FAO
FISHERIES
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AQUACULTURE
TECHNICAL
PAPER

580

ISSN 2070-7010

Social and economic dimensions of carrageenan seaweed farming

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Rome, 2013

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ISBN 978-92-5-107746-7 (print)
E-ISBN 978-92-5-107747-4 (PDF)

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Preparation of this document

The goal of this document is to provide a comprehensive and balanced assessment of the socio-economic impacts of carrageenan seaweed farming. The document includes six country case studies on carrageenan seaweed farming in India, Indonesia, Mexico, the Philippines, Solomon Islands, and the United Republic of Tanzania. The six papers were prepared based on the country case study reports submitted by the following seaweed farming experts: M. Krishnan and R. Narayanakumar for India; Iain C. Neish for Indonesia; Daniel Robledo, Eucario Gasca-Leyva and Julia Fraga for Mexico; Anicia Q. Hurtado for the Philippines; Mechthild Kronen and collaborators for Solomon Islands; and Flower E. Msuya for the United Republic of Tanzania. In order to make the entire document more coherent and succinct, the contents in the case study reports were reorganized and condensed by the editors. Readers may contact the experts for the original reports, which contain more detailed information.

In order to compare the experiences of carrageenan seaweed farming in different countries and provide a global overview, the document also includes a global synthesis report based on the six country case studies and other existing literature. The main contributors in the preparation of the synthesis were Junning Cai (FAO), Nathanael Hishamunda (FAO) and Neil Ridler (FAO Consultant).

Jiaxin Chen (China), PingSun Leung (the United States of America) and Alessandro Lovatelli (FAO) are acknowledged for their valuable comments on the various drafts of this document. Elisabetta Martone (FAO Consultant), Tina Farmer (FAO), Marianne Guyonnet (FAO), and Ettore Vecchione (FAO Graphic Consultant) are acknowledged for their assistance in editing and formatting.

Abstract

Carrageenan seaweed farming based primarily on the cultivation of *Kappaphycus* and *Eucheuma* species has grown significantly in the Philippines and Indonesia in the last two decades. Growth has also taken place on a smaller scale in the United Republic of Tanzania and a few other developing countries. Thanks to attributes such as relatively simple farming techniques, low requirements of capital and material inputs, and short production cycles, carrageenan seaweed farming has become a favourable livelihood source for smallholder farmers or fishers and generated substantial socio-economic benefits to marginalized coastal communities in developing countries. However, further development of carrageenan seaweed farming needs to overcome various barriers and constraints such as inclement weather conditions, disease outbreaks, uncertain and fluctuating market conditions, lack of value-added products and value-adding activities in most of seaweed farming countries, low incomes of seaweed farmers in some countries, and occupational health hazards. With six country case studies and one global synthesis, this document attempts to provide a balanced assessment and comparison of the social and economic performance of carrageenan seaweed farming in different countries. Various issues related to seaweed–carrageenan value chains are highlighted. The technical and economic performance of a number of carrageenan seaweed farming cases are systematically evaluated and compared. The positive and negative social impacts of carrageenan seaweed farming are discussed. Issues related to governance and institutions in the sector are reviewed. Challenges and constraints faced by different countries in the future development of their seaweed industries are identified. The document also highlights a series of information and knowledge gaps that need to be filled in order to form a clearer vision of carrageenan seaweed farming development in the future and facilitate evidence-based policy decision-making and sector management.

Valderrama, D., Cai, J., Hishamunda, N. & Ridler, N., eds. 2013. *Social and economic dimensions of carrageenan seaweed farming***.** Fisheries and Aquaculture Technical Paper No. 580. Rome, FAO. 204 pp.

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Foreword

Within the framework of its continued efforts to reduce food insecurity and alleviate poverty, the FAO Fisheries and Aquaculture Department encourages commercial or business-oriented aquaculture as a means of increasing food availability and accessibility, generating employment and income, and improving national economies, especially in developing countries. Reflecting on the large variety of aquatic species and environments, commercial aquaculture can be practised in many different forms, some of which will adjust better than others to the physical and socio-economic conditions of any given country. Carrageenan seaweed farming, in particular, has evolved into a successful commercial endeavour in a number of tropical countries endowed with clear, unpolluted intertidal environments and protected beach locations. In contrast to other forms of aquaculture, carrageenan seaweed farming has minimum capital and technological requirements and, as such, can provide important economic opportunities to marginal coastal communities with limited livelihood options. The major goal of this document is to provide an assessment of the social and economic impacts of carrageenan seaweed farming on the livelihoods of coastal communities engaged in this particular type of aquaculture. The document is expected to yield valuable insights on the socio-economic benefits of seaweed farming to policy-makers involved in the promotion of national aquaculture sectors.

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Abbreviations and acronyms

ACDI/VOCA	Agricultural Cooperative Development International/ Volunteers in Overseas Cooperative Assistance (United States of America)
ACP	African, Caribbean and Pacific Group of States
ADB	Asian Development Bank
ADGR	average daily growth rate
AFI	Aquaculture Foundation of India
AI	Alliance Initiative
AIs	aid institutions
AMARTA	Agribusiness Market and Support Activity (United States of America)
AMCA	Arnavon Marine Conservation Area (Solomon Islands)
AMPEP	Acadian marine plant extract powder
AP	Andhra Pradesh (India)
APBIRLI	Asosiasi Pengusaha Budidaya Dan Industri Rumput Laut Indonesia (Business Association of Farms and Seaweed Industry – Indonesia)
APEC	Asia-Pacific Economic Cooperation
APEDA	Agricultural and Processed Food Products Export Development Authority (India)
ARMM	Autonomous Region for Muslim Mindanao (Philippines)
ASEAN	Association of Southeast Asian Nations
ASL	Acadian Seaplants Limited (Canada)
ASPERLI	Asosiasi Petani dan Pengelola Rumput Laut Indonesia (Association of Seaweed Farmers and Managers – Indonesia)
ASSOCHAM	Associated Chambers of Commerce and Industry (India)
ATC	alkali-treated chips
AusAID	Australian Agency for International Development
BAFPS	Bureau of Agricultural and Fisheries Products Standards (Philippines)
BANRURAL	Banco de Desarrollo Rural (Mexico)
BAPPEDA	Badan Perencanaan Pembangunan Daerah (Regional Body for Planning and Development – Indonesia)
BAS	Bureau of Agricultural Statistics (Philippines)
BDS	business development service
BFAR	Bureau of Fisheries and Aquatic Resources (Philippines)
BIMP-EAGA	Brunei Darussalam, Indonesia, Malaysia and the Philippines – East ASEAN Growth Area
BPL	below the poverty line
BPPT	Badan Pengkajian Dan Penerapan Teknologi (Agency for the Assessment and Application of Technology of Indonesia)
CAC	Codex Alimentarius Commission (FAO/WHO)
CARE	Cooperative for Assistance and Relief Everywhere, Inc. (United States of America)
CBM	Corredor Biológico Mesoamericano
CEO	chief executive officer

CETES	Certificados de la Tesorería de la Federación (Mexico)
CIBA	Central Institute of Brackishwater Aquaculture (India)
CICY	Centro de Investigación Científica de Yucatán (Mexico)
CIDA	Canadian International Development Agency
CIF	cost, insurance and freight
CINVESTAV	Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional (Mexico)
CIPSED	Canada-Indonesia Private Sector Enterprise Development Project
CMCA	Arnavon Island Community Marine Conservation Area (Solomon Islands)
CMDRS	Consejo Mexicano para el Desarrollo Rural Sustentable
CMFRI	Central Marine Fisheries Research Institute (India)
Co.	company
CODECY	Coordinación para el Desarrollo de la Zona Costera de Yucatán (Mexico)
CoET/UDSM	College of Engineering and Technology of the University of Dar es Salaam (United Republic of Tanzania)
CONABIO	Comisión Nacional de Conocimiento para la Biodiversidad (Mexico)
CoSPSI	Commercialization of Seaweed Production in Solomon Islands
CP	Copenhagen Pectin (Denmark)
CRDB	Cooperative and Rural Development Bank
CRZ	Coastal Regulation Zone (India)
CSIR	Council of Scientific and Industrial Research (India)
CSMCRI	Central Salt and Marine Chemicals Research Institute (India)
CSR	corporate social responsibility
CT	Coral Triangle
DA	Department of Agriculture (Philippines)
DBT	Department of BioTechnology, Ministry of Science and Technology (India)
DGR	daily growth rate
DKP	Departemen Kelautan dan Perikanan (Indonesian Department of Oceans and Fisheries)
DRDA	District Rural Development Agency (India)
EAI-BDS	East ASEAN Initiative Business Development Services Project
EEZ	exclusive economic zone
EU	European Union (Member Organization)
EUREP	Euro Retailer Produce Working Group
FAO	Food and Agriculture Organization of the United Nations
FICCI	Federation of Indian Chamber of Commerce and Industry (India)
FINCA	Foundation for International Community Assistance (United States of America)
FOB	fixed off bottom
f.o.b.	free on board
GAP	good aquaculture practice
GCI	galvanized corrugated iron
GEF	Global Environment Facility
GIP	Growers Investment Program (India)
GO	government order
GO	government organization
GoM	Gulf of Mannar (India)

GoMBRT	Gulf of Mannar Biosphere Reserve Trust (India)
GoMMNP	Gulf of Mannar Marine National Park (India)
GTZ	German Agency for Technical Cooperation
Ha or ha	hectare
HDPE	high density polyethylene
HIV/AIDS	acquired immune deficiency syndrome caused by the human immunodeficiency virus
HLL	hanging long line
HP	horsepower
ICAR	Indian Council of Agricultural Research
ICCI	Indian Chamber of Commerce and Industry (India)
IDRC	International Development Research Center (Canada)
IF	Indian Pharmacopoeia
IFAD	International Fund for Agricultural Development
IFC	International Finance Corporation (World Bank)
IFI	international finance institution
IFS	Indian Forest Service
IMS/UDSM	Institute of Marine Sciences of the University of Dar es Salaam (United Republic of Tanzania)
IMSS	Instituto Mexicano del Seguro Social
IMTA	integrated multitrophic aquaculture
INAPESCA	Instituto Nacional de Pesca (Mexico)
INEGI	Instituto Nacional de Estadística y Geografía (Mexico)
INI	Instituto Nacional Indigenista (Mexico)
INI RADEF	Indonesian International Rural and Development Foundation
INR	Indian rupee
IRR	internal rate of return
ISCP	Innovation Systems and Cluster Programmes (United Republic of Tanzania)
ISDA	Integrated Services for the Development of Aquaculture and Fisheries (Philippines)
ISO	International Organization for Standardization
ISSA	Indonesian Seaweed Society Association
IT	information technology
IWP	International Waters Project
IYF	International Youth Foundation (United States of America)
JaSuDa	Jaringan Sumber Daya (Indonesia)
JECFA	Joint FAO/WHO Expert Committee on Food Additives
JICA	Japan International Cooperation Agency
JLG	Joint Liability Group (India)
JOCDO	Jozani Community Development Organization (United Republic of Tanzania)
KCl	potassium chloride
KFI	Kasanyangan-Mindanao Foundation, Inc. (Philippines)
kg	kilogram
KITS	knowledge, information, tools and solutions
KMC	Kudumbam Model of Cultivation (India)
KNSE	Kasangyangan Nursery Seaweed Enterprise (Philippines)
KTF	Kauai Tete Family (Solomon Islands)
KUKM	Kementerian Negara Koperasi dan Usaha Kecil dan Menengah Republik Indonesia (National Ministry of Cooperatives and Small to Medium Enterprises in Indonesia)
LGSP	Local Government Support Program (Philippines–Canada)

LGUs	Local Government Units (Philippines)
LIPI	Lembaga Ilmu Pengetahuan Indonesia (Indonesian Institute of Sciences)
MACEMP	Marine and Coastal Environment Management Project (United Republic of Tanzania)
MALE	Ministry of Agriculture, Livestock, and Environment (United Republic of Tanzania)
MAO	Municipal Agriculturist Office (Philippines)
MC	moisture content
MFMR	Ministry of Fisheries and Marine Resources (Solomon Islands)
MLYWCD	Ministry of Labour, Youth, Women and Children Development (United Republic of Tanzania)
MNRT	Ministry of Natural Resources and Tourism (United Republic of Tanzania)
MoU	memorandum of understanding
MPEDA	Marine Products Exports Development Authority (India)
MRLL	multiple raft long line
M.S.	Manonmaniam Sundaranar (University) (India)
MSME	micro, small or medium enterprise
MSSRF	M.S. Swaminathan Research Foundation (India)
MSU-TCTO	Mindanao State University Tawi-Tawi College of Technology and Oceanography (Philippines)
MTTI	Ministry of Tourism, Trade and Investment (United Republic of Tanzania)
MUCHS/UDSM	Muhimbili College of Health Sciences, University of Dar es Salaam (United Republic of Tanzania)
MXN	Mexican peso
MYRADA	Mysore Resettlement and Development Agency (India)
NAAS	National Academy of Agricultural Sciences (India)
NABARD	National Bank for Agricultural and Rural Development (India)
NACA	Network of Aquaculture Centres in Asia-Pacific
NaCl	sodium chloride
NALO	National Aquaculture Legislation Overview
NASO	National Aquaculture Sector Overview
NCST	National Committee on Science and Technology (India)
NEMC	National Environment Management Council (United Republic of Tanzania)
NFDB	National Fisheries Development Board (India)
NFRDI	National Fisheries Research and Development Institute (Philippines)
NGO	non-governmental organization
NIRD	National Institute of Rural Development (India)
NPV	net present value
NSO	National Statistics Office (Philippines)
NTB	Nusa Tenggara Barat (Indonesia)
NTT	Nusa Tenggara Timur (Indonesia)
ODA	Overseas Development Agency (United Kingdom)
OHSAS	occupational health and safety management system
OSY	out-of-school youth
PADEP	Participatory Agricultural Development Empowerment Project (United Republic of Tanzania)
PB	Palk Bay
PBSP	Philippine Business for Social Progress

PCAMRD-DOST	Philippine Council for Aquatic and Marine Research and Development - Department of Science and Technology
PDAP	Philippine Development Assistance Programme, Inc.
PEMEX	Petróleos Mexicanos
PENSA	Program for Eastern Indonesia Small and Medium Enterprise Assistance
PET	Programa de Empleo Temporal (Mexico)
PFnet	People First Network (Solomon Islands)
PHT	post-harvest treatment
PNCS	Philippine National Carrageenan Standard
PNM	Permodalan Nasional Madani (Indonesia)
PNS	Philippine National Standard
POETCY	Programa de Ordenamiento Ecológico del Territorio Costero del Estado de Yucatán (Mexico)
POREMAD	Poverty Reduction through Environmental Management, Mariculture, Agribusiness and Association Development (United Republic of Tanzania)
PP	polypropylene
ppt	parts per thousand
PROCAMPO	Programa de Apoyos Directos al Campo (Mexico)
PROFEPA	Procuraduría Federal de Protección al Ambiente (Mexico)
QoL	Quality of Life Index
R&D	research and development
RAGS	red algal galactan seaweed
RBC	reinforced brick concrete
RC	refined carrageenan
RCC	reinforced cement concrete
RDS	raw dried seaweed
ReCoMaP	Regional Programme for the Sustainable Management of the Coastal Zones of the Indian Ocean Countries
RI	Republic of Indonesia
ROI	return on investment
RRDA	Ramanathapuram Rural Development Agency (India)
RFEP	Rural Fishing Enterprise Project (Solomon Islands)
SACCOS	Savings and Credit Cooperative Societies (United Republic of Tanzania)
SAGARPA	Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (Mexico)
SBD	Solomon Islands dollar
SBI	State Bank of India
SCC	Sociedad Cooperativa de Crédito (Mexico)
SCPP	Sociedad Cooperativa de Producción Pesquera (Mexico)
SDEV	standard deviation
SDSP	Seaweed Development Strategic Plan (United Republic of Tanzania)
SEAFDEC/AQD	Southeast Asian Fisheries Development Center / Aquaculture Department
SECOL	Secretaría de Ecología del Gobierno del Estado de Yucatán (Mexico)
SEDESOL	Secretaría de Desarrollo Social (Mexico)
SEDUMA	Secretaría de Desarrollo Urbano y Medio Ambiente, Estado de Yucatán (Mexico)

SEEGAAD	Small-holder Empowerment and Economic Growth through Agribusiness and Association Development (United Republic of Tanzania)
SEMARNAT	Secretaría de Medio Ambiente y Recursos Naturales (Mexico)
SEMMA	Sustainable Environmental Management through Mariculture Activities (United Republic of Tanzania)
SEP	Secretaría de Educación Pública (Mexico)
SFAB	seaweed farming as a business (United Republic of Tanzania)
SGSY	Swarnjayanti Gram Swarozgar Yojana (India)
SHG	self-help group
SIAP	Seaweed Industry Association of the Philippines
SIAVI	Sistema de Información Arancelaria vía Internet (Mexico)
Sida	Swedish International Development Cooperation Agency
SIPCOT	State Industries Promotion Corporation of Tamil Nadu Limited (India)
SLF	sustainable livelihood framework
SMEs	small and medium enterprises
SNAP	SNAP Natural & Alginate Products Ltd. (India)
SPC	Secretariat of the Pacific Community
SPE3	Sitangkai Seaweed Productivity Enhancement through Education and Extension (Philippines)
SPREP	Secretariat of the Pacific Regional Environment Programme
SRC	semi-refined carrageenan
SSA	Secretaría de Salud (Mexico)
SSS	Sociedad de Solidaridad Social (Mexico)
STABEX	Système de Stabilisation des Recettes d’Exportation
SUA	Sokoine University of Agriculture (United Republic of Tanzania)
SUCCESS	Sustainable Coastal Communities and Ecosystems (United Republic of Tanzania)
SW	Spider Web
SWOT	strengths, weaknesses, opportunities and threats
TAWLAE	Tanzania Association of Women Leaders in Agriculture and Environment
TCMP	Tanzania Coastal Management Partnership
TIRDO	Tanzania Industrial Research and Development Organization
TN	Tamil Nadu (India)
TNC	The Nature Conservancy (United States of America)
TNCDW	Tamil Nadu Corporation for Development of Women (India)
TNDoF	Tamil Nadu Department of Fisheries (India)
TNMB	Tamil Nadu Maritime Board
TZS	Tanzanian shilling
UAIM	Unidad Agrícola Industrial para la Mujer (Mexico)
UDSM	University of Dar es Salaam (United Republic of Tanzania)
UK	United Kingdom
UMA	Unidad de Manejo Ambiental (Mexico)
UNHAS	Universitas Hasanuddin, Makassar (Indonesia)
UNIDO	United Nations Industrial Development Organization
UNSRAT	Universitas Sam Ratulangi Manado (Indonesia)
UP	University of the Philippines
UP-MSI	University of the Philippines – Marine Science Institute
USAID	United States Agency for International Development
USD	United States dollar
USFDA	United States Food and Drug Administration

VICOBA	Village Corporate Banks (United Republic of Tanzania)
WHO	World Health Organization
WIOMSA	Western Indian Ocean Marine Science Association
ZANEA	Zanzibar East African Seaweed Company (United Republic of Tanzania)
ZaSCI	Zanzibar Seaweed Cluster Initiative (United Republic of Tanzania)
ZASCOL	Zanzibar Agro-Seaweed Company Limited (United Republic of Tanzania)
ZAZOSO	Zanzibar Zoological Society (United Republic of Tanzania)
ZDFMR	Zanzibar Department of Fisheries and Marine Resources (United Republic of Tanzania)
ZDoE	Zanzibar Department of Environment (United Republic of Tanzania)
ZDFMR	Department of Fisheries and Marine Resources, Zanzibar (United Republic of Tanzania)
ZERI	Zero Emissions Research and Initiatives

Introduction

Carrageenan is a gelling agent extracted from red seaweeds. It can be used as an emulsifier, a binder, or for suspension and stabilization in a remarkably wide range of products in the food processing, pharmaceutical and cosmetic industries. Demand for carrageenan has risen accordingly with demand for processed foods since research undertaken during the Second World War demonstrated that it could substitute for agar, the most popular colloid for food processing at the time. For almost three decades, production of carrageenan was restricted by availability of natural stocks of *Chondrus crispus* (also known as Irish moss) from Canada, Ireland, Portugal, Spain and France and *Gigartina* from South America and Southern Europe.

