by the farmers themselves. These programmes instructed farmers to form cooperatives to facilitate assistance with training and the purchase of farming materials and boats. Under MACEMP, farmers were instructed to set up communal banking accounts to receive funds for seaweed aquaculture. In some cases (e.g. Rufiji), cooperatives were formed but funding from MACEMP was protracted, which discouraged farmers. However, the formation of cooperatives has greatly assisted farmers in other areas, e.g. in Bweleo, Zanzibar, where MACEMP provided farmers with a fibre boat, a storage building and a farming materials shop. Farmers in Chwaka village, Zanzibar, also received a fibre boat from MACEMP.

In Bagamoyo, a group of farmers known as "Msichoke"[20] has received assistance from the Tanzania Association of Women Leaders in Agriculture and Environment (TAWLAE), the TCMP and SUCCESS-WIOMSA. Formed in 1998 with 58 members, this is an example of a group that has held on for many years; unfortunately not much seaweed production has been achieved during this time. Some members complain of inefficient leadership (and thus lack of a reliable buyer);[21] in addition, they have to deal with the problem of die-offs. A similar but more functional cooperative called "Tusife Moyo"[22] was formed in 1992 in Kidoti, Zanzibar. The group is now an active member of ZaSCI.

Cooperatives are not common in the mainland southern areas of Mtwara, Lindi and Kilwa, probably because farming has not been consolidated yet. This situation is likely to change in the near future, especially if credit organizations extend their services to farmers. Interviewed fisheries officers (Ms Rita Maly, Mr Seleman Ngaweje and Mr Oga Dadi in "Dar-es-Salaam", Lindi, and Mtwara, respectively) explained that formation of cooperatives will be encouraged in the area.

In Tanzania, small (and even large) scale businesses are moving towards the formation of SACCOS, which are usually established through the voluntary contributions of their own members. SACCOS systems for seaweed farming have been established throughout the country, in Zanzibar Islands as well as on the mainland.

[20] Translates as "Do not tire".

[21] This is the group whose younger members are planning to break up to form their own association as explained previously.

[22] Translates as "We should not lose heart".

Interviews with farmers have revealed that cooperatives are helpful as a mechanism to receive assistance from different organizations. For example, Tusife Moyo in Kidoti Zanzibar has received help from the British Embassy, the First Lady of Zanzibar, and the ZaSCI, under which new ideas and products have been released. Msichoke of Bagamoyo has benefited in similar ways. SACCOS has provided assistance with the procurement of farming materials. The SACCOS members in Mwambani, Tanga receive TZS 200 thousand per month, which is more than sufficient to cover the cost of farming materials. Farmers have reported that SACCOS can even cover the election costs of leaders within the cooperative.

4.6 Seaweed exporters

The key role of exporters is to buy the seaweed produced by farmers and provide farming materials and extension services where applicable. In addition to importing the first seeds from the Philippines (in collaboration with the government), exporters have recently imported new strains of *Kappaphycus* (e.g., *K. striatum*) as a way of tackling the die-off problems of *K. alvarezii*.

Usually, exporters allocate a share of their business funds to community development or to provide direct services. As an example, the C-Weed Company and farmers in Kidoti village have an agreement whereby 5 percent of the value of the seaweed harvest is contributed towards a Farmers Committee Fund for community development. The funds can be used for constructing school buildings, dispensaries, etc. It has also been learnt that two seaweed exporters working in Songosongo Island in southern Tanzania were contributing TZS 400 000 per month for community development. Contributions, however, were interrupted in 2009 because of seaweed die-offs, which brought production down from 424 tonnes in 2003 to only 26 MT in 2008 (Msuya and Porter, 2009).

5. CHALLENGES AND THE WAY FORWARD

5.1 Issues and challenges

The problems associated with seaweed farming as perceived by farmers, exporters, government, organizations and other stakeholders have been indicated in previous research. A more recent problem is that associated with "free trade" marketing. Under this scheme, farmers purchase their own farming materials and sell their harvest to any buyer of their choice. While this idea is very important in promoting entrepreneurship and increasing farmers' income, it has to be implemented as a process, involving discussions and agreements between the farmers/government/scientists on one hand and buyers on the other hand. However, the Zanzibar government has embarked on this idea without implementing proper negotiations, providing producers with farming materials that are not purchased after the seaweed has been sold. As a result, some companies and individuals have procured seaweed in areas where they have not invested (e.g. Nyamwese as mentioned above). With such buyers, some farmers sell seaweed before it is fully grown or dry enough, thus lowering the quality of Tanzanian seaweed and threatening the financial position of other exporters. This has also led to farmers being abandoned by the new buyers while breaching the agreements with the original buyers.