By the late 1960s, dwindling availability of wild seaweed stocks led commercial carrageenan producers to scout the world's seas in order to diversify seaweed supplies; at the same time, resources were invested in seaweed ecology research as the possibility of cultivation offered a solution to the instability of raw material supply. *Chondrus crispus* was successfully cultured in tanks but these techniques soon proved to be economically unfeasible. The scouting efforts finally found success in the south of the Philippines, where native *Eucheuma* seaweed was found to produce high-quality carrageenan and ecological conditions made cultivation possible. The first seaweed farm was established jointly in 1969 by Marine Colloids Inc. and University of Hawaii Professor Maxwell Doty in the province of Tawi-Tawi in the south of the Philippines.

Its plentiful beds of *Chondrus crispus* had allowed Canada to emerge as the world's largest supplier of carrageenan seaweed between 1948 and 1974. However, production of *Eucheuma* seaweeds spread rapidly in the Philippines, which soon displaced Canada as the world's top supplier. The lower cost of labour in the Philippines relative to Canada also incentivized companies to shift their buying to the Asian nation. Although the same corporations that controlled the Canadian market tried to control production in the Philippines through plantation-style seaweed farms, they soon realized that they could not compete with small, family-run farms. The reasons were twofold: (i) the labour for seaweed cultivation must be highly flexible to work on the cyclical time scales of tides and the moon, making it difficult to pay workers stable wages; and (ii) seaweed farming has low capital and technological requirements for entry.

The success of seaweed aquaculture in the Philippines was rapidly replicated in Indonesia. Farm production came to be dominated by two species: *Kappaphycus alvarezii* (commonly known as cottonii) and *Eucheuma denticulatum* (known as spinosum). Natural collection of *Sarcothalia* and *Gigartina* species from Chile and Mexico and *Chondrus crispus* from Canada and France accounts for the rest. Outside the Philippines and Indonesia, cultivation of the warm water species *K. alvarezii* and *E. denticulatum* have been attempted in a number of tropical countries around the world. However, significant production for export markets has been achieved only in Malaysia and the United Republic of Tanzania. The Philippines remained as the world's top producer of *K. alvarezii* until the late 2000s, when it was surpassed by Indonesia.

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

However, carrageenan seaweed farming is not without its own set of challenges. Environmentally, farmers face a myriad of challenges such as the incidence of tropical storms and predation by herbivorous fish. In particular, a disease condition named "ice-ice" represents a formidable threat. Devastating "ice-ice" outbreaks have been reported in almost all the major carrageenan seaweed farming countries. Because rampant "ice-ice" outbreaks prevented them from farming the more lucrative *K. alvarezii*, many seaweed farmers in Zanzibar (the United Republic of Tanzania) chose to abandon seaweed farming altogether. Economically, a major challenge is represented by the uncertain and volatile market conditions. This was particularly evident during the "seaweed price bubble" of 2008, when farm prices reached exorbitant levels and then collapsed in the course of a few months. Given the sudden price increase, many farmers rushed to harvest immature or low-quality seaweed, flooding the market and precipitating the subsequent price crash. Socially, the recent literature has drawn attention to some negative social impacts of carrageenan seaweed farming, such as low incomes for farmers in some places and occupational health hazards.

Given this background, the goal of this document is to conduct a comprehensive and balanced assessment of the socio-economic impacts of carrageenan seaweed farming in different locations. The assessment includes six country case studies that cover countries with established commercial production (Indonesia, the Philippines, and the United Republic of Tanzania) and with nascent or potential aquaculture sectors (India, Solomon Islands and Mexico). Each country study provides a review of carrageenan seaweed farming development and attempts to quantify the impacts of the sector on the socio-economic status of farmers. The assessment also includes a global synthesis intended to compare carrageenan seaweed farming experiences in different countries and provide a global overview. The synthesis highlights various knowledge and information gaps that need to be filled in order to deepen and broaden understanding of the industry and it also suggests several areas for further study.

This study unveils the clear potential of carrageenan seaweed farming in raising the socio-economic status of coastal communities in developing countries. Nevertheless, it is also evident that this potential needs to be evaluated in the context of local conditions and from a global and dynamic perspective. Why has carrageenan seaweed farming developed into a lucrative commercial business in some places (e.g. Indonesia and the Philippines), whereas in other places (e.g. Eastern Africa and Pacific islands) it has largely remained a diversified livelihood source for marginalized coastal villagers who have no access to alternative, higher-return economic activities? Further study is needed to deepen understanding of this fundamental question, but it is expected that the information, knowledge and insights provided by this report should help governments and other interested parties design policies most suitable to their countries.

Although the six country case studies and the global synthesis have been prepared under similar frameworks and included as different chapters in this document, they are self-contained papers by themselves. The global synthesis is placed as the first chapter to provide readers with a global overview. The ensuing country studies provide more detailed and specific information on the experiences of individual countries. The sequence of the six studies is determined, in descending order, by the countries' carrageenan seaweed farming production in 2010 according to FAO statistics.

Social and economic dimensions of carrageenan seaweed farming: A global synthesis

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ACKNOWLEDGEMENTS

The authors wish to thank Jiaxin Chen, Anicia Hurtado, Mahadeva Krishnan, Mechthild Kronen, PingSun Leung, Flower Msuya, Ramani Narayanakumar, Daniel Robledo, and Diego Valderrama for their valuable comments on and inputs to the paper.

1. INTRODUCTION

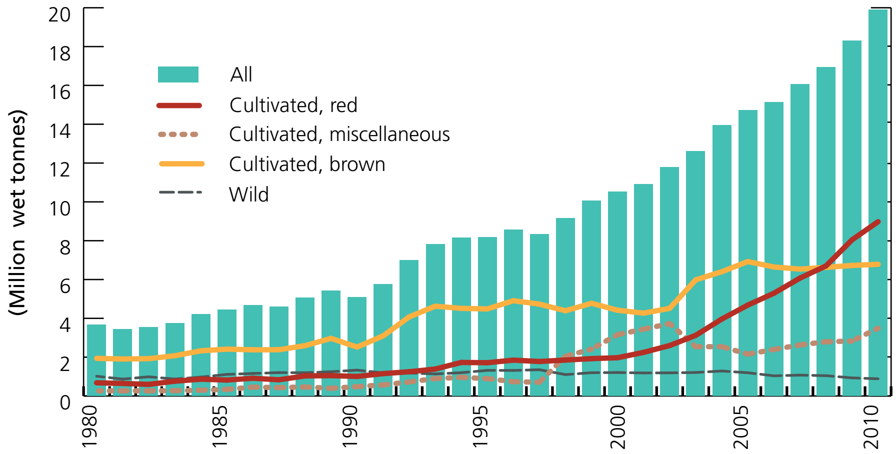
Seaweed is a versatile product that can be used for direct human consumption or processed into food additives, pet food, feeds, fertilizers, biofuel, cosmetics, and medicines, among others (McHugh, 2003; Bixler and Porse, 2011). According to FAO statistics (FishStat),[1] global production of seaweed increased from less than 4 million wet tonnes[2] in 1980 to almost 20 million wet tonnes in 2010 (Figure 1).

Not only has production increased but the source has also changed. Increasingly, seaweed is cultivated rather than collected from the wild. According to FAO statistics, the share of wild seaweed in global seaweed production fell from 28 percent in 1980 to 4.5 percent in 2010. This declining share reflects both the increased volume of cultivated seaweed and an absolute decrease in wild seaweed tonnage (Figure 1).[3]

Cultivation of red seaweeds (Rhodophyceae) contributed to most of the recent expansion in global seaweed production (Figure 1). According to FAO statistics, red seaweed farming production worldwide increased from 2 million wet tonnes in 2000 (21 percent of the production of all cultivated seaweeds) to almost 9 million wet tonnes in 2010 (47 percent). Major red seaweed species under cultivation include *Kappaphycus* and *Eucheuma*, which are primary raw materials for carrageenan, *Gracilaria* (primary raw materials for agar) and nori (mainly for direct human consumption) (Figure 2).

Agar and carrageenan are thickening and gelling agents (called hydrocolloids[4]) primarily used as food additives. Demand for hydrocolloids has grown with increased consumption of processed food. There was also an insufficient supply of wild seaweed.

FIGURE 1
World seaweed production



Note: Red seaweeds include species belonging to Rhodophyceae; brown seaweeds include species belonging to Phaeophyceae; miscellaneous seaweeds include species belonging to Chlorophyceae and Cyanophyceae as well as species unspecified.
Source: FAO Fishstat

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[1] Unless specified otherwise, the FAO statistics cited in this synthesis paper were obtained from the FishStat data set on "Aquaculture Production (Quantities and values) 1950-2010" released by the FAO Fisheries and Aquaculture Department in March 2012.

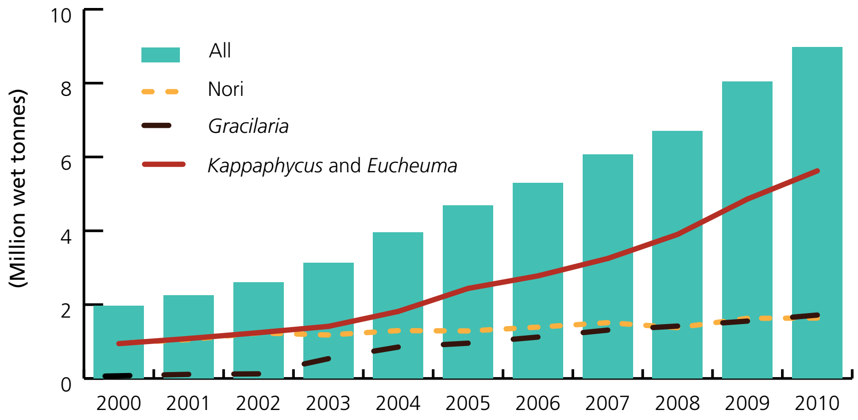
[2] Wet tonne measures the weight of fresh seaweed; whereas dry tonne measures the weight of raw dry seaweed. Unless specified otherwise, the weight of seaweed is measured in dry tonnes.

[3] World production of wild seaweed in 2010 (886 000 wet tonnes) was only two-thirds of the production in 1990 (1.3 million wet tonnes).

[4] Alginate, which is mainly extracted from wild brown seaweeds, is another major hydrocolloid (McHugh, 2003).

FIGURE 2

World red seaweed farming production



Note: Kappaphycus and *Eucheuma* includes species belonging to Solieriaceae. *Gracilaria* includes species belonging to Gracilariaceae; nori includes species belonging to Bangiaceae.
Source: FAO FishStat.

This motivated experimentation of cultivating carrageenan seaweeds in tropical waters and resulted in rapid expansion of *Kappaphycus* and *Eucheuma* cultivation (Figure 2) from 944 000 wet tonnes in 2000 (48 percent of total red seaweed cultivation) to 5.6 million wet tonnes in 2010 (63 percent).[5]

A comprehensive study of the socio-economic impacts of such an expanding sector is opportune. The six case studies included in this technical paper cover not only countries that have an established carrageenan seaweed industry (Indonesia, the Philippines and the United Republic of Tanzania) but also newcomers (India, Mexico and Solomon Islands). Information and insights provided by the studies indicate that carrageenan seaweed farming is a profitable activity with great potential, especially for coastal communities with abundant labour and few alternative activities (e.g. fisheries or tourism). A short production cycle, low capital requirement, and relatively simple farming technology are among the factors that make carrageenan seaweed farming a means of poverty alleviation particularly attractive to smallholder farmers or fishers. However, future development of the carrageenan seaweed industry faces various challenges such as inclement weather conditions, disease outbreaks, uncertain and fluctuating market conditions, competition from other sectors (e.g. fisheries, tourism and urban development), a lack of value-added products and value-adding activities in seaweed farming countries, low incomes of seaweed farmers in some countries, and occupational health hazards.

Based on the six case studies as well as other existing literature, this synthesis chapter is intended to provide a global review of the socio-economic performance of carrageenan seaweed farming. In the next section, the status and trends of seaweed-carrageenan value chains are reviewed based on official statistics (primarily FAO FishStat and UN COMTRADE) on the production and trade of seaweeds and seaweed products, specific data and information on seaweed value chains in individual countries provided by the six case studies, and those provided by other existing literature (e.g. McHugh, 2003; Panlibuton, Porse and Nadela, 2007; Neish, 2008a; Bixler and

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[5] According to FishStat, world cultivation of *Gracilaria* seaweeds increased from 73 000 wet tonnes in 2000 (3.7 percent of red seaweed cultivation) to 1.7 million wet tonnes in 2010 (17 percent of red seaweed cultivation). World cultivation of nori seaweeds increased from 954 000 wet tonnes in 2000 to 1.6 million wet tonnes in 2010, but its share in red seaweed cultivation declined from 48 percent to 18 percent during the period.

Porse, 2011). Various issues at different stages of the carrageenan seaweed value chain identified in the six case studies are highlighted in Section 2.4.

In Section 3, the economic performance of carrageenan seaweed farming is assessed based on the data and information provided by the six case studies. Various performance indicators (e.g. productivity, efficiency and profitability) are used to compare the economic costs and benefits of 23 cases of carrageenan seaweed farming examined in the six case studies. The cases vary in terms of farming systems, scales, production cycles and other technical parameters. The assessment also consults other literature on carrageenan seaweed farming practices and technology (e.g. Neish, 2008b).

In Section 4, the social performance of carrageenan seaweed farming is reviewed based primarily on the survey results discussed in the six case studies. The assessment covers the contributions of carrageenan seaweed farming to various social aspects such as employment, income, gender equality and community development. The assessment also highlights some negative social impacts of carrageenan seaweed farming (e.g. low income and occupational health hazards) based on the six case studies as well as other literature (e.g. Fröcklin *et al.*, 2012).

Section 5 focuses on issues related to governance and institutions in carrageenan seaweed farming. Governance structures and institutions in both the private sector (e.g. market governance, contract farming and farmers organizations) and the public sector (e.g. legal and policy frameworks, licensing, quality standards and public assistance) are discussed based on the experiences of the six case study countries. Some controversial issues are highlighted. In addition to the data and information provided by the six case studies, the discussion also consults the FAO's National Aquaculture Legislation Overview (NALO) and FAOLEX for legal issues and utilizes much information from various countries policy and planning reports.

Section 6 concludes the paper. Although the six case studies and other existing literature provide extensive information on the carrageenan seaweed industry, there are still substantial knowledge and information gaps to be filled in order to obtain better understanding of the development trends of carrageenan seaweed farming in the future and propose specific policy recommendations. Some of these gaps are discussed in this section; based on which areas for further study are suggested.

2. CARRAGEENAN SEAWEED PRODUCTION AND VALUE CHAIN

Carrageenan seaweed farming has expanded rapidly since 2000 because of the growing use of carrageenan. As an approved food additive, carrageenan is used worldwide to enhance dairy and meat products; it also has a variety of applications ranging from toothpaste to pet food.

Historically, carrageenan used to be extracted from wild seaweeds, especially *Chondrus crispus* (Irish moss). However, supply from wild seaweed was insufficient, and in some countries such as the United Republic of Tanzania, wild seaweed became depleted (Msuya, 2011). This prompted successful cultivation of carrageenan-containing seaweeds in tropical waters in the 1970s. Starting in the Philippines and then Indonesia where they are native, carrageenan-containing seaweeds have been introduced as an exotic species to the other four case-study countries, i.e. the United Republic of Tanzania, Solomon Islands, India and Mexico. In total, about 30 countries have introduced carrageenan-containing seaweeds to evaluate potential biomass production (Neish, 2008b).

Among various carrageenan-containing seaweeds, only warm-water *Eucheuma* seaweeds have been cultivated substantially and commercially. The main *Eucheuma* seaweeds under cultivation are *Kappaphycus* (primarily *K. alvarezii*)[6] and *Eucheuma* (primarily *E. denticulatum*). *K. alvarezii* (commercially called cottonii) and

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[6] *Kappaphycus* used to be classified as *Eucheuma* seaweed. *Kappaphycus alvarezii* was called *Eucheuma cottonii*. See McHugh (2003, p. 51) for a detailed clarification on the terminology.

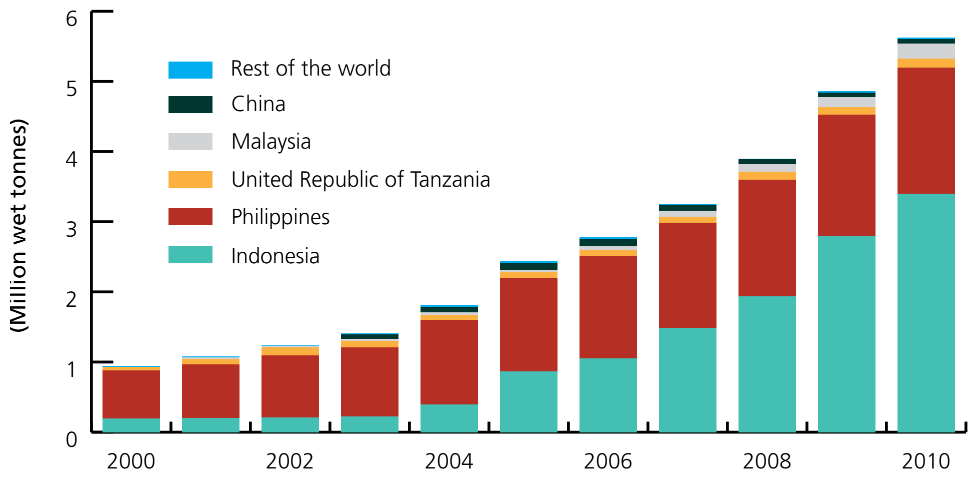
E. denticulatum (commercially called spinosum) are raw materials for extracting kappa and iota carrageenan, respectively. Generally speaking, kappa carrageenan is stronger (thicker) and hence a more favoured gelling agent than iota.

Several cold-water red seaweed species (e.g. *Gigartina skottsbergii* and *Sarcothalia crispata* from Chile and *Chondrus crispus* from Canada) have also been used to extract special carrageenans that cannot be supplied by warm-water *Kappaphycus* and *Eucheuma* (Bixler and Porse, 2011). Although cultivation of cold-water carrageenan-containing seaweeds has been experimented (Buschmann *et al.*, 2004), to date their production has depended almost entirely on wild collection (Bixler and Porse, 2011).

2.1 Production

According to FAO statistics, world carrageenan seaweed farming production increased from less than 1 million wet tonnes in 2000 to 5.6 million wet tonnes in 2010, with the corresponding farmgate value increasing from USD72 million to USD1.4 billion. Major carrageenan seaweed farming countries include Indonesia, the Philippines, the United Republic of Tanzania, Malaysia and China (Figure 3 and Table 1).

FIGURE 3
World carrageenan seaweed farming production



Note: Carrageenan seaweeds under cultivation are *Kappaphycus* and *Eucheuma* seaweeds (Solieriaceae)
Source: FAO FishStat

Salient facts about the main producers include the following:

- Indonesia is currently the largest carrageenan seaweed farming country, accounting for 61 percent of world production in 2010. *Kappaphycus* is the main cultivated species in Indonesia.
- The Philippines used to be the largest carrageenan seaweed farming country, accounting for 72 percent of world production in 2000. Its share declined to 32 percent in 2010 following the rapid expansion of carrageenan seaweed farming in Indonesia. *Kappaphycus* is the main cultivated species in the Philippines.
- Compared with Indonesia and the Philippines, which together accounted for 90 percent of world production in 2010, carrageenan seaweed cultivation in the United Republic of Tanzania is on a much smaller scale, accounting for only 2.3 percent of world production in 2010. The operation is concentrated in Zanzibar (accounting for 95 percent of the country's seaweed farming production in 2010). Unlike Indonesia and the Philippines, the main cultivated species in the United Republic of Tanzania is *Eucheuma denticulatum*.

TABLE 1
Major carrageenan seaweed farming countries, 2000 vs 2010

Year 2000			Year 2010		
Top 5 producers	**Quantity (thousand wet tonnes)**	**Share (%)**	**Top 5 producers**	**Quantity (thousand wet tonnes)**	**Share (%)**
World	**944**	**100.0**	**World**	**5 623**	**100.0**
Philippines	679	71.9	Indonesia	3 399	60.5
Indonesia	197	20.9	Philippines	1 795	31.9
United Republic of Tanzania[1]	51	5.4	Malaysia	208	3.7
Kiribati	11	1.2	United Republic of Tanzania[1]	132	2.3
Fiji	5	0.6	China	64	1.1
Top 5 total	**943**	**99.9**	**Top 5 total**	**5 599**	**99.6**

Note: Carrageenan seaweeds under cultivation include *Kappaphycus* and *Eucheuma* seaweeds. [1] Including Zanzibar.
Source: FAO FishStat.

- Carrageenan seaweed farming is on a much smaller scale in the other three case-study countries. According to FAO statistics, the production of cultivated carrageenan seaweed in 2010 was 8 000 wet tonnes in Solomon Islands and 4 240 wet tonnes in India, while the production in Mexico is not reported in the FAO statistics.
- The six case-study countries accounted for about 95 percent of world cultivation of carrageenan seaweed in 2010. Other major cultivating countries include Malaysia (3.7 percent of world production in 2010) and China (1.1 percent).

The performance of carrageenan seaweed farming is constrained by a number of environmental factors:

- Seasonality, which is one of the main causes of production fluctuations, has been a common issue for Indonesia and the Philippines. Experience of seaweed farmers in Indonesia indicated that monthly harvest could be 2.8 times of the average in the best season but only 42 percent in the worst season. Shifting cultivating sites and changing cultivars have been approaches used by farmers to accommodate seasonality, but most farmers reported that seasonal effects on growth were a major handicap (Neish, 2013). In another study that surveyed two hundred seaweed farmers in Indonesia (Zamroni and Yamao, 2011), changes in the monsoon seasons were ranked as the most critical challenge.
- Disease is another major problem, which not only discourages farmers but also contributes to supply uncertainty for processors. "Ice-ice" disease is a common disease that affects carrageenan seaweed farming worldwide. Primarily because of perennial "ice-ice" outbreaks, cottonii cultivation in Zanzibar (the United Republic of Tanzania) declined from over 1 000 tonnes in 2001 to almost zero in 2008 (Msuya, 2013). Indonesia and the Philippines have also suffered from "ice-ice" disease (Neish, 2013; Hurtado, 2013).
- Inclement weather is a great risk to seaweed farming. Indeed, the experimental carrageenan seaweed farming project on which the Mexico case study is based had to be terminated prematurely after the experimental farms were destroyed by a hurricane (Robledo, Gasca-Leyva and Fraga, 2013). In the Philippines, typhoons have damaged seaweed farms several times in the last three decades, and seasonal weather patterns can prevent production throughout the year. Crop insurance is available in the Philippines; and farmers are encouraged to purchase insurance even though it adds to their costs (Hurtado, 2013). In India, insurance

on infrastructure and cultivar is sometimes part of a contract farming scheme (Krishnan and Narayanakumar, 2013). However, crop insurance is not readily available in Indonesia (Neish, 2013). Some relief from weather damage may be obtained from government. For example, providing seaweed farmers with floating rafts was part of India's effort to rehabilitate tsunami-affected areas (Krishnan and Narayanakumar, 2013).

- Other environmental factors negatively affecting the performance of seaweed farming include grazing by fish or other organisms (which is a common problem identified in all six case studies) and rising sea temperatures, which could slow seaweed growth (Hurtado, 2013; Kronen, 2013).

Seaweed farming also faces competition from other sectors. For example, seaweed production in Solomon Islands declined in 2007 after the opening of the more-lucrative sea cucumber fishery (Kronen, 2013). In the United Republic of Tanzania, seaweed farming sites in some areas may become unavailable because of urban development (Msuya, 2013).

Notwithstanding various constraining factors, carrageenan seaweed farming should tend to continue expanding as long as the demand for carrageenan seaweeds keeps growing. There are still many areas yet to be exploited, even in Indonesia where seaweed farming has expanded substantially (Neish, 2013). It has been estimated that India has the potential to produce one million tonnes of dried seaweed (Krishnan and Narayanakumar, 2013).

2.2 Trade

International trade in carrageenan products

The demand for carrageenan seaweeds is a derived demand influenced primarily by the market for carrageenan products. Refined or semi-refined carrageenan has been widely used in dairy, meat, pet food, water gels and other products (McHugh, 2003; Neish, 2008a; Bixler and Porse, 2011). Europe and Northern America (mainly the United States of America) have been the main international markets for carrageenan. As more processed food is consumed by growing, wealthier and more urbanized populations, the carrageenan market has expanded in developing regions. The price of carrageenan in the international market was generally stable in the first half of the 2000s but has increased rapidly since the mid-2000s and become more volatile. This development pattern can be exemplified by the status and trend of carrageenan exports from the Philippines (Figure 4). The Philippines is a major carrageenan producing and exporting country. The other five case-study countries have a much smaller carrageenan processing capacity.

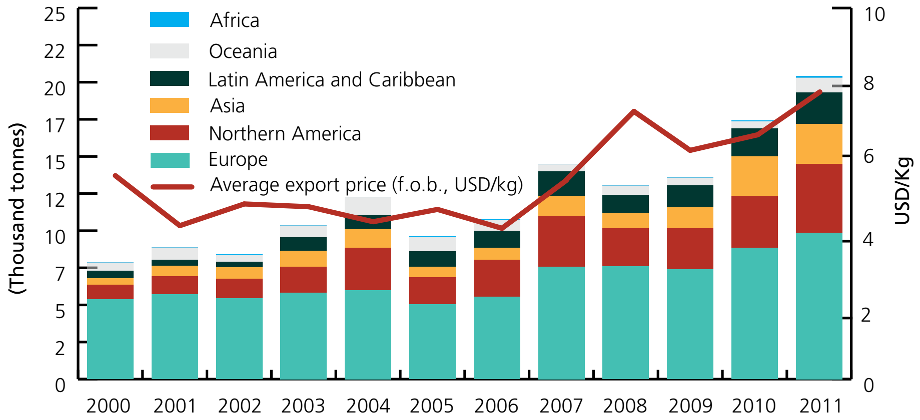
International trade in carrageenan seaweeds

Most carrageenan seaweeds in international trade come from the three major carrageenan seaweed farming countries (i.e. Indonesia, the Philippines and the United Republic of Tanzania). Chile also exports carrageenan-containing, cold-water species from wild collection (Bixler and Porse, 2011).

Specific data on the international trade of cultivated carrageenan seaweeds are not readily available. In UN COMTRADE data set, the commodity HS121220 (seaweeds and other algae) includes all types of seaweeds (red, brown and others) from different sources (wild and farmed) and in different forms (dry and fresh). However, most of seaweed production in Indonesia, the Philippines and the United Republic of Tanzania comes from aquaculture, and their total carrageenan seaweed farming production accounts for more than 90 percent of the world total (Table 1). Therefore, the status and trend of seaweed exports from these three countries (Figure 5) can be used to reflect the status and trends of international markets for cultivated carrageenan seaweeds. Some stylized facts are summarized as follows:

FIGURE 4

Export volume and price of carrageenan products from the Philippines

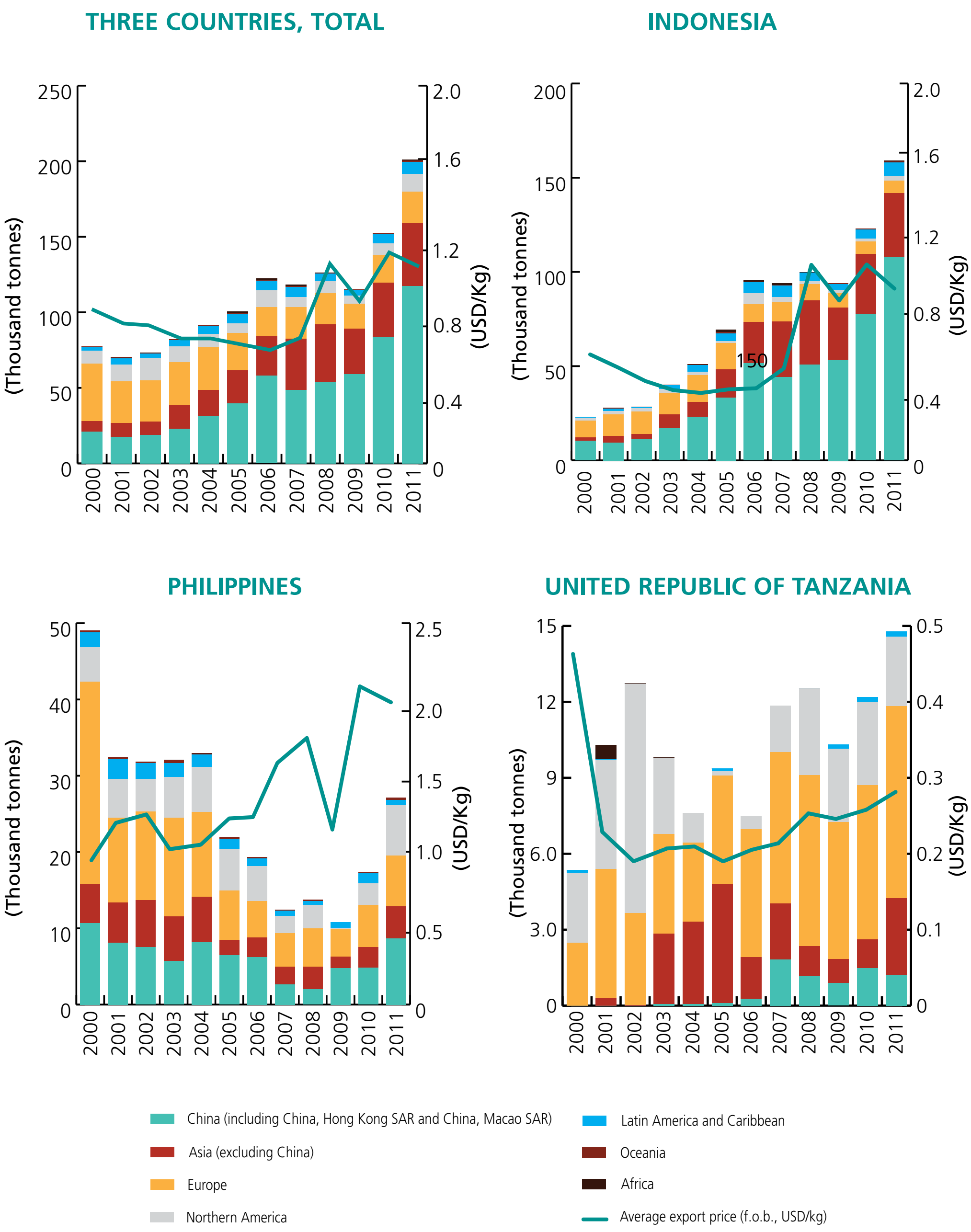


Note: For the Philippines, the export of HS130239 comprises mainly carrageenan products. Price calculated from value and quantity.
Source: UN COMTRADE; commodity HS130239 (mucilages and thickeners nes).

- As indicated by the total seaweed export of the three countries, the international market for cultivated carrageenan seaweed doubled from about 100 000 tonnes in 2005 to 200 000 tonnes in 2011. Exports to China accounted for most of the expansion; its share in total exports increased from 27 percent in 2000 to 58 percent in 2011. Europe used to be the largest international market for carrageenan seaweed, but its share in the total seaweed exports of the three countries declined from 49 percent in 2010 to 10 percent in 2011.
- Indonesia is the largest carrageenan seaweed exporting country. Its seaweed exports have increased almost eightfold (in terms of volume) since 2000, reaching almost 160 000 tonnes in 2011. Asian markets accounted for 95 percent of the expansion; China alone accounting for 72 percent. In 2011, 68 percent of Indonesia's seaweed export (in terms of volume) went to China (including China, Hong Kong SAR and China, Macao SAR), 22 percent to other Asian countries, 4.5 percent to Latin America and the Caribbean, 4.1 percent to Europe, 1.5 percent to Northern America, 0.3 percent to Oceania, and 0.3 percent to Africa. The top ten markets for seaweed exports from Indonesia in 2011 are summarized in Table 2.
- The Philippines was the largest carrageenan exporting country in 2000. However, its seaweed exports declined from almost 50 000 tonnes in 2000 to about 11 000 tonnes in 2009. Its exports rebounded to 27 000 tonnes in 2011. While 54 percent of the Philippines' seaweed exports (in terms of volume) went to Europe in 2000, it was distributed more evenly in 2011: China (32 percent), other Asian countries (15 percent), Europe (24 percent), Northern America (24 percent), Latin America (2.6 percent) and Oceania (1.2 percent). The top ten markets for seaweed exports from the Philippines in 2011 are summarized in Table 2.
- The seaweed exports of the United Republic of Tanzania increased from 5 000 tonnes in 2000 to about 13 000 tonnes in 2002 and then declined to 7 000 tonnes in 2006. However, they rebounded to almost 15 000 tonnes in 2011. Europe and Northern America remained the two major international markets for seaweed exports from the United Republic of Tanzania (about 60 and 20 percent of the total, respectively, in 2011). The share of Asia increased from nil in 2000 to almost 30 percent in 2011. The top ten markets for seaweed exports from the United Republic of Tanzania in 2011 are summarized in Table 2.

FIGURE 5

Seaweed export volume and price of major carrageenan seaweed farming countries



Notes: Carrageenan seaweeds account for most seaweed and algae production and export in Indonesia, the Philippines and the United Republic of Tanzania. Price calculated from value and quantity.
Source: UN COMTRADE; commodity HS121220 (seaweeds and other algae).

- The trends in seaweed export prices for the period 2000–2011 (Figure 5) are similar to that of carrageenan (Figure 4). Generally speaking, seaweed exports from the Philippines were more expensive than those from Indonesia. The prices of seaweed exports from the United Republic of Tanzania were much lower than those of Indonesia and the Philippines because of the dominance of the cheaper spinosum in its exports. A more detailed discussion on seaweed prices is set out below.

TABLE 2
Major markets for seaweed exports from Indonesia, the Philippines and the United Republic of Tanzania in 2011

Seaweed exports from Indonesia			Seaweed exports from the Philippines			Seaweed export from United Republic of Tanzania		
Destination	Volume (tonnes)	Share (%)	Destination	Volume (tonnes)	Share (%)	Destination	Volume (tonnes)	Share (%)
World	**159 075**	**100.0**	**World**	**27 141**	**100.0**	**World**	**14 773**	**100.0**
China[1]	107 632	67.7	China[1]	8 695	32.0	Denmark	3 982	27.0
Viet Nam	14 229	8.9	United States of America	6 155	22.7	France	3 060	20.7
Philippines	10 404	6.5	France	3 395	12.5	Viet Nam	2 941	19.9
Republic of Korea	8 085	5.1	Spain	2 464	9.1	United States of America	2 736	18.5
Chile	4 268	2.7	Republic of Korea	1 778	6.6	China[1]	1 220	8.3
France	2 803	1.8	Thailand	797	2.9	Spain	560	3.8
United States of America	2 257	1.4	Indonesia	599	2.2	Chile	200	1.4
Brazil	2 037	1.3	Viet Nam	539	2.0	United Arab Emirates	49	0.3
Germany	1 460	0.9	Belgium	486	1.8	Malaysia	25	0.2
Spain	1 139	0.7	Canada	388	1.4			
Top 10 total	**154 314**	**97.0**	**Top 10 total**	**25 295**	**93.2**	**Top 10 total**	**14 773**	**100.0**

[1] Including China, Hong Kong SAR and China, Macao SAR.
Source: UN COMTRADE; commodity HS121220 (seaweeds and other algae).