Other problems that have direct impact on farmers and were identified through interview respondents and personal observations are discussed in the following.

Husbandry

The most commonly reported on-farm problems were the breakage of seaweed by the action of strong winds[23], eye soreness caused by the combined action of sun and sand,

[23] Strong winds also tangle seaweed lines, which must be untangled by farmers.

and grazing by intertidal organisms. These same problems had already been reported in previous research, e.g. Eklund and Pettersson (1992); Shechambo *et al.* (1996); Semesi (2002); Msuya and Kyewalyanga (2006); Msuya and Salum (2006; 2007). Farmers also mentioned that high temperatures lower seaweed growth and that harvesting and drying seaweed may become complicated tasks during the rainy seasons: rain water may bleach seaweed and make it slimy, which makes drying difficult.

An additional problem is caused by the stings from sea urchins, box fish and other organisms, which may take more than a week to heal. Farmers have requested assistance to procure appropriate shoes (e.g. gum boots, canvas shoes or plastic sandals) through loans from export companies.

Transport

A problem mentioned by most farmers had to do with the task of carrying wet seaweed from the farm sites to the drying sites on shore, especially when harvests are large. Farmers strongly request assistance with the procurement of carrying devices such as canoes. Currently, farmers need to hire people to carry the seaweed for them. In Zanzibar they mentioned the hiring cost as TZS 100–120 per bag of wet seaweed (holding between 10 and 20 kg). In Kidoti, farmers pay TZS 150–160 per bag. In Jambiani the cost is TZS 200 per bag; this cost increases to TZS 1 000 per bag if the seaweed is placed in sacks after drying. Given these costs, farmers in Jambiani state that prices of dry seaweed must be raised to TZS 200–300 per kg for seaweed farming to be considered worthwhile. The situation is similar in the mainland, with transportation costs hovering around TZS 150–200 per bag. If a farmer in Kidoti or Jambiani needs to carry from 50 to 60 bags, she/he must spend around TZS 9 000 to TZD 10 000 in transportation costs alone.

ZASCOL has designed a floating device (Figure 11) to tackle the transportation problem. To use the device, farmers need to place 20-litre plastic oil cans (which have been emptied) below it. The device has been designed for use in the Mwambani and Mchukuuni villages in Tanga. However, field trials conducted by ZASCOL extension officers have revealed that placing 50 bags of seaweed on the floater makes it too heavy to pull it to the shore. Similar but lighter devices could prove to be much useful to farmers.

FIGURE 11

A floating device for carrying seaweed designed by ZASCOL in Mwambani, Tanga



Diseases

Tanzania has been experiencing die-offs of *K. alvarezii* in many farming areas. The plants are being affected by "ice-ice" disease (i.e. whitish thalli), which leads the seaweed to disintegrate and die. According to Mmochi *et al.* (2005), die-offs have spread almost throughout the country with areas such as Tanga in northern Tanzania being the most affected.

Die-offs have been a major factor hindering seaweed aquaculture in Tanzania. For example, primarily because of die-offs, a village in Songosongo used to produce nearly one thousand tonnes of seaweed per year reduced the production to less than 500 tonnes; the number of farmers has also gone down from about 1 500 to 500[24].

Msuya (1996) recommended that farmers be allowed to grow *E. denticulatum* whenever the crops of *K. alvarezii* fail in order to guarantee a steady supply to the market. However, because of the low price of the former and the fact that there was already high production of the latter, *K. alvarezii* is preferred in the mainland. The problem of die-offs has emerged as the major cause of low production in the mainland as compared to Zanzibar, which produces mostly *E. denticulatum*. In some areas, seaweed production has decreased by more than 70 percent: in the small island of Songosongo (with a population of 5 600) in southern Tanzania, production fell from 84 tonnes in 2003 to only 26 tonnes in 2008 (Msuya and Porter, 2009). Ice-ice disease has reportedly wiped out entire farms in other countries (e.g. the Philippines in 1974 [Largo *et al.,* 1995]).

Apparently, seaweed die-offs are caused by stress induced by variations in salinity and temperature, fouling, predation, epiphytes, pollution, siltation, etc. Stress may also be caused by farming in the same areas for excessively long periods of time (Mmochi *et al.,* 2005; Hurtado *et al.,* 2006; Hurtado and Critchley, 2006a; Vairappan, 2006; Carlsson *et al.,* 2007; Muñoz and Sahoo, 2007; Vairappan *et al.,* 2008; Msuya and Porter, 2009).

To minimize die-off problems, it has been recommended to use uninfected, clean, and healthy seed, select a farming site with clean and moderate to fast water movement, harvest the entire crop of cultured seaweed, rotate farming sites, implement quarantine procedures, and resort to deep-water farming methods in some cases (Paula *et al.,* 1999; Mmochi *et al.,* 2005; Hurtado and Critchley, 2006a, 2006b; Msuya, 2006b; Sulu *et al.,* 2006).

Many farmers in the areas where *K. alvarezii* no longer grows have expressed their disappointment for not being able to farm this species. Some of them argue that if no solution is found they may abandon seaweed farming altogether, as higher seaweed prices are necessary for them to stay in business.

Seaweed prices

Seaweed prices in Tanzania during 1989–1992 (at the beginning of seaweed farming) were around TZS 20–30 per kg of dry seaweed; prices increased since then to reach the current levels. However, although seaweed farming has undoubtedly improved livelihood conditions of farmers, it is also apparent that prices are low relative to the amount of work demanded by the activity. In addition, the price gap between the two major species has continued to widen. While the price per kg of *E. denticulatum* has changed only slightly from TZS 100 to TZS 140–160, the price of *K. alvarezii* has increased steadily and can currently fetch TZS 300–400, depending on the farming area and the farmers' ability to negotiate prices.

In general farmers felt that the price of seaweed does not fully compensate for the amount of work that needs to be invested in its culture. The minimum price farmers

[24] Gas-extracting activities during the die-offs may be another contributing factor to the decline of seaweed farming in the area.

would like to see for *E. denticulatum* ranges from TZS 200 to TZS 500 per kg[25]. Some farmers mentioned that while the prices of day to day items have drastically increased, the price of seaweed has barely moved up.[26] In Chwaka village, farmers compared the price of one kilo of rice and salt with the price of seaweed. In 1986, the prices per kg of seaweed, rice and salt were TZS 60, 90, and 20, respectively. Nowadays, the price of one kg of rice is TZS 1 500 and that of salt is TZS 500.

The statement that "the price does not match the work you put in" was echoed by all interviewed farmers and a number of government officials. In Kidoti, village farmers remarked that "much noise is made even by the government, but exporters do not listen". Although exporters explain that the price declines are caused by conditions in the world market, the farmers' feelings are summarized by the local term "*kutudhalilisha*", i.e. exporters are "putting us down" by buying at such low prices. Farmers also revealed that they frequently thought about "striking" to demand higher prices but could not actually do so because they had daily needs to attend to. In another village in Zanzibar, farmers pointed out that each time they requested intervention from the government, the response they got was that exporters should provide a solution. But when farmers turned to exporters, the response they got was that government needs to take actions.

Buyers argue that they pay low prices because they are also providing farming materials and offering extension services to the farmers. However, the recent shortage of seaweed coupled with the rising prices for *K. alvarezii* in the world market have led many people to wonder whether prices are in fact controlled by the provision of farming materials. During the field visits it was noticed that many coastal dwellers (fishermen) on the mainland have turned back to farming because of the high prices for *K. alvarezii*.

The problem of low prices affects farmers throughout Tanzania (Eklund and Pettersson, 1992; Shechambo *et al.,* 1996; and Msuya, 2006a). Probably the only solution to this problem is to continue with the process of making farmers independent from exporters, which could give them some price bargaining power. However, care should be taken to ensure that alternative marketing opportunities are available to farmers. This problem was observed in Bagamoyo, where members of the Msichoke cooperative were unable to sell seaweed for two years because their leaders were not proactive in looking for alternative buyers.

Marketing

As discussed above, seaweed farmers depend on exporters to purchase their products under agreed farming schemes. In many places (Mtwara, Lindi, and Kilwa districts) there used to be only one exporter; hence production was hampered when the exporter delayed the purchase of seaweed and supply of farming materials. The coming of new exporters provided seaweed farmers with more marketing channels, but various confusions (e.g. companies not supplying enough farming materials or not able to honouring the promised prices, etc.) occurred during the process of establishing new business relationships between farmers and new companies. Conflicts between exporters, which have been discussed above, have further complicated the business.

[25] Low prices were reportedly the most acute problem in the seaweed industry of Tanzania. One interviewed farmer stated that "when we compared the work with the selling price of TZS 100 paid in 2005, we found out that they did not match". When they were asked about the prospects for going back to farming, a leader of 30 farmers operating in 2005 said that farming would be possible if they could sell at TZS 260-300.

[26] It is noted here that while prices in the local currency (TZS) have increased, the corresponding prices in USD have declined (Brycesson, 2002). Between 1989 and 2008, prices per kg declined from USD 0.30 to USD 0.10 and from USD 0.30 to USD 0.20 for *E. denticulatum* and *K. alvarezii*, respectively (Brycesson, 2009).