2.3 Price

Because of strong demand for kappa carrageenan, the price of cottonii (*K. alvarezii*) has doubled in the last decade. The price of spinosum (*E. denticulatum*), which is the raw material for iota carrageenan, has been stagnating at a much lower level (Bixler and Porse, 2011). As mentioned above, these price trends are illustrated in Figure 5 by the price trends of seaweed exports from major carrageenan seaweed farming countries (Indonesia, the Philippines and the United Republic of Tanzania). For further analysis, the trends of the three countries' average seaweed export price in different international markets are depicted in Figure 6. Based on Figures 5 and 6, some stylized facts on the status and trends of the prices of carrageenan seaweed in international markets are summarized as follows:

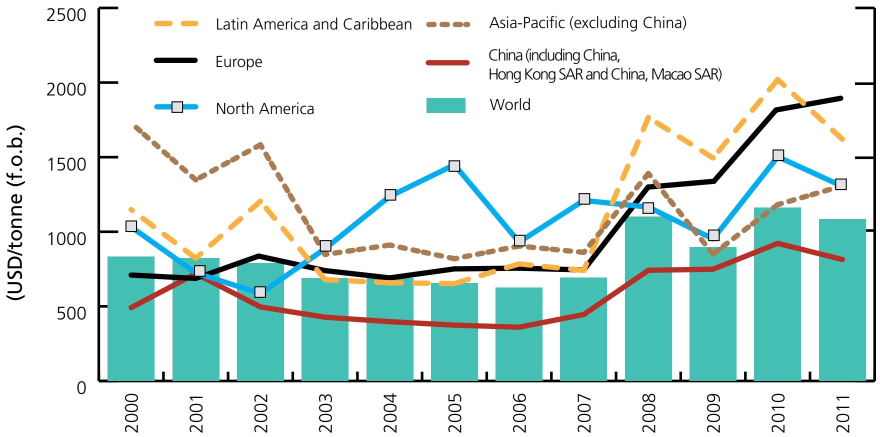
- Indonesia's average seaweed export price increased from about USD500 per tonne in the first half of the 2000s to about USD1 000 per tonne in 2011; that of the Philippines increased from about USD1 000 to USD2 000 per tonne (Figure 5). As cottonii accounted for most of the seaweed exports from these two countries, it can be concluded that, generally speaking, the price of cottonii in the international market doubled in the 2000s.
- Generally speaking, the price of spinosum in the international market was lower than, and did not rise as fast as, that of cottonii. The average seaweed export price of the United Republic of Tanzania (whose main species was spinosum) increased from about USD200 per tonne in the mid-2000s to USD290 in 2011 (Figure 5).
- From being declining and relatively stable in the first half of the 2000s, seaweed export prices started rising in the mid-2000s in most international markets and increased rapidly in 2008 (Figure 6). While supply shortage caused by unfavourable farming conditions (rising sea water temperature, diseases, etc.) may be a contributing factor, a sudden rise in demand from China was deemed the main cause of the abnormal price hike in 2008 (Neish, 2008a). This event was referred to

as a carrageenan "seaweed crisis" because of its disruptive impacts on the cohesion of carrageenan seaweed value chains (Neish, 2008a). After the seaweed crisis, seaweed prices in international markets became more volatile (Figure 6).

- The prices of carrageenan seaweed exports to China (the largest export market) appear to be lower and less volatile than other export markets (Figure 6). It is difficult to make general inferences on this pattern because seaweed exports to different markets may not be of the same quality. Nonetheless, industry experts have argued that seaweed buyers from China have been using "campaign buying" scheme (i.e. concentrating purchases within a short period when the price is low) to lower the cost of their purchases (Bixler and Porse, 2011).

FIGURE 6

Average seaweed export price of major carrageenan seaweed farming countries (Indonesia, the Philippines and the United Republic of Tanzania) in different international markets



Note: Price calculated from value and quantity.
Source: UN COMTRADE; commodity HS121220 (seaweeds and other algae).

Despite the growth of the cottonii price in the international market, the low farmgate price has been one of the major concerns of seaweed farmers. In 2009, when the farmgate price of cottonii was about USD1 200 in Indonesia and the Philippines (Bixler and Porse, 2011; Hurtado, 2013), it was only about USD390 in India (Krishnan and Narayanakumar, 2013), USD330 in Solomon Islands (Kronen, 2013), and USD210 in the United Republic of Tanzania (Msuya, 2013). Linked to the low farmgate pricing is oligopsonistic pricing. There are relatively few processors to purchase raw seaweed, which leaves farmers in a weak bargaining position. To remain competitive, processors must therefore buy at the lowest possible price. This is a particular concern for Solomon Islands and the United Republic of Tanzania, whose seaweed industries are relatively small and dependent on overseas processors. Rising fuel costs for shipping have reduced the margins of exporters, and therefore the farmgate price they can offer.

In the United Republic of Tanzania, most seaweed farmers deemed the prices of seaweed (which did not rise as fast as their cost of living) not worth the efforts they put in but felt powerless in the face of such "unfair" and discouraging prices because it was difficult to find alternative buyers (Msuya, 2013). After the collapse of cottonii cultivation due to "ice-ice" disease outbreaks, many farmers (especially men) in Zanzibar have abandoned seaweed farming because the farmgate price of the alternative, spinosum, was only half that of cottonii (Msuya, 2011). Seaweed buyers, on the other hand, deemed their prices justified because of the aids they provided to farmers (e.g. farming materials and extension services). They argued that in order for them to offer high prices, farmers should increase the production level so as to help lower the unit cost of marketing seaweed (Msuya, 2013). Lack of economies of scale in seaweed farming was also a problem in Solomon Islands, where exporters offered monetary awards to motivate farmers to increase their deliveries (Kronen, 2013).

Volatility in seaweed prices is another problem, which reflects periodic disequilibrium in supply and demand under an oligopsonistic market structure. The volatility appears to have increased recently with the loss of cohesion in the value chain. In addition to Figure 6, evidence of more volatile seaweed prices is also documented in the six case studies:

- In the Philippines, the export price of dry cottonii (f.o.b. Cebu City) averaged about USD800 a tonne between 2003 and 2007 with relatively little fluctuation, whereas in 2007 the price was driven enormously high by strong demand from China and reached USD2 750 a tonne in 2008. When the supply reacted swiftly to the price hike, the price was dampened and dropped to USD1 300 a tonne in 2009 and then rebounded to USD1 600 in 2010 (Hurtado, 2013).
- In Solomon Islands, the farmgate price of cottonii declined from about USD300 in the early 2000s to about USD200 in the mid-2000s because of an increase in fuel prices; the price then increased to about USD400 in 2008 because of the strong demand in the international market (Kronen, 2013).

Price volatility is a common phenomenon for economic activities dictated by market mechanisms that may not function properly because of imperfect institutions and/or information. A seaweed industry that contains many small-scale price-takers is especially prone to boom–bust cycles. When strong demand drives up the market price, seaweed farmers tend to increase their production; farmers may even harvest immature crops in order to grasp the opportunity of a good price (Hurtado, 2013), especially when they are afraid that the price hike may be transitory. On the other hand, processors would tend to reduce demand as prices rise by substituting cheaper alternatives (McHugh, 2006). A likely result would then be supply exceeding demand and consequently a collapse in price. At the trough, seaweed farmers become discouraged and abandon their farms. This has happened in the Philippines, Solomon Islands and the United Republic of Tanzania.

Price volatility is also compounded by the absence of relevant, reliable and timely production statistics and market intelligence. Unlike for some agricultural commodities such as coffee or tea, there are no organized markets to provide benchmarking international prices for seaweed (Tinne, Preston and Tiroba, 2006). Under the situation where seaweed farmers, traders and processors make decisions based on speculations or misinformation, market fluctuations tend to be inevitable. Unavailability of reliable information is especially detrimental to uninformed seaweed farmers who are at the lowest end of the seaweed value chain and often forced to accept whatever price is offered.

2.4 Value chain

A seaweed-carrageenan value chain begins with seaweed farmers and ends with the users of carrageenan products. Typically, the value chain involves four stages: cultivation, post-harvest treatment, trading and processing. The cultivation stage produces fresh seaweeds through planting, daily management and harvesting. The post-harvest treatment stage purifies and dries fresh seaweeds into raw dry seaweeds (RDS). The trading stage consolidates and delivers RDS to processors. Then, the processing stage turns RDS into carrageenan and/or other products. Key players in the value chain include farmers, trading agents (collectors, consolidators, traders and exporting companies) and processors.

The value chains vary in the case-study countries. The Philippines has the most complete and sophisticated value chain – containing every stage from seaweed cultivation to carrageenan blending (Panlibuton, Porse and Nadela, 2007; Hurtado, 2013). Indonesia still exports most of its RDS to overseas markets (primarily China), yet it has developed substantial carrageenan (especially semi-refined carrageenan) processing capacity (Neish, 2013). The United Republic of Tanzania has little carrageenan processing capacity and exports most of its RDS (Msuya, 2013); so does Solomon Islands (Kronen, 2013). The value chain in India is the shortest with most contracted farmers selling their seaweed directly to the processor (Krishnan and Narayanakumar, 2013).

Cultivation

Cultivation of fresh seaweed is usually conducted by a number of small-scale, independent seaweed growers. As compared with the wage worker system, such an industrial structure allows more flexible and efficient labour participation in seasonal, labour-intensive seaweed farming activities. However, it also means that decision-making on seaweed production is decentralized to numerous independent growers. Contract farming has been used to coordinate the production of independent seaweed farmers in some countries such as India (Krishnan and Narayanakumar, 2013) and the United Republic of Tanzania (Msuya, 2013).

In addition to the performance constraints highlighted above, other issues at the farming stage indentified by the case studies include:

- Premature harvest because of cash flow problems or rashness to seize the opportunities of high price (Hurtado, 2013).
- Difficulties encountered by small-scale farmers in harvesting and transporting large crops to the drying site (Msuya, 2013).
- Lack of proper shoes to protect farmers from being stung by organisms (e.g. sea urchins and box fish) at the farming site (Msuya, 2013).

Post-harvest treatment

Typically, harvested fresh seaweeds need to go through post-harvest treatment to remove impurities and reduce the moisture content in order to become RDS suitable for storage, transport and processing.

Impurities that ought to be removed from harvested fresh seaweeds may come from the farming environment (e.g. junk weeds, shells, sands, stones, mud and dirt) or from the farming system (e.g. raffia/tie-ties and ropes). Salt is also considered an impurity, but its removal may not be necessary because natural potassium chloride may facilitate the processing of cottonii (Neish, 2013).

Fresh seaweeds are usually sun-dried on a variety of drying apparatus (e.g. concrete slabs, wooden/bamboo platforms or racks, coconut branches, mats and fishing nets) or directly on grass or sandy beaches. The drying process may take 2–3 days in sunny weather but could take up to 7 days in rainy seasons (Msuya, 2013).

Generally speaking, the drier the RDS is, the higher the quality is. The industry standard for the maximum moisture content of dry cottonii is 38 percent in Indonesia (Neish, 2013) and 40 percent in the Philippines (Hurtado, 2013). More-detailed quality standards on dried seaweeds in the Philippines can be found in Hurtado (2013).

Fresh seaweeds decompose quickly after harvest; whereas sun-drying is subject to weather uncertainties. Thus, finding more controllable and cost-effective drying methods has been a key technical issue persistently preoccupying the industry (Neish, 2013). However, to date, sun-drying remains the main (if not the only) option in practice.

Drying may not be necessary under special situations. For example, in India, seaweed farmers under contract farming can ship their fresh seaweed harvests directly to processing facilities for production of biofertilizer (Krishnan and Narayanakumar, 2013).

Post-harvest treatment is usually done by seaweed growers. However, additional drying and quality control may be conducted by trading agents to achieve the quality desired by processors (Kronen, 2013; Neish, 2013). In the Philippines, seaweed growers who find the sun-drying process laborious and time-consuming may pass the task to traders or farmers associations by selling them fresh or semi-dried seaweeds (Hurtado, 2013).

Issues at the post-harvest stage identified by the case studies include:

- seaweed not dried enough and/or impurities not removed sufficiently (Hurtado, 2013; Neish, 2013);
- added impurities through drying directly on sandy beach (Krishnan and Narayanakumar, 2013);
- added impurities by trading games such as sand–salt adulteration (Hurtado, 2013).

Trading

Seaweed farmers usually sell their harvests to local collectors or consolidators who accumulate seaweed collections to a substantial amount and then sell them to large traders who eventually deliver the products to processors. In Indonesia, a large farmer may bypass collectors and sell RDS directly to a central trading centre (Neish, 2013). In the Philippines, there may be a small trader between local consolidators and a large trader who owns a warehouse (Hurtado, 2013). In the United Republic of Tanzania and Solomon Islands, traders usually hire local agents to help them collect seaweeds from farmers (Msuya, 2013; Kronen, 2013).

In Indonesia, collectors and traders usually charge price-based brokerage fees that normally do not exceed 5 percent of the seaweed price (Neish, 2013). In the Philippines, collectors and traders may charge brokerage fees at weight-based rates (Hurtado, 2013).

In addition to the main function of being the broker between farmers and processors, trading agents may play other roles in seaweed value chains. For example, collectors and large traders in the Philippines often take on the task of drying (Hurtado, 2013). A central trading centre in Indonesia offered cash advances to farms and collectors who would pay back the advances with their seaweed deliveries (Neish, 2013). Under the price-based charging scheme, as the brokerage fee varies with the seaweed price, traders essentially shoulder part of the risk of price variations.

In Indonesia and the Philippines, commercial collectors are usually ex-farmers and come from the same ethnic background and villages as the farmers from whom they collect seaweeds. According to the farm survey in Neish (2013), trust and integrity are two key elements facilitating and sustaining good business relationship between Indonesian seaweed farmers and collectors. The farm survey also indicates a relatively high degree of trust and commitment between farmers and collectors in Indonesia.

Besides commercial collectors and traders, farmers associations may also serve as brokers between farmers and processors. In Indonesia, many farmers sold their harvests to farmers groups, cooperatives or credit unions (Neish, 2013). In the Philippines, farmers associations helped reduce the layers of intermediaries by collecting seaweeds from member farmers, drying the seaweeds and then selling them directly to processors with the assistance of government agencies or non-governmental organizations (NGOs) (Hurtado, 2013).

Generally speaking, a more direct trading scheme could increase the profits of seaweed farmers by reducing the layers of intermediaries. However, while farmers associations could play an active role in improving the efficiency of seaweed trading, the vital roles of commercial trading agents may be irreplaceable in seaweed value chains where a large number of smallholder farmers try to satisfy the demand of processors that may locate overseas. Therefore, the key is to establish an enabling yet competitive environment to improve the efficiency of commercial trading agents rather than trying to bypass them completely.

In special situations, traders may not be necessary. For example, seaweed farmers in India may follow predetermined arrangements under a contract farming scheme to deliver their harvests directly to the processor (Krishnan and Narayanakumar, 2013).

Issues at the trading stage include:

- high transportation costs (especially regarding domestic freight and for small-scale operations) caused by inadequate infrastructure and/or high fuel prices (Neish, 2013; Kronen, 2013; Msuya, 2013);
- high trading costs due to multiple layers of collecting or trading (Neish, 2013);
- cost of RDS export affected by exchange rate fluctuations (McHugh, 2006).

Processing

Carrageenan seaweeds can be processed into refined carrageenan (RC) or semi-refined carrageenan (SRC). The former is a traditional product with a high carrageenan content, fit for human consumption, but difficult and expensive to produce. The latter, SRC, as the name suggests, is a product with a lower carrageenan content. It was initially unfit for human consumption and used primarily for pet food or as raw materials to produce RC. The production of pet-grade SRC declined in the 2000s because of the pet food industry's increased use of dry pellets and substitution of low-cost gelling agents (Bixler and Porse, 2011). However, food-grade SRC, which is called Philippine Natural Grade (PNG) or Processed *Eucheuma* Seaweed (PES), was developed in the 1970s and it has become a popular substitute for RC since the 1990s. It is almost equivalent to RC in many applications but much cheaper (Panlibuton, Porse and Nadela, 2007; Bixler and Porse, 2011).

It is estimated that, at the end of the 2000s, RC accounted for about half of the world carrageenan production; food grade SRC (PES) for 40 percent; and non-food grade SRC for 10 percent (Bixler and Porse, 2011; Neish, 2013). The processing capacity for RC is located primarily in Europe, the Americas, China and the Philippines, while that for SRC is primarily located in the Philippines, Indonesia and China (Bixler and Porse, 2011; Neish, 2013).

Being capital-intensive and technically demanding, RC production used to be highly consolidated and controlled primarily by a few large companies, which were usually subsidiaries of large transnational food and/or agriculture corporations in Europe and Northern America (Bixler and Porse, 2011). Because of cost-saving and other considerations, there has been a trend for large RC producers to shift their processing facilities to areas such as the Philippines and China (Panlibuton, Porse and Nadela, 2007). The SRC industry has lower capital and technical requirements and allows the participation of many small companies. This has caused a significant change in the structure of the carrageenan business, which is discussed in greater detail below.

As the main ingredient, RC or SRC usually needs to be blended with other hydrocolloids and ingredients based on custom-made formulations to serve the special needs of different end users. Carrageenan blending is usually conducted by large carrageenan producers or "blending houses" that specialize in the formulation and marketing of carrageenan-blended products (Panlibuton, Porse and Nadela, 2007).

Generally speaking, food-grade SRC and gel-press RC are often used for relatively low-end applications such as improving the texture and tenderness of pre-cooked poultry products, suspending cocoa particles in chocolate milk, and making water-gel products. Alcohol-precipitation RC is often used for relatively high-end applications such as toothpaste, cold soluble dairy products, and pharmaceutical products (McHugh, 2003; Bixler and Porse, 2011).

Table 3 provides a summary of different types of carrageenan products. More detailed discussion on carrageenan processing and products can be found in McHugh (2003), Panlibuton, Porse and Nadela (2007) and Bixler and Porse (2010).

Depending on the quality of the RDS as well as the processing method, the gum yield of carrageenan seaweed processing ranges from about 8 to 30 percent. Although the other 70–92 percent contains useful nutrients (proteins, minerals, etc.), it is usually not recovered but treated as waste (Neish, 2013). An exception is the case in India where carrageenan seaweeds were processed to produce organic fertilizer with carrageenan extracted as a by-product (Krishnan and Narayanakumar, 2013). Carrageenan seaweeds have also been used to make other value-added products such as cosmetic products (e.g. soap and body cream) and confectionery products (e.g. candies and crackers) (Msuya, 2011).

Major issues at the processing stage identified by the case studies include:

- Lack of value addition in the carrageenan seaweed business, which mainly exports RDS as raw materials for overseas processors (Neish, 2013), especially for small countries such as the United Republic of Tanzania (Msuya, 2013) and Solomon Islands (Kronen, 2013). Lowered capital and technical requirements allow small-scale processors to enter the carrageenan business (Pickering, 2006), yet access to the markets for carrageenan products remains a major barrier to overcome.
- Useful nutrients not recovered during the production of carrageenan, which is not only wasteful but also could increase the cost of effluent treatment or inflict environmental costs to the surrounding environment (Neish, 2013).

Value chain structure

Generally speaking, carrageenan seaweed cultivation and post-harvest treatment are labour-intensive activities entailing relatively small amounts of initial capital

TABLE 3

A summary of carrageenan products

Carrageenan products	**Alkali-treated cottonii (ATC) chips**	**Semi-refined carrageenan (SRC)**		**Refined carrageenan (RC)**	
		Non-food-grade SRC	**Food-grade SRC (PES)**	**RC (gel-press)**	**RC (alcohol)**
Major raw materials used (Panlibuton, Porse and Nadela, 2007)	Cottonii			Cottonii or *Gigartina*	Any kind of carrageenan seaweed: cottonii, *spinosum, Gigartina* or *Chondrus*
Processing method (McHugh, 2003)	Seaweed treated in hot alkaline solution of potassium hydroxide to remove water-soluble contents; dried; then:			Carrageenan first extracted into an aqueous solution; then recovered by:	
	chopped into pieces	milled	bleached, milled, and sterilized	gel-press method	alcohol-precipitation method
Main contents (McHugh, 2003)	Kappa + cellulose			Kappa	Any type of carrageenan: kappa/iota/lambda
Main uses (McHugh, 2003; Panlibuton, Porse and Nadela, 2007; Bixler and Porse, 2011).	Further processed into SRC or RC	Pet food	Low-end product: meat (ham, pre-cooked poultry, fat replacement), dairy (cheese, chocolate milk, etc.), water-based food (water-gel, salad dressing, etc.)		High-end product: toothpaste, cold-soluble dairy products, pharmaceutical products (capsules, etc.)
Major producing regions/countries (Neish, 2008a; Bixler and Porse, 2011).	China, Indonesia and the Philippines			Europe, Americas, China and the Philippines	
Share of total carrageenan production worldwide in 2009 (%), based on the estimation in Bixler and Porse (2011)		10	41	26	23

Source: Based on information provided by McHugh (2003); Panlibuton, Porse and Nadela (2007); Neish (2008a); Bixler and Porse (2011).

investments and material inputs. The use of farming areas in the ocean is usually free of charge except for some licensing or registration fees in some countries.

The price paid to farmers is determined in part by the complexity of the supply chain and partly by the quality of the seaweed. The existence of large and persistent price gaps between cottonii and spinosum (whose production costs are similar) indicates that seaweed farmgate prices have been primarily demand-driven. However, this situation could change in the future as the costs of labour and natural resources in carrageenan seaweed farming countries increase because of economic growth.

Typical costs incurred at the trading stage include the cost of collecting, consolidating and packing (primarily labour cost), cost of transportation, and brokerage fees charged by collectors and traders. Based on information and assumptions in Neish (2013), an example of the cost of RDS exported by Indonesia under different seaweed farmgate prices is presented in Table 4.[7] The results indicate that seaweed is the main component of the cost of RDS exported from Indonesia to processors in southern China; the total mark-up at the trading stage is generally less than 20 percent of the cost.[8] Some implications of this value chain structure are summarized as follows:

- Given that other factors remain the same, if the farmgate price of semi-dry seaweed doubled from USD500/tonne to USD1 000/tonne, the cost of RDS for processors in southern China would rise by about 87 percent from USD674/tonne to USD1 257/tonne. The 87 percent reflects not only the share of the farmgate value of semi-dry seaweed in the cost of RDS (82.4 percent) but also the share of collector and trader fees (4.1 percent), which is assumed to be 5 percent of the farmgate value.

TABLE 4
An example of the cost of RDS exported by Indonesia to Southern China

Item No.	Cost items for one tonne of RDS	Low farmgate price		High farmgate price	
		Value	% of the cost of RDS	Value	% of the cost of RDS
(1)	Farmgate price of semi-dry seaweed (USD/tonne)	500	-	1 000	-
(2)	Semi-dry seaweed needed (tonne)	1.111	-	1.111	-
(3)	**Farmgate value of semi-dry seaweed (USD)**	**556**	**82.4**	**1 111**	**88.4**
(4)	**Total cost of trading (USD)**	**118**	**17.6**	**146**	**11.6**
(5)	- Cost of sorting and sacking (USD)	13	2.0	13	1.1
(6)	- Cost of transport to market (USD)	22	3.3	22	1.8
(7)	- Cost of baling (USD)	25	3.7	25	2.0
(8)	- Collector and trader fees (USD)	28	4.1	56	4.4
(9)	- Cost of transport to overseas processors (USD)	30	4.5	30	2.4
(10)	**Cost of dry seaweed for overseas processors (USD/tonne)**	**674**	**100.0**	**1 257**	**100.0**

Notes: (1): Price paid to seaweed farmers. (2): 10 percent of shrinkage (i.e. one tonne of seaweed delivered at farmgate would become 0.9 tonnes of RDS after further drying by traders); (3) = (1) × (2). (4) = (5) + (6) + (7) + (8) + (9). (5): Cost of consolidating seaweed (USD12/tonne of semi-dry seaweed). (6) Cost of transportation to the trading centre (USD20/tonne of semi-dry seaweed). (7) Collector and trader fees equal to 5 percent of the farmgate value of semi-dry seaweed. (8) Cost of baling dry seaweed for export (USD25/tonne of RDS). (9): Transportation cost for exporting to southern China (USD30/tonne). (10) = (3) + (4).
Source: Based on information and assumptions in Neish (2013).

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[7] The analysis in Table 4 is slightly different from Neish (2013, Table 3) in some aspects. First, instead of treating the "shrinkage" due to further drying as a separate cost item, the analysis here includes it as part of the cost of semi-dry seaweed paid to farmers. Second, the analysis here also includes the cost for export shipment. Third, the analysis considers only two scenarios (low and high prices); the high farmgate price is assumed to be twice as much as the low price in order to facilitate discussion.

[8] As indicated in Table 4, the share is 17.6 and 11.6 percent for the case of low and high farmgate prices, respectively. As some trade costs (e.g. insurance) are not accounted for, these numbers should be treated as indicative only.

- Conversely, given that other factors remain the same, if the overseas processors wanted to reduce the cost of RDS from USD1 257/tonne to USD674/tonne (a 46 percent decline), the farmgate price of semi-dry seaweed would need to drop by half from USD1 000 to USD500.
- Suppose an increase in fuel price doubles the cost of transportation (including the cost of transport to market [USD13] and that of export shipment [USD30]); and the shock be shouldered entirely by seaweed farmers, who tend to be price-takers, then the farmgate price would need to go down from USD500 to USD461 (a decline by 7.7 percent).

The production cost of carrageenan includes the cost of RDS and the processing cost. An example of the cost of SRC produced in Indonesia is presented in Table 5. The results indicate that, generally speaking, RDS is the main component of the production cost of SRC in Indonesia;[9] the share of processing cost is only 36 percent in the case of a low seaweed price and 23 percent in the case of a high price.

- Given that other factors remain the same, if the price of farmgate seaweed doubled from USD500/tonne to USD1 000/tonne, the cost of SRC produced in Indonesia would rise by 56 percent from USD4 196/tonne to USD6 529/tonne. The 56 percent reflects the shares of farmgate seaweed and collector and trader fees in the cost of SRC (53 and 2.6 percent, respectively), which are under the influence of the farmgate price.

In addition to the production cost, the value of carrageenan products when reaching end users may also reflect the expenses on research and development (R&D), formulation, marketing, etc. Specific information on these aspects is lacking, but industrial experts have pointed out that tailor-making carrageenan products to suit the needs of end users tends to be a high-value-added business (Panlibuton, Porse and Nadela, 2007; Bixler and Porse, 2011).

Generally speaking, the global seaweed-carrageenan value chains have changed from a highly integrated structure in the 1970s to a much more diverse, market-oriented structure in the 2000s (Bixler and Porse, 2011; Neish, 2013). The advent of SRC in the mid-1980s and its increasing popularity (especially after food-grade SRC was accepted by western markets) are deemed a key factor driving the transformation. The less demanding (in terms of capital and technical aspects) SRC processing technology

TABLE 5
An example of the estimated cost of SRC exported by Indonesia

Item No.	Cost items for one tonne of SRC	Low farmgate price for semi-dry seaweed (USD500/tonne)		High farmgate price for semi-dry seaweed (USD1 000/tonne)	
		Value	% of the cost of SRC	Value	% of the cost of SRC
(1)	**Cost of RDS (USD)**	**2 696**	**64.2**	**5 029**	**77.0**
(2)	- Cost of farmgate seaweed (USD)	2 222	53.0	4 444	68.1
(3)	- Collector and trader fees	111	2.6	222	3.4
(4)	- Other trading cost	362	8.6	362	5.5
(5)	**Cost of processing (USD)**	**1 500**	**35.8**	**1 500**	**23.0**
(6)	**Cost of SRC (USD/tonne)**	**4 196**	**100.0**	**6 529**	**100.0**

Notes: (1) Take the cost of exported RDS (Item 10 in Table 4) as a proxy of the cost of RDS for local processors; multiply it by four (assuming 25 percent of gum yield; i.e. 4 tonnes of RDS needed to produce 1 tonne of SRC). (2) Item (3) in Table 4 multiplied by four. (3) Item (8) in Table 4 multiplied by four. (4) = (1) – (2) – (3). (5) Assume that the processing cost for one tonne of SRC is USD1 500 (Neish, 2013). (6) = (1) + (5).
Source: Based on information and assumptions in Neish (2013).

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[9] The indicative numbers in Table 5 may underestimate the share of RDS in the cost of SRC, which could be increased because of costly local shipping, quantity and/or quality losses during trading, local taxation, and rent-seeking activities (Neish, 2013).

allowed many small carrageenan processors to enter the business and disrupt the traditional direct and stable relationships between seaweed farmers and a few dominant carrageenan processors (Neish, 2013). Other factors, such as the rapid expansion of carrageenan seaweed cultivation in Indonesia and the fast-growing carrageenan industry in China, also contributed to the loss of cohesion in the seaweed-carrageenan value chains. With more and more newcomers joining both ends of the value chains, direct and stable business relationships between farmers and processors have been gradually replaced by a market mechanism dictated by price and mediated through traders (sometimes multiple layers of them). Under this "market governance" structure (Neish, 2013), the industry has become more competitive yet volatile. The sudden and large demand shock from China in 2008 caused severe price fluctuations that destabilized the industry to the extent that some experts called it a "seaweed crisis" (Neish, 2008a, 2013).

Given time, the competitive market mechanism is expected to help the industry gradually regain its order through consolidation and/or integration. However, the process can be facilitated by more proactive actions, such as promoting collective actions of farmers through farmers organizations and providing more reliable and timely market intelligence to reduce premature harvest, speculation and/or other irrational behaviour (Neish, 2013).

3. ECONOMIC PERFORMANCE OF CARRAGEENAN SEAWEED FARMING

The economic performance of seaweed farming is determined by its economic costs and benefits. The main economic costs include capital, material inputs and labour. The economic benefits can be measured by the revenue and cash flow generated by seaweed production. Profit is an indicator of the net benefit, which measures trade-offs between benefits and costs. A synthesis of the technical and economic performance of 23 cases of *Kappaphycus* farming examined in the six case studies (Table 6) is provided overleaf.

3.1 Investment and capital cost

The physical capital needed for carrageenan seaweed farming usually includes farming systems, vessels, shelters, drying facilities, and miscellaneous equipment or tools.

Farming system

A variety of farming systems have been used in carrageenan seaweed farming (Neish, 2008b; Hayashi *et al.*, 2010). The most widely used are "off-bottom" and "floating" systems. In both systems, cultivars (or propagules) are tied to (polypropylene) lines as the substrate. Off-bottom systems are usually used in near-shore, shallow waters with the substrate placed near the sea floor. Floating systems are usually used in deeper waters with the substrate floating near the sea surface.

Off-bottom is the traditional system widely used in carrageenan seaweed farming. A typical off-bottom system hangs cultivation lines between stakes pegged to the ocean floor. Off-bottom systems located at near-shore farming sites could be constructed and managed by family labour (also women). However, an off-bottom system may face high risks of fish grazing and rope breaking and, hence, need more-intensive plot maintenance (Krishnan and Narayanakumar, 2013).

Near-shore areas are limited and subject to the competition of other sectors (e.g. tourism and urban development). In the United Republic of Tanzania, suitable farming sites for off-bottom systems have largely been utilized (Msuya, 2013). In India, near-shore water quality has been threatened by industrial and urban effluent (Krishnan and Narayanakumar, 2013).

A floating system uses ropes, floats, weights and other materials (e.g. bamboo) to build a floating structure to suspend cultivation lines. Floating systems expand seaweed farming to deeper waters that provide more abundant farming sites.

TABLE 6
Cases of Kappaphycus farming in the six case-study countries

Case No.	Country	Notes	Farming system	Cultivation line (km)	Farm area (ha)	Annual production (tonne/year)	Source
1	India	Two scenarios of a representative farm	Floating raft (4 cycles/year)	54	1.00	72	Krishnan & Narayanakumar (2013, Tables 5, 6 & 7)
2	India		Floating raft (6 cycles/year)	54	1.00	108	
3	Indonesia, South Sulawesi	Average of surveyed farms in different regions.	Floating raft	10.8	0.99	5.9	Neish (2013, Table 5)
4	Indonesia, Bali		Off-bottom (short-stake)	5.3	0.11	6.6	
5	Indonesia, Nusa Tenggara Timur		Floating raft	3.4	0.50	5.7	
6	Indonesia, South Central Sulawesi		Off-bottom (long-stake)	2.7	0.36	3.1	
7	Indonesia	A representative small-scale nuclear family farm	Floating raft	6	–	6.6	Neish (2013, Tables 7, 8, 9, 10 & 11)
8	Indonesia	A representative large-scale leader farm	Floating raft	30	–	33	
9	Mexico	Two scenarios of a hypothetical off-bottom farm	Off-bottom (50 g seed)	–	1.00	27	Robledo, Gasca-Leyva & Fraga (2013, Tables 1, 2 & 3)
10	Mexico		Off-bottom (100 g seed)	–	1.00	54	
11	Mexico	Two scenarios of a hypothetical floating raft farm	Floating raft (50 g seed)	–	1.00	27	
12	Mexico		Floating raft (100 g seed)	–	1.00	54	
13	Philippines, Zamboanga	Six representative farms using different farming systems and/or in different locations	Off-bottom (FOB)	1.8	–	2.143	Hurtado (2013, Tables 4, 5 & 6)
14	Philippines, Tawi-Tawi		Off-bottom (FOB)	1.62	–	0.9	
15	Philippines, Palawan		Floating line (HLL)	2.7	–	8.57	
16	Philippines, Tawi-Tawi		Floating line (HLL)	1.8	–	2.75	
17	Philippines, Zamboanga		Floating raft (MRLL)	–	0.05	2.85	
18	Philippines, Zamboanga		Floating line (SW)	–	0.27	8.5	
19	United Republic of Tanzania	Two representative farms using different farming systems	Off-bottom	0.3	–	0.662	Msuya (2013, Tables 1, 2, 3, 4 & 5)
20	United Republic of Tanzania		Floating line	0.324	–	0.806	
21	Solomon Islands	Three representative farms based on field survey	Off-bottom	4	–	17.4	Kronen (2013, Table 2)
22	Solomon Islands		Off-bottom	4	–	21.7	
23	Solomon Islands		Off-bottom	2.4	–	9.2	

Floating raft systems are widely used in carrageenan seaweed farming countries such as India (Krishnan and Narayanakumar, 2013), Indonesia (Neish, 2013), Mexico (Robledo, Gasca-Leyva and Fraga, 2013) and the Philippines (Hurtado, 2013). Floating rafts can be used as drying racks; they can be moved to another location to avoid fish grazing or even removed from the water during bad weather conditions (Krishnan and Narayanakumar, 2013). The use of floating raft systems in the United Republic of Tanzania has been constrained by the low durability of rafts as well as a lack of materials (bamboo) needed for raft construction (Msuya *et al.*, 2007).

Floating lines, such as the hanging long-line (HLL) system used in the Philippines (Hurtado, 2013) and the deep-water floating line system used in the United Republic of Tanzania (Msuya, 2013), are other popular floating systems. In the United Republic of Tanzania, a floating line system was deemed more "forest friendly" than an off-bottom system because it does not need to use wood stakes (Msuya, 2013).

Unlike an off-bottom system, a floating system is more technically demanding to construct and/or install and, hence, may entail hired labour. Sophisticated floating systems such as the multiple raft long line (MRLL) and spider web (SW) usually require professionals to install them (Hurtado, 2013).

Off-bottom systems are the most common in Indonesia, the Philippines and the United Republic of Tanzania, whereas in India, bamboo raft culture accounts for almost all of cultivation (Krishnan and Narayanakumar, 2013). However, there may be differences within countries. In Indonesia, farmers generally use off-bottom horizontal "short-stake" systems or small bamboo rafts in Bali; and horizontal long-stake systems in South-central Sulawesi (Neish, 2013). In the Philippines, the off-bottom technique is widespread, but some regions use hanging long-lines while others prefer floating or submerged rafts (Hurtado, 2013).

Technical efficiency in utilizing ocean area

In Indonesia, the short-stake off-bottom system used in Bali had an average of 48 km of cultivation line in one hectare of farming area, which was much higher than the long-stake off-bottom system and the floating raft system used in other places of the country (Figure 7, Case 4 vs Cases 3, 5 and 6). The floating raft system used in India also had high efficiency (54 km/ha) in utilization of ocean area (Figure 7, Cases 1 and 2).

Productivity of a farming system

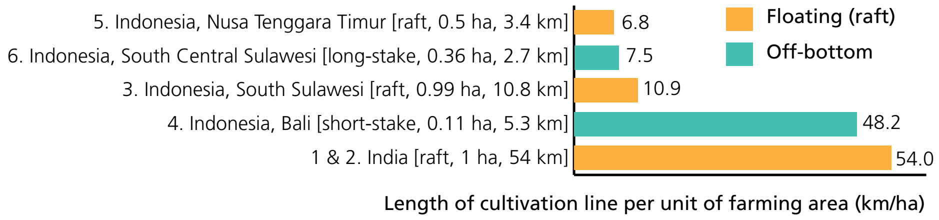
Figure 8 illustrates the productivity of farming systems in terms of dried seaweed production per unit of cultivation line. The evidence indicates that:

- The productivity of an off-bottom system varied widely from the low end for the fixed-off-bottom (FOB) system in the Philippines (Cases 14 and 13) as well as the short-stake and long-stake systems in Indonesia (Cases 6 and 4) to the high end for the off-bottom systems in Solomon Islands (Cases 22, 21 and 23). Even for the same country, the productivity of the FOB system in Zamboanga, the Philippines (Case 13) was twice as high as that in Tawi-Tawi (Case 14).
- From a global perspective, the floating raft systems locate at the lower end of the productivity spectrum in Figure 8. However, the raft system in Nusa Tenggara Timur (NTT), Indonesia (Case 5) had a higher productivity (in terms of tonnes per kilometre) than the other systems used in Indonesia.
- The floating line systems (Cases 15, 20 and 16) locate at the higher end of the productivity spectrum in Figure 8. The productivity of the HLL system used in Tawi-Tawi, the Philippines (Case 16) was almost three times as high as that of the FOB system in the same area.