Interviewees explained that problems with the marketing of seaweeds occurred in the past, but nowadays they are always able to sell their harvest. Currently, an exporter would refuse to buy seaweed only in the case of seaweed that contains impurities or is not dry enough. If the farmer can address these problems, then the seaweed will be purchased. The selling problems reported in Bagamoyo were more related to the internal dynamics of the cooperative than a lack of cooperation from buyers.

Buyers on the other hand point out that some villages (e.g. Tanga) are very remote, making it difficult to buy seaweed from these locations. Some of these villages have also low production levels. Buyers stated that the only way to make purchases from these areas viable is by having farmers produce greater amounts. Whereas many farmers still produce less than 500 kg of dry seaweed per month regardless of the species, the SDSP goal of 500 kg of dried *K. alvarezii* per farmer per month is far from being met.

5.2 The way forward

This investigation reveals that seaweed farming has significantly contributed to improve the living standards of coastal people in Tanzania. In particular, it has conferred economic power to coastal women, whose livelihoods would otherwise depend solely on their husbands. Nevertheless, given the world preference of *K. alvarezii* over *E. denticulatum*, farmers – men in particular – are getting discouraged by the fact that most of them cannot successfully farm the higher priced *K. alvarezii*. Thus, the future of seaweed farming in Tanzania will depend on finding ways to increase the production of *K. alvarezii* and add value to seaweeds.

Nearly all farming sites suitable for off-bottom production are being used in Zanzibar while only limited sites are available on the mainland. Therefore, a sound strategy to increase seaweed production is simply to go into deeper waters using the floating lines method. Seaweeds can be farmed in monoculture (Hurtado-Ponce, 1992; Msuya, 2006b) or integrated with other organisms to provide additional products to farmers (Lombardi *et al.,* 2001; 2006; Rodrigueza and Montano, 2007; Hayashi *et al.,* 2008). However, the floating lines method requires the use of boats/canoes, which may not be immediately accessible to farmers. To solve this problem, the different stakeholders in the industry need to coordinate efforts to provide technical and financial assistance to the producers. Obtaining resistant varieties of *K. alvarezii* through genetic improvement programmes could hold the key for further development of the industry.

Besides adopting innovative farming techniques, productivity of seaweed farming can also be improved through more efficient plot or farm arrangements. For example, "standardization", which arranges plots in such ways as to ensure that all seaweed lines face the same direction, would help maximize farming area and reduce seaweed breakage caused by strong winds. The "block farming" concept could improve the productivity of the traditional off-bottom systems through increase of the scale of operation.

Value addition provides another means to enhance the economic returns of the activity. Farmers need to receive training on value-added processes and technologies as well as financial assistance. Markets for such products – both domestic and overseas – also need be identified. The development of semi-processing capabilities aimed at the extraction of carrageenan and agar is also essential for generating added value.

Some viewpoints on way forward of different stakeholders are summarized as follows:

Perceptions of farmers and NGOs

- Devices for carrying seaweed from the farming to the drying sites should be provided directly to farmers or financed through low-interest loans.
- The availability of farming materials should be increased, if farmers are still dependent.

- The price of seaweed should be increased.
- The government, NGOs, and other stakeholders should facilitate meetings between farmers, the government and exporters to discuss seaweed farming issues, including prices paid to farmers.
- Expanded media coverage to demonstrate how difficult the farm work is and why higher prices are fair.
- Basic research is needed to formulate solutions to the die-off problems of the higher-priced *K. alvarezii.*
- The government should expand efforts to explore alternative markets for seaweed.

Perceptions of exporters

- Farmers should increase production levels so that costs incurred by exporters are reduced and prices can be increased.
- Shift cultivation. This was mentioned by a Birr Company's employee. The idea is that if farmers practice shift cultivation (i.e. rotate the farming grounds), it is possible to farm *K. alvarezii* in areas where it is failing.

Perceptions of governments

- Ensure that farmers and the exporters develop signed agreements.
- Farmers need to end their dependency from exporters. Efforts can be implemented to help farmers procure their own farming materials, e.g. via loans provided by the exporters, with payments made by deducting funds from the farmers' sales. Another strategy could be based on initial "seed" grants provided by the government, along with training on how to use this money to buy more materials. This should increase the price of seaweed paid to farmers. The shops for selling farming materials promoted by ZaSCI (Msuya, 2009c; 2009d) are a way of realizing this goal.
- Exporters should buy seaweed in remote areas, even if production is low. Means that minimize the costs that hinder such buying should be identified and implemented.
- New export companies should enter the industry; this will increase competition, which will be advantageous to farmers.
- Devise strategies to raise seaweed prices.

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