Figure 9 illustrates the productivity of farming systems in terms of dried seaweed production per unit of farm area. The evidence indicates that:

FIGURE 7

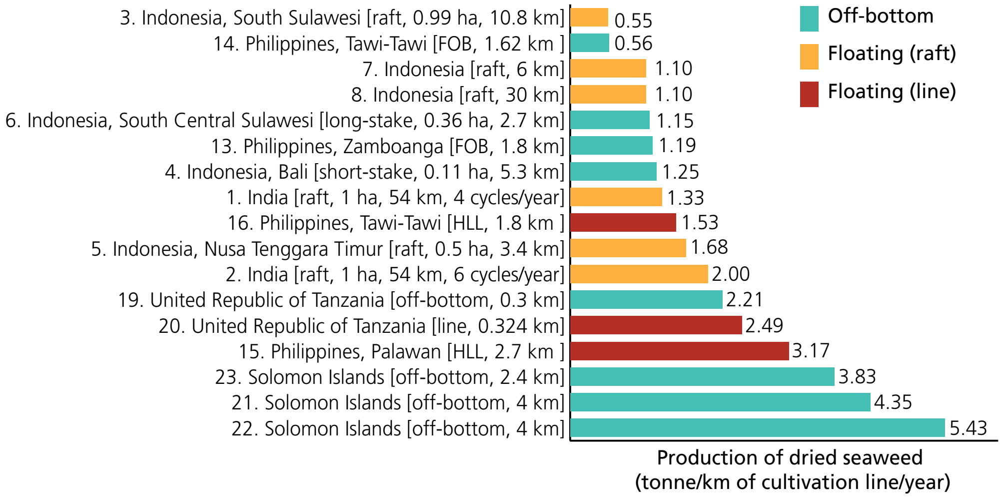
Technical efficiency in utilizing ocean area: evidence from India and Indonesia



Notes: "km" measures the total length of the cultivation lines of a farming system; "ha" gauges the farm area.
Source: Calculated, based on cases listed in Table 6.

FIGURE 8

Productivity of different farming systems (in terms of the length of cultivation line)



Notes: "km" measures the total length of the cultivation lines of a farming system; "ha" gauges the farm area.
Source: Calculated, based on cases listed in Table 6.

- The productivity of an off-bottom system varies from the 9 tonnes/ha for the long-stake system used in South Central Sulawesi, Indonesia (Case 6) to 60 tonne/ha for the short-stake system used in Bali (Case 4).
- The productivity of a raft system varies widely from 6 tonne/ha for the raft system used in South Sulawesi, Indonesia (Case 3) to 108 tonne/ha for that used in India (Cases 1 and 2).

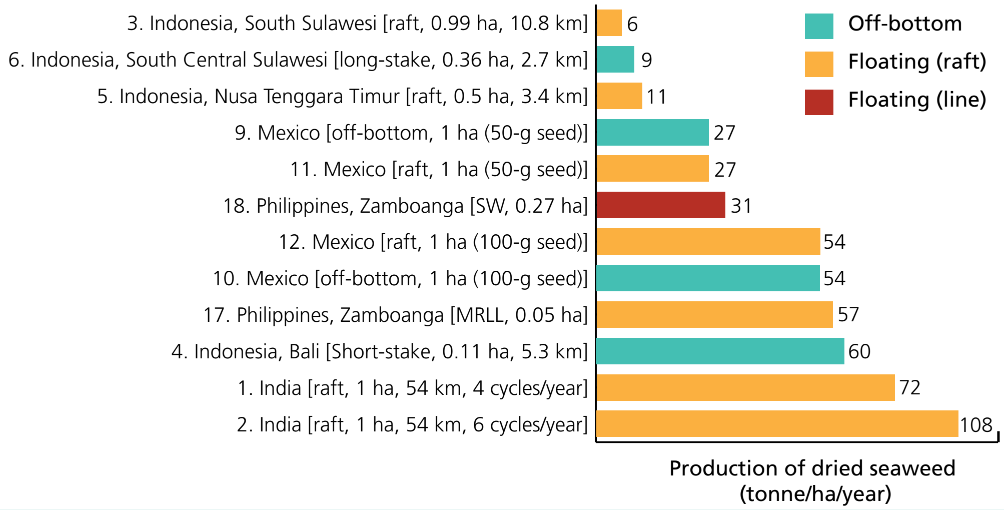
In summary, the evidence does not indicate distinct patterns in the productivity of different farming systems, neither in terms of production per unit of cultivation line (Figure 8) nor in terms of production per unit of farming area (Figure 9). This should not be surprising because a direct comparison of the productivity of two farming systems may reflect mostly the differences in their farm locations (e.g. temperature, weather condition, and water quality) that affect the growth rate of seaweed and the number of growing cycles (as two primary factors determining the productivity). Evidence from the literature (summarized in Hayashi *et al.*, 2010) indicates that the growth rate of *Kappaphycus* varies widely across different farming systems and/or the same system used at different locations (ranging from 0.2 to 10.86 percent per day).

Investment for building a farming system

Off-bottom is generally deemed the least-capital-intensive farming system. Evidence provided by the case studies confirms this perception. As indicated in Figure 10, the FOB

FIGURE 9

Productivity of different farming systems (in terms of the size of farming area)



Notes: "km" measures the total length of the cultivation lines of a farming system; "ha" gauges the farm area.
Source: Calculated, based on cases listed in Table 6.

system in Tawi-Tawi, the Philippines (Case 14) cost about one-third as much as the HLL system in the same area (Case 16). The same holds for the FOB system in the United Republic of Tanzania (Case 19) as compared with the floating line system (Case 20).

However, it should be noted that the low investment cost of an off-bottom system may not necessarily be the result of its economical use of materials but could be thanks to the availability of "free" materials such as wood stakes gathered from nearby mangroves (Kronen, 2013; Msuya, 2013). In the Philippines, a FOB system relying on free wood stakes cost only USD28.4/km of cultivation line (Case 14), while one relying on purchased wood stakes cost USD115/km (Case 13).

Amortized capital cost of a farming system

It should also be noted that because of its longer lifespan, the relatively high initial investment for a farming system does not necessarily result in a high annual amortized capital cost (i.e. depreciation). For example, while building the floating line system in the United Republic of Tanzania (Figure 10, Case 20) cost almost three times as much as building the off-bottom system in the country (Figure 10, Case 19), the amortized annual capital costs of the two systems (Figure 11, Cases 20 and 19) were almost the same because of the longer lifespan of the floating line system (2.7 years) compared with the off-bottom system (1 year).

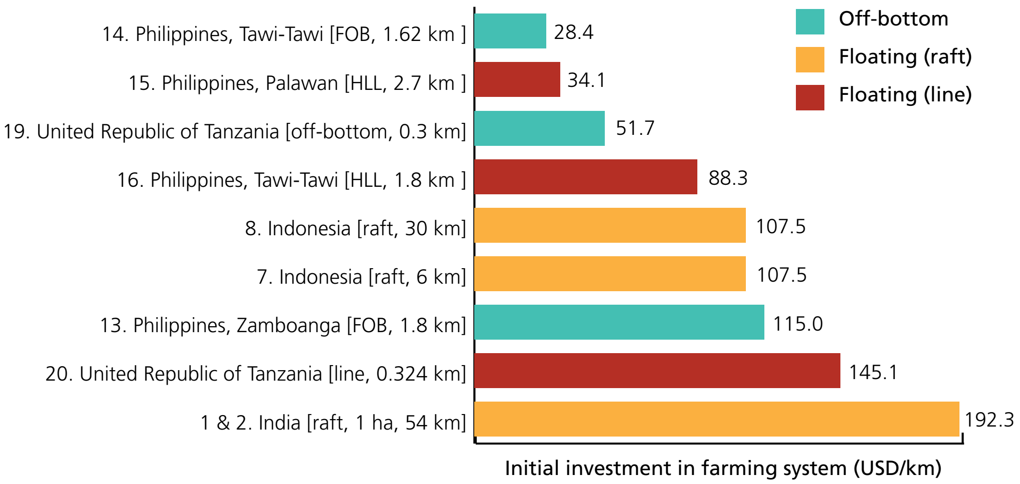
In Figure 11, the amortized capital costs of some off-bottom systems (Cases 13 and 19) and floating systems (Cases 1, 2, 7, 8 and 20) were not very different, in the range of USD50–60 km. The FOB system in Tawi-Tawi, the Philippines (Figure 11, Case 14) and the HLL system in Palawan, the Philippines (Figure 11, Case 15) had relatively low amortized capital costs because of the free materials they used (free wood stakes for the former and free floats for the latter).

Economic efficiency of a farming system

The economic efficiency (i.e. cost-effectiveness) of a farming system can be measured by its amortized capital cost per unit of seaweed production. The indicator measures the trade-offs between the productivity of a farming system (Figure 8) and its amortized capital cost (Figure 11). A farming system with a relatively low amortized capital cost per unit of production has a relatively high economic efficiency.

FIGURE 10

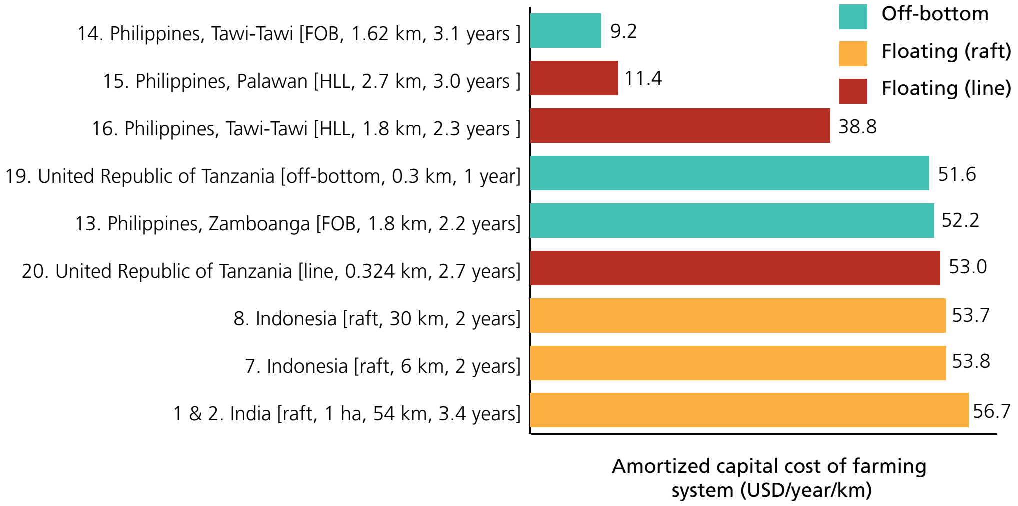
Initial investments for different farming systems



Notes: "km" measures the total length of the cultivation lines of a farming system; "ha" gauges the farm area.
Source: Calculated, based on cases listed in Table 6.

FIGURE 11

Amortized capital costs of different farming systems



Notes: "km" measures the total length of the cultivation lines of a farming system; "years" measures the lifespan of a farming system.
Source: Calculated, based on cases listed in Table 6.

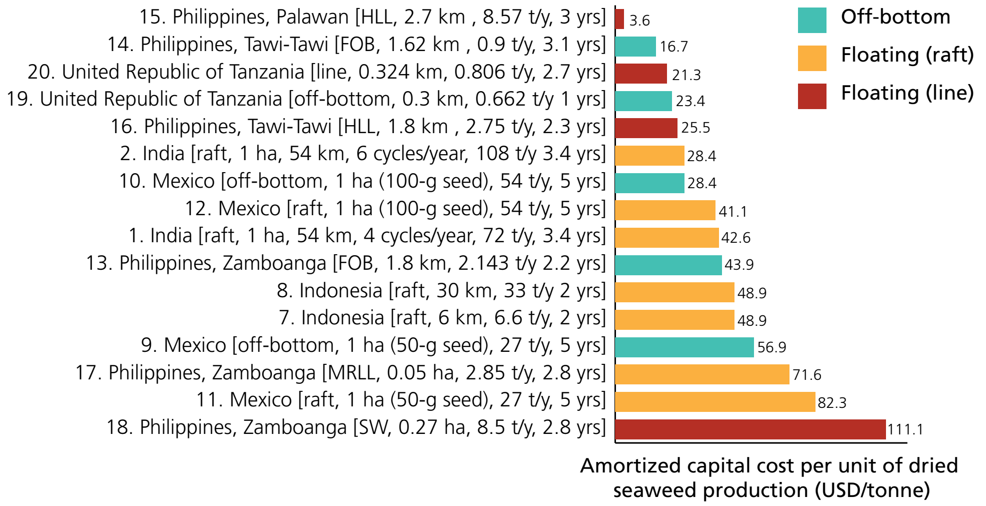
In Figure 12, the floating line (HLL) system in Palawan, the Philippines (Case 15) is the most economically efficient farming system, costing only USD3.6 for one tonne of dried seaweed production. The high efficiency of Case 15 was thanks to its relatively high productivity (Figure 8) and low amortized capital cost (Figure 11).

Most of the floating line systems in Figure 12 (Cases 15, 20 and 16) have a relatively high economic efficiency. The SW system in Zamboanga, the Philippines (Case 18) is the only exception. Indeed, this expensive farming system (Hurtado, 2013) has the highest amortized capital cost per unit of seaweed production (USD111.1/tonne) in Figure 12.

In Figure 12, most of the off-bottom systems have a relatively high economic efficiency. Case 9 has the lowest efficiency among the off-bottom systems in Figure 12

FIGURE 12

Economic efficiency of farming systems: evidence from the case studies



Notes: "km" measures the total length of the cultivation lines of a farming system; "ha" gauges the area of a farm site; "t/y = tonnes/year" measures the farm's annual production of dried seaweed; "years" measures the lifespan of a farming system.
Source: Calculated, based on cases listed in Table 6.

because its use of small cuttings (50 g) resulted in relatively low productivity (Robledo, Gasca-Leyva and Fraga, 2013). Although Case 13 has a relatively low efficiency among the off-bottom systems, its efficiency is nevertheless higher than the floating raft system (Case 17) and the floating line system (Case 18) in the same area.

In Figure 12, most of the floating raft systems have a relatively low economic efficiency. Case 2 is an exception. Despite its relatively high amortized capital cost (Figure 11), the floating raft system in India operating six cycles per year (Case 2) achieved a relatively high economic efficiency because of its relatively high productivity (Figure 8).

Supposing the price of dried seaweed were USD1 000, then the amortized capital costs of the farming systems in Figure 12 would be between 0.36 and 11.1 percent of their farm revenues.

Vessel

Vessels (boats or canoes) are needed for seeding, crop management, harvesting, and transport of cargos (cultivars, harvested fresh seaweeds, dried seaweed, etc.). Non-motorized vessels are usually used in small-scale operations and they are convenient for tasks that do not require transporting heavy cargos (e.g. routine crop management). Motorized vessels are needed for large operations and special tasks such as transporting harvested fresh seaweeds (especially for large harvests and/or long-distance transportation).

An off-bottom farm located in shallow waters may only allow the use of non-motorized boats (Hurtado, 2013), which tends to make the transport of large crops inconvenient and costly. A floating device was developed in the United Republic of Tanzania to help farmers transport harvested fresh seaweeds to drying sites (Msuya, 2013).

Depending on the size, materials and cost of labour used in boat construction, the costs of non-motorized boats used in carrageenan seaweed farming vary (Table 7). The evidence from the Indonesia and Philippines cases indicates that motorized vessels tend to be more expensive than non-motorized vessels (Table 7).

Many smallholder farmers own at least non-motorized vessels (e.g. dug-out canoes) to facilitate routine crop management. Farmers with large operations may own

TABLE 7
Examples of investment in vessels used in carrageenan seaweed farming

Countries	Capital investment in vessels (USD per boat)		Source
	Non-motorized	Motorized	
Indonesia	150	500	Neish (2013, Table 7)
Philippines	120	526	Hurtado (2013, Table 4)
United Republic of Tanzania	343[1]	–	Msuya (2013)

[1] A boat (worth TZS430 000) owned by a 58-member cooperative.

motorized boats that tend to be used also for activities other than seaweed farming (Hurtado, 2013; Neish, 2013).

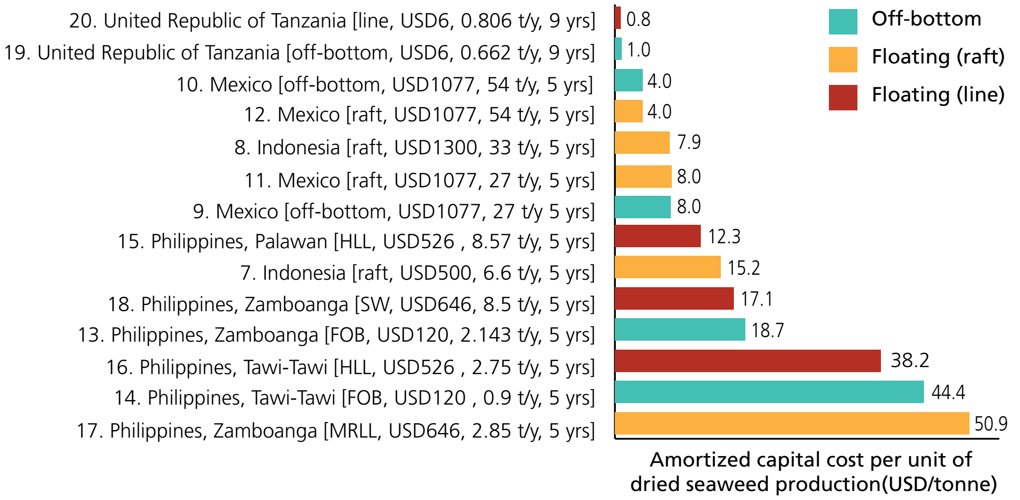
In Solomon Islands, owning a motorized boat was usually uneconomical for smallholder farmers. Although some of them may be able to borrow motorized boats for use during harvest seasons, establishment of community-owned motorized boat transport was requested by seaweed farmers in the country to help them deliver dried seaweeds to selling points (Kronen, 2013). In the United Republic of Tanzania, 58 members of a cooperative contributed an average of USD5.9 (TZS7 414) each to build a community-owned vessel (Msuya, 2013).

Evidence provided by the cases in Table 6 reveals no clear patterns on the economic efficiency of vessels used in different farming systems and/or different countries (Figure 13).

- The two cases in the United Republic of Tanzania (Cases 20 and 19) had the highest economic efficiency in vessels because of their low investment (USD6) in the community-owned vessels.
- Given the same investment, the economic efficiency of vessels would be higher for a larger production scale (e.g. Case 9 vs 10; Case 11 vs 12; Case 15 vs 16; and Case 17 vs 18).

It should be noted that as vessels may be used for activities other than seaweed farming, the amortized capital cost for vessels in Figure 13 may be overestimated. On the other hand, besides amortized capital cost, the cost of vessels may be reflected

FIGURE 13
Economic efficiency of vessels: evidence from the case studies



Notes: "USD" measures the farm's investment in vessels. "t/y = tonnes/year" measures the farm's annual production of dried seaweed; "years" measures the lifespan of vessels.
Source: Calculated, based on cases listed in Table 6.

elsewhere such as the expense for hiring a boat or the price discount given to traders that shoulder the task of transportation.

Other physical capital investments

In addition to the farming system and vessels, other physical capital investments in carrageenan seaweed farming include shelters for activities such as attaching cultivars to lines (Neish, 2013), drying apparatus (Neish, 2013; Msuya, 2013), and miscellaneous equipment and tools (e.g. knives, diving masks, mats, ladders, baskets, tarps, sacks, and plastic bags). These items are often used in activities other than seaweed farming (Neish, 2013).

Only a few cases in Table 6 provide information on other capital investments (Figure 14). In the Mexico cases, the economic efficiency of other physical capital investments was increased by the use of larger cultivar cuttings (Case 9 vs 10, and Case 11 vs 12). The Indonesia cases do not indicate apparent difference in the economic efficiency for a small operation (Case 7) and a large one (Case 8).

Financial capital

In India, farmers in a self-help group (SHG), especially one in a contract farming relationship with the processor, may be able to obtain bank loans to finance their initial investments in seaweed farming (Krishnan and Narayanakumar, 2013).

In the India cases in Table 6, seaweed farmers paid USD12 (Case 1) or USD8 (Case 2) of loan interest for one tonne of dried seaweed production, which was 6.0 and 4.4 percent of the total production cost, respectively (Krishnan and Narayanakumar, 2013, Table 6).

3.2 Operating expenses

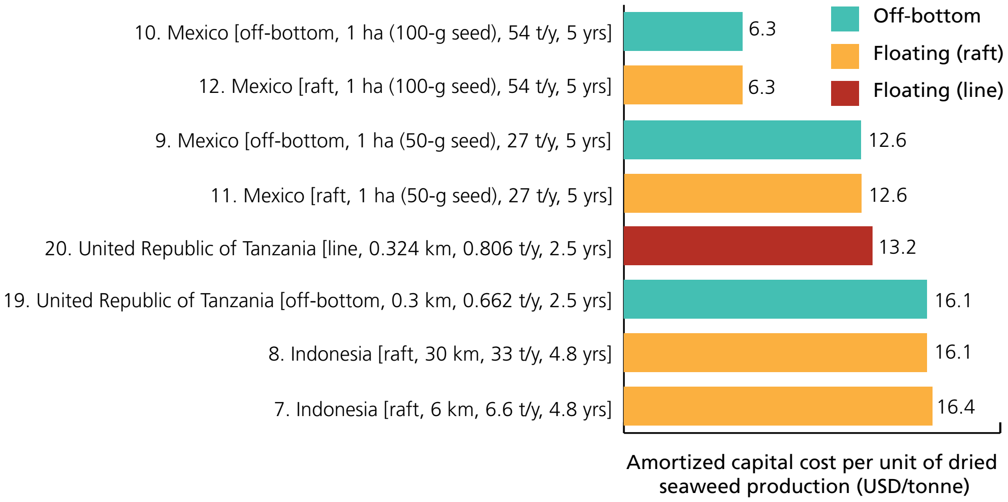
Seed

Species

Because of the popularity of kappa carrageenan, *K. alvarezii* (cottonii) has become the main carrageenan seaweed species under cultivation in most carrageenan seaweed farming countries. *K. alvarezii* generally has a relatively high growth rate compared

FIGURE 14

Economic efficiency of other physical capital investments: evidence from the case studies



Notes: Other capital investments include shelters, drying apparatus and/or miscellaneous equipment and tools. “km” measures the total length of the cultivation lines of a farming system; “ha” gauges the area of a farm site;; “t/y =tonnes/year” measures the farm’s annual production of dried seaweed; “years” measures the average lifespan of other capital investments.
Source: Calculated, based on cases listed in Table 6.

with other species (Neish, 2008b). "Ice-ice" disease is a major constraint on *K. alvarezii* farming.

K. striatum (commercially called sacol) is another *Kappaphycus* strain under substantial cultivation in the Philippines (Hurtado, 2013). *K. striatum* was introduced in the United Republic of Tanzania as a substitute for *K. alvarezii* but did not perform well in trials (Msuya, 2013).

Because of stagnant demand for iota carrageenan, *E. denticulatum* (spinosum) is a less popular and cheaper species compared with cottonii. The price gap has grown recently as the price of cottonii has risen significantly because of strong demand (Bixler and Porse, 2011). However, spinosum has remained the main cultivated species in the United Republic of Tanzania because of the failure of cottonii cultivation owing to disease and other environment factors (Msuya, 2013).

Seed cost

Cultivar represents a major cost in carrageenan seaweed farming. In the hypothetical cases of Mexico (Case 9–12 in Table 6), which are assumed to be completely commercial operations, the cost of purchased cultivars accounted for more than 30 percent of the total production cost of seaweed farming (Robledo, Gasca-Leyva and Fraga, 2013, Table 3). In India, the cost of seed materials was 27 percent of the imputed value of seaweed production from a 3 m × 3 m raft (Krishnan and Narayanakumar, 2013).[10]

However, carrageenan seaweed farmers usually purchase cultivars only in the initial production cycles and use part of the harvest in one cycle as cultivars for the next. In Indonesia, a farmer usually starts with stocking one kilometre of line; hence, it takes 2–3 years for the farm to develop to full size through self-propagation of cultivars (Neish, 2013). In the United Republic of Tanzania, a farmer may reserve about one-tenth of the fresh seaweed harvest as cultivars (Msuya, 2013).

Under such self-propagation schemes, there are different ways to account for the initial cash expenditure on cultivars. One method, which is adopted in the cases of Indonesia (Cases 7 and 8 in Table 6) and the Philippines (Cases 13–18), treats the expenditure as a cost in the period when it is incurred. Under this method, seaweed farming would appear to have relatively low (even negative) profits in early periods. Such low profits are not an indicator of underperformance but reflect an accounting discrepancy caused by not accounting self-propagated cultivars as part of farm revenue. The discrepancy would be offset or mitigated in later periods by not accounting self-propagated cultivars as seed cost.

Another method, which is adopted in the cases of India (Cases 1 and 2), treats expenditures on purchased cultivars as an initial investment. This method helps correct the problem of seemingly low profits in initial periods.

Under certain situations, farmers may not need to spend money on cultivars. For example, in the cases of Solomon Islands (Cases 21–23), cultivars were provided by the government as a public assistance to seaweed farming development (Kronen, 2013). In the cases of the United Republic of Tanzania (Cases 19 and 20), cultivars were provided by the exporters. However, these seed materials were not actually free because farmers needed to sell their seaweed produce at discounted prices to cover the materials provided by exporters (Msuya, 2013).

Labour

Carrageenan seaweed farming entails intensive labour inputs in various activities, such as attaching cultivars to cultivation lines, placing cultivation lines in sea (i.e. planting),

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[10] The seed materials cost INR105 (Krishnan and Narayanakumar, 2013, Table 3). The sales revenue of dried seaweed was INR320. The fresh seaweed harvest reserved as seed materials (18 percent of the total fresh seaweed production) would have earned an additional INR69 in revenue had it been sold as dried seaweed. Thus, the share of seed materials in the imputed value of seaweed production is equal to 105/(320 + 69) = 27 percent.

routine maintenance and caring, harvesting, drying, packing, transporting, maintenance of farming system or vessels, etc. Many of these activities often rely on family labour. Hired labour (wage workers or hired services) is often needed for laborious tasks (e.g. attaching cultivars and harvesting) and/or relatively large operations.

Family labour

In the cases of the United Republic of Tanzania (Cases 19 and 20), family labour were used in most of the activities except transportation. The total family labour input needed to produce one tonne of dried seaweed was 85 person-days for Case 19 and 80 person-days for Case 20. About 53 percent of the labour input was used for seed preparation and planting (including attaching cultivars to lines and placing cultivation lines in sea), 28 percent for maintenance and care (including farm management and separation of entangled tie-ties and ropes), and 19 percent for harvesting and packing (Msuya, 2013).[11]The imputed value of the family labour was USD0.24 per person-day (Msuya, 2013),[12] which implies about USD23 of imputed labour cost for one tonne of dried seaweed production in Case 19 and USD19/tonne in Case 20.

In the cases of Solomon Islands, the imputed cost of family labour was USD3.76 per person-day (USD0.47 per person-hour; eight working hours per day). For Case 22, which was a relatively large operation relying substantially on hired labour, the total imputed value of family labour used was USD80 per tonne of dried seaweed production and 20 percent of its farm revenue. For the relatively smaller operations relying more on family labour, the total imputed value of family labour was USD138 per tonne (35 percent of the farm revenue) for Case 21 and USD238 per tonne (61 percent of the farm revenue) for Case 2 (Kronen, 2013, Table 2).

Hired labour

Figure 15 presents the operating expenses of hired labour in the cases of the Philippines, Indonesia, Mexico and the United Republic of Tanzania.[13] The evidence indicates that the cases of the Philippines had relatively small expenses for hired labour. For small operations in relatively shallow waters (Cases 13, 14 and 16), hired labour was used only in seed preparation and planting. For relatively large operations in deeper waters (Cases 17 and 18), hired labour was also used in harvest and drying (Hurtado, 2013).

In Indonesia, seaweed farmers usually paid hired workers on a piecework basis for labour-intensive tasks such as attaching cultivars to lines (costing USD6 per kilometre of lines in South Sulawesi), placing lines in sea, harvesting, and drying (Neish, 2013). For the small nuclear farm (Case 7), workers were hired only for attaching cultivars to lines (Figure 15). For the large leader farm (Case 8), one-third of the labour expense was used for hiring labour to attach cuttings; the rest was evenly distributed among hired labour for placing cultivation lines to sea, harvesting and drying (Neish, 2013, Table 10).

In the Mexico cases, expenses on hired labour accounted for over 30 percent of the total production cost (Robledo, Gasca-Leyva and Fraga, 2013, Table 3). Most of the expenses were used to pay the wages of full-time employees who were responsible for routine maintenance and care. As the wages were fixed regardless of the production scale, the use of larger cultivar cuttings (Cases 10 and 12) would lower the labour expense needed for the same amount of production (Figure 15). Extra workers were also hired on a piecework basis to help conduct the task of seeding, harvesting and drying (Robledo, Gasca-Leyva and Fraga, 2013).

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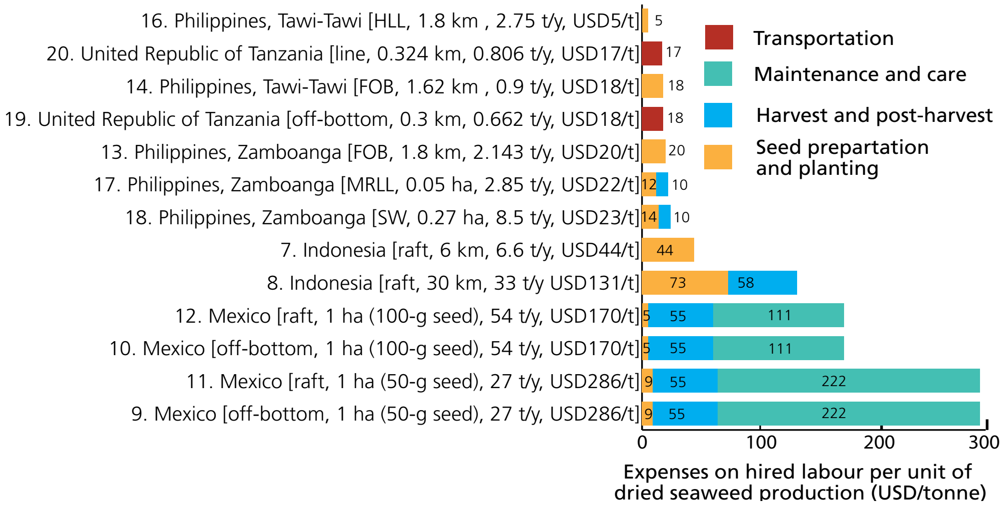
[11] Calculated based on information provided in Msuya (2013, Table 4).

[12] TZS37.5 per hour (USD1 = TZS1 255). Assuming eight working hours per day.

[13] The cases of India and Solomon Islands do not provide specific information on the cost of labour.

FIGURE 15

Expenses on hired labour or service: evidence from the case studies



Notes: "km" measures the total length of the cultivation lines of a farming system; "ha" gauges the area of a farm site; "t/y = tonnes/year" measures the farm's annual production of dried seaweed; "USD/tonne" measures the total expense on hired labour or service; "Seed preparation and planting" includes attaching cultivars to lines and placing cultivation lines to sea; "Harvest and post-harvest treatments" includes removing cultivation lines from sea, drying and/or packing; "Maintenance and care" indicates farm management activities (seeding, routine caring, harvesting, drying, etc.) conducted by full-time employees.
Source: Calculated, based on cases listed in Table 6.

In the cases of the United Republic of Tanzania (Cases 19 and 20), it cost USD16 to hire service (labour plus the vehicle) for transporting fresh seaweed harvest that could generate one tonne of dried seaweed; and it cost about USD1.2 to hire service for transporting one tonne of dried seaweed from the drying place to market (Msuya, 2013, Table 4).

Fuel and boat maintenance

In Case 22, the off-bottom farm in Solomon Islands incurred USD52 (per tonne of dried seaweed production) in fuels and maintenance expenses on a motorized boat used for daily operations; the expense was equal to 13.4 percent of its farm revenue (Figure 16). For Case 23, where only fuel expense for a borrowed boat was accounted for, the ratio was 6.3 percent of farm revenue. The evidence confirms the claims of surveyed farmers that high transportation cost represented a major constraint on carrageenan seaweed farming in the country (Kronen, 2013).

The fuel and boat maintenance cost was equal to more than 10 percent of the farm revenue for the relatively small operations in the Philippines (Cases 16 and 17) but only about or less than 5 percent for relatively large operations (Cases 15 and 18). Similar economies of scale also exist in Indonesia (Case 7 vs 8) and Solomon Islands (Case 21 vs 23).

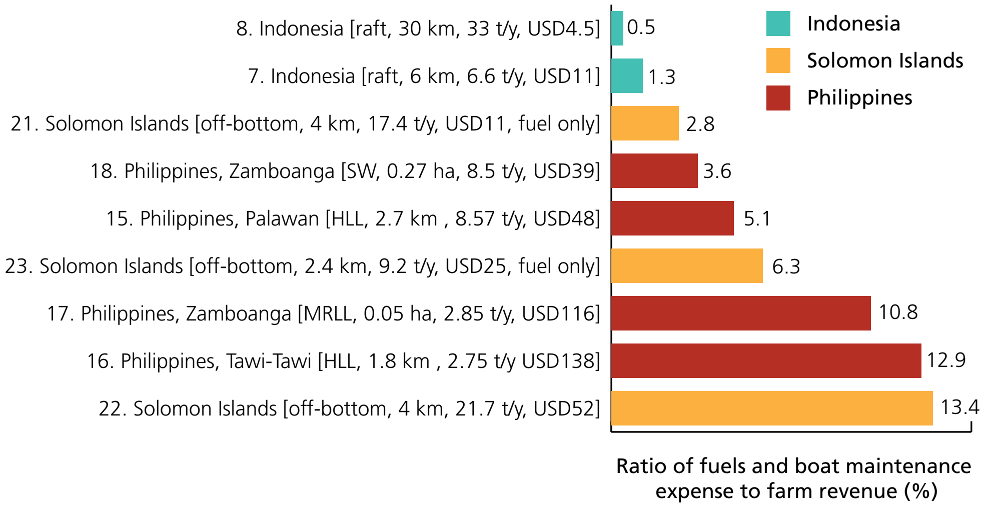
Total operating expense

Figure 17 summarizes the total (cash) operating expenses in the cases in Table 6. For the reason explained above, the total operating expense does not include the expenditure on initial seed materials for cases using self-propagated cultivars (i.e. all cases except those of Mexico). Total operating expense also does not include the imputed value of family labour, which does not incur cash expenditure.

The total cash operating expenses in Figure 17 vary from less than USD50 (per tonne of dried seaweed production) for simple off-bottom or floating line systems in the United Republic of Tanzania (Cases 20 and 19) and Solomon Islands (Cases 21 and 23) to more than USD400 per tonne for the sophisticated farming systems in the

FIGURE 16

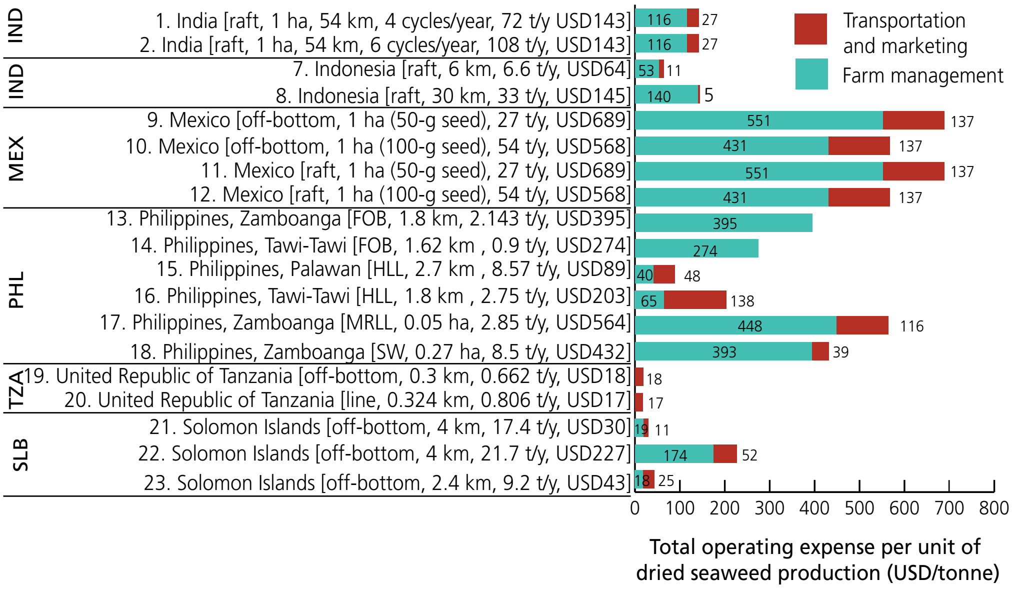
Expenses on fuel and boat maintenance: evidence from the case studies



Notes: "km" measures the total length of the cultivation lines of a farming system; "ha" gauges the area of a farm site; "t/y = tonnes/year" measures the farm's annual production of dried seaweed; "USD" measures the fuel and boat maintenance expense per tonne of dried seaweed production. Farm revenues of the cases in Indonesia calculated based on the price of dried seaweed being USD850.
Source: Calculated, based on cases listed in Table 6.

FIGURE 17

Total cash operating expense (excluding seed materials) in carrageenan seaweed farming: evidence from the case studies



Notes: "km" measures the total length of the cultivation lines of a farming system; "ha" gauges the area of a farm site; "t/y = tonnes/year" measures the farm's annual production of dried seaweed; "USD" measures total cash operating expense; "Farm management" includes expenses on hired labour (excluding hired service for transportation) and maintenance of farming system as well as seed materials for the cases of Mexico; "Transportation and marketing" includes expense on fuel and boat maintenance, hired service for transportation (the United Republic of Tanzania), and marketing (Mexico).
Source: Calculated, based on cases listed in Table 6.

Philippines (Cases 17 and 18) and the completely commercial operations in Mexico (Cases 9–12).

3.3 Revenue and profit

Revenue

Farm revenue is determined by production and price. Besides the growth rate of cultivar, seaweed production also depends on the number of cycles or days available for farming during a year. In the Indonesia cases (Cases 7 and 8), seaweed farming was conducted all throughout the year in eight cycles (45 days per cycle and 360 days in total). For the United Republic of Tanzania, the floating-line case (Case 20) also had eight 45-day cycles, while the off-bottom system (Case 19) lost one crop because of disease and, hence, had only seven 45-day cycles (315 days in total) of successful production.

The number of cycles or days is lower for countries in higher-latitude zones with winters being too cold to conduct carrageenan seaweed farming. For the India cases, the first-year operation (Case 1) had only four 45-day cycles (180 days in total), while the operations afterwards (Case 2) had six cycles (270 days in total). The Mexico cases had four 60-day cycles (240 days in total), while those of the Philippines had five 45-day cycles (225 days in total).

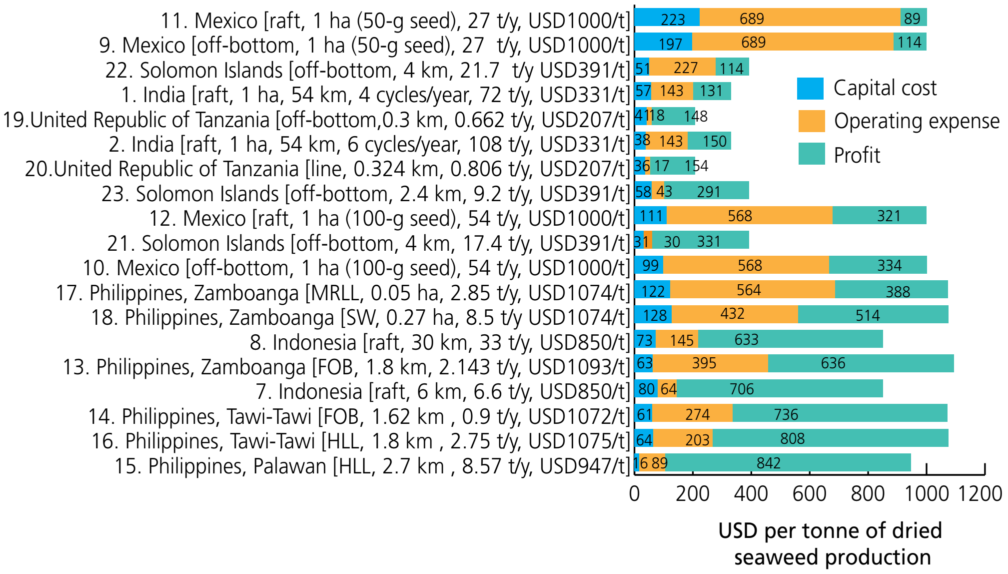
Given production, farm revenue is determined by the price of dried seaweed, which essentially measures revenue per unit of production. The prices of dried seaweed are between USD947/tonne and USD1 093/tonne in the Philippines cases, USD1 000/tonne for Mexico, USD391/tonne for Solomon Islands, USD331/tonne for India, and USD207/tonne for the United Republic of Tanzania. Three price scenarios (USD500/tonne, USD850/tonne and USD1 200/tonne) were examined in the Indonesia cases; the average (i.e. USD850/tonne) is used in the analysis here. Low prices may partly reflect the poor quality of seaweeds and/or price discounts given to trader that provide farming materials and/or extension services (Msuya, 2013).

Profit

Profit is equal to farm revenue minus total cost (capital cost plus operating expense). Figure 18 summarizes the profits of 19 cases in Table 6. The operating expenses in Figure 18 do not include expenditures on initial seed materials by farms relying on self-

FIGURE 18

Profitability of carrageenan seaweed farming: evidence from the case studies



Notes: "km" measures the total length of the cultivation lines of a farming system; "ha" gauges the area of a farm site; "t/y = tonnes/year" measures the farm's annual production of dried seaweed; "USD/tonne" indicates the price of dried seaweed (assuming USD850 as the price of dried seaweed in the Indonesia cases); "Capital cost" includes amortized annual capital cost (i.e. depreciation) of physical investments and financial cost (interests and insurance premiums); "Operating expense" indicates total cash operating expense excluding seed materials (except for the cases for Mexico) and family labour (same as Figure 17); "Profit" is equal to price minus capital cost and operating expense (discrepancy due to rounding); i.e., Price = Profit + Capital cost + Operating expense.

Source: Calculated, based on cases listed in Table 6.

propagated cultivars (the Mexico cases being the only exceptions) or the imputed value of family labour; thus, the profits here may not be exactly the same as those calculated in the case study papers.

All the 19 cases in Figure 18 had positive profits, ranging from USD89 per tonne of dried seaweed (Case 11) to USD842/tonne (Case 15). Points to note are:

- Seaweed price as a key factor affecting profit. Because of low seaweed prices, the cases from India, Solomon Islands and the United Republic of Tanzania had relatively low profits even though they had low capital costs and operating expenses. Indeed, given the price in the United Republic of Tanzania (USD207/tonne), which is the lowest among all the cases, only 8 cases out of the total of 19 cases would be able to break even (Cases 19 and 20 of the United Republic of Tanzania; Cases 21 and 23 of Solomon Islands; Case 15 of the Philippines; Case 7 of Indonesia; and Cases 1 and 2 of India).
- High break-even price for sophisticated and/or commercialized farms. In the Philippines, the seaweed price would need to be at least USD686/tonne to cover the total cost of the sophisticated MRLL system (Case 17); whereas the break-even price is USD560/tonne for the SW system (Case 18). In Mexico, the break-even prices for the commercial off-bottom farm (Case 10, 100 g seed) and floating raft farm (Case 12, 100 g seed) are USD666/tonne and USD679/tonne, respectively.
- More cost-effective floating line systems. In the Philippines, the two HLL systems (Cases 15 and 16) had lower total costs (per tonne of dried seaweed production) than other farming systems in the country; the two cases had the highest profits among all the cases. Being sophisticated systems used in deeper waters, the floating line system (SW) in Case 18 had a lower total cost than the floating raft system (MRLL) in Case 17. In the United Republic of Tanzania, the floating line system (Case 20) had a lower total cost than the off-bottom system (Case 19).
- Economies of scale in stocking density. The use of small cultivar cuttings (50 g) in Cases 9 and 11 result in underutilization of the production capacity and, hence, a relatively high capital cost as well as operating expense per unit of production. The two cases have the lowest profits among all the cases.
- Small vs large operations. In Indonesia, the small nuclear farm that used relatively less hired labour (Figure 15) had a slightly higher capital cost but a much lower operating expense than the large leader farm. In Solomon Islands, the large farm (Case 21) had a lower capital cost as well as operating expense than the smaller farm (Case 23).

Profit per unit of family labour

Profit that does not exclude the value of family labour can measure the "net income" of family labour. In Solomon Islands, the net income of family labour was USD1.14/hour, USD0.68/hour and USD0.58 for cases 21, 22 and 23, respectively; all the three were higher than the average hourly wage of unskilled labour (USD0.47/hour) in Honiara, the capital of the country (Kronen, 2013).

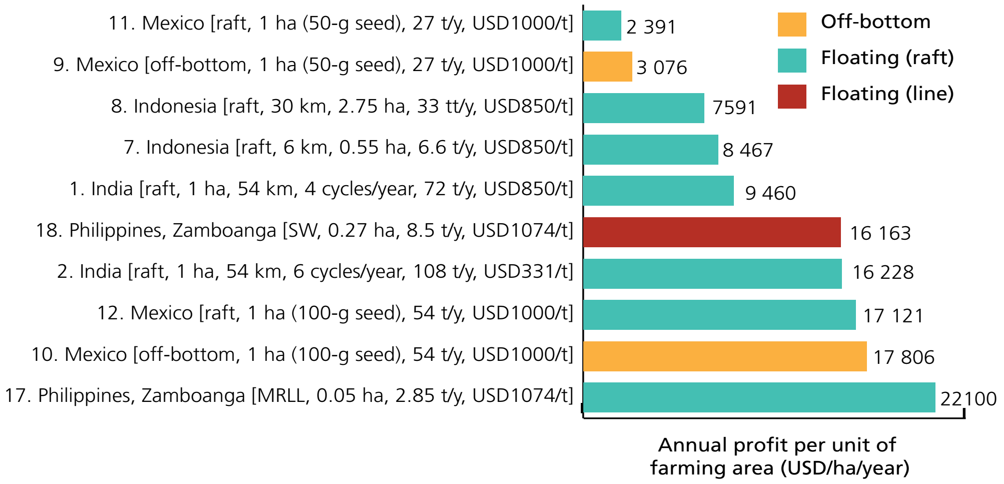
In the United Republic of Tanzania, the net income for family labour was USD0.19/hour for the off-bottom system (Case 19) and USD0.24/hour for the floating line system (Case 20); both were higher than the hourly wage paid to hired labour for tying cultivars (USD0.03/hour) (Msuya, 2013). Further discussion on the low income of seaweed farming in the United Republic of Tanzania is given in Section 4.1.

Profit per unit of farming area

Figure 19 presents profit per unit of farming area for some cases in Table 6; the measure provides an indicator of the profitability of land use in carrageenan seaweed farming. In Figure 19, the land profitability ranges from less than USD2 500/ha to more than USD20 000/ha.

FIGURE 19

Profitability of land use in carrageenan seaweed farming: evidence from the case studies



Notes: "km" measures the total length of the cultivation lines of a farming system; "ha" gauges the area of a farm site; the farming area of Cases 7 and 8 (farms located in South Sulawesi, Indonesia) estimated based on the technical efficiency parameter for Case 3 in Figure 7; "t/y = tonnes/year" measures the farm's annual production of dried seaweed; "USD/tonne" indicates the price of dried seaweed (Figure 18).
Source: Calculated, based on cases listed in Table 6.

The land profitability in Figure 19 does not accurately measure the economic return to land use in seaweed farming, especially when the value of other productive factors (e.g. family labour) is not excluded from the profit. However, the indicator could provide useful information for spatial planning to determine the allocation of coastal areas among different economic activities.

Profit margin

As indicated in Figure 20, the profit margin (i.e. the ratio of profit to farm revenue) of most of the 19 cases exceeded 50 percent. This implies that even if their farm revenues were reduced by half (e.g. by a 50 percent drop in price or loss of half of the crops) or their total costs doubled, these farms would still break even.[14]

Generally speaking, a case with lower profit tends to have a lower profit margin. However, the cases from the United Republic of Tanzania (Cases 19 and 20) and Cases 21 and 23 of Solomon Islands had relatively low profits but relatively high profit margins.

3.4 Cash flow and pay-back period

Figure 21 summarizes the cash flow situations of 17 cases in Table 6.[15] The evidence indicates that most cases had positive net cash inflow in the first year, which means that these farms were able to recover their initial investments within one year.

Case 22 of Solomon Islands and Case 17 of the Philippines had net cash outflows (i.e. negative net cash inflows) in the first year because of their investments in motorized boats. However, their positive net cash inflows in the second year were more than enough to cover the outflows in the first year, which implies that the pay-back periods of their investment were less than two years.

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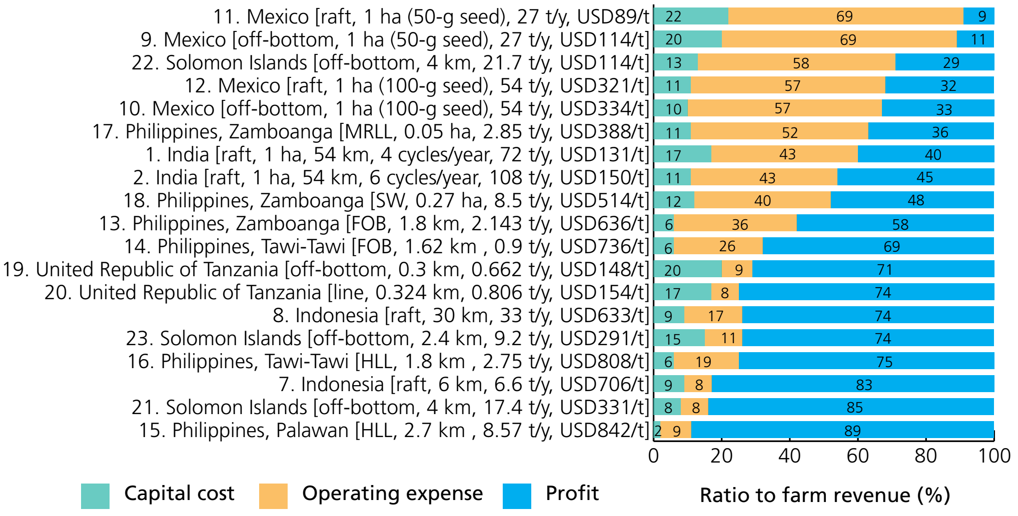
[14] Usually, break-even means a profit greater than zero. The zero-profit threshold is used here for simplicity, but it should be noted that for cases where profit does not exclude family labour, break-even profit should at least be enough to cover the opportunity cost of family labour.

[15] Cases 1 and 2 from India are combined because they represent the first- and second-year situations of the same farm. The initial investments in drying facilities and boats in the Solomon Islands cases are estimated from the amortized annual capital cost based on the assumption of a five-year lifespan.

FIGURE 20

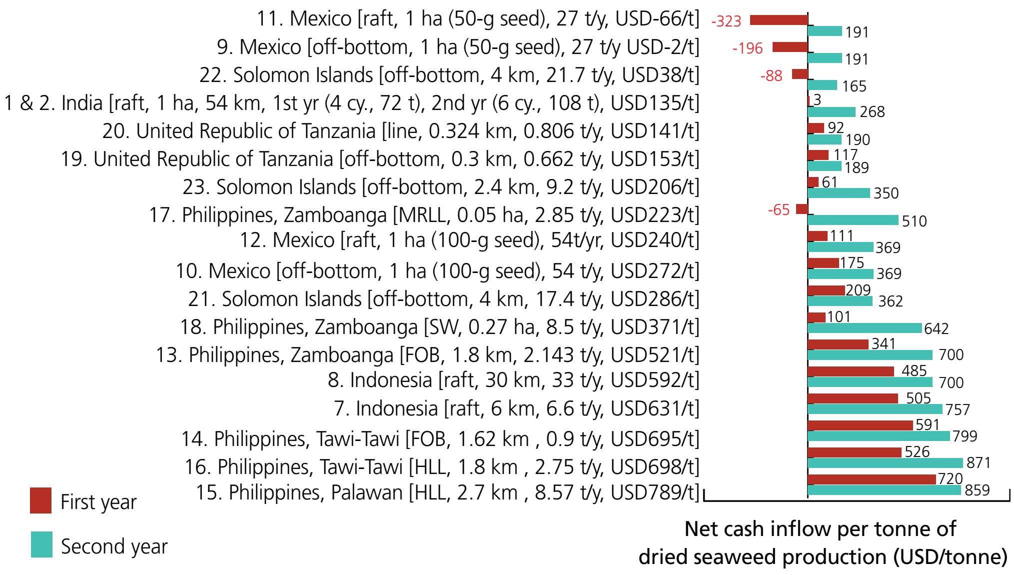
Cost structure and profit margin in carrageenan seaweed farming: evidence from the case studies



Notes: "km" measures the total length of the cultivation lines of a farming system; "ha" gauges the area of a farm site; "t/y = tonnes/year" measures the farm's annual production of dried seaweed; "USD/tonne" indicates the value of profit (Figure 18); "Capital cost" includes amortized annual capital cost (i.e. depreciation) of physical investments and financial cost (interest and insurance premiums); "Operating expense" indicates total cash operating expense excluding seed materials and family labour (same as Figure 17); "Profit" is equal to price minus capital cost and operating expense (discrepancy due to rounding).
Source: Calculated, based on cases listed in Table 6.

FIGURE 21

Cash flows in carrageenan seaweed farming: evidence from the case studies



Notes: "km" measures the total length of the cultivation lines of a farming system; "ha" gauges the area of a farm site; "tonnes/year" measures the farm's annual production of dried seaweed; "USD/tonne" indicates average annual net cash inflow in the first two years.
Source: Calculated, based on cases listed in Table 6.

The off-bottom and floating raft farms in Mexico would be able to recover their initial investments within one year with 100 g seeds (Cases 10 and 12, respectively) but not with 50 g seeds (Cases 9 and 11, respectively). Indeed, it would take more than two years for the understocking off-bottom and floating raft farms to recover their investment (Robledo, Gasca-Leyva and Fraga, 2013).

3.5 Summary

The economic analysis above indicates that, where properly conducted, carrageenan seaweed farming can be highly profitable and viable. Relying on free or low-cost materials and own labour, family farms in the Philippines (Cases 15 and 16) could earn more than USD800 per year from one tonne of dried seaweed worth about USD1 000 (Figure 18). Even with the cost of materials and labour fully accounted for, commercial farms in Mexico (Cases 10 and 12) could still earn more than USD300/tonne per year (Figure 18).

Physical capital is usually not a major cost in carrageenan seaweed farming. In Figure 20, the annual capital cost was less than 10 percent of farm revenue in many cases and less than 20 percent for almost all the cases. Most of the farms were able to recover their initial investments within one year (Figure 21).

Materials are usually not a major expense. No fertilizer is needed. Seed materials are usually self-propagated. However, fuel and boat maintenance could cost more than 10 percent of farm revenue (Figure 16).

Labour is a primary cost in carrageenan seaweed farming. Routine maintenance and care usually relies entirely on family labour, whereas hired labour is used to help with labour-intensive activities such as attaching cultivars, planting and harvesting. Farms relying mostly on family labour had high profit margins (more than 50 percent), whereas the profit margin for the two commercial operations in Mexico (Cases 10 and 12) had profit margins of more than 30 percent (Figure 20).

4. SOCIAL PERFORMANCE OF CARRAGEENAN SEAWEED FARMING

4.1 Employment and livelihoods

Contribution to employment

Seaweed farming is a labour-intensive activity. In a family operation, spouses, children and immediate family members work together on the farm. They prepare and seed the lines, harvest the crop, and provide maintenance. Labour is shared particularly during busy periods such as harvesting and drying. Tying the seed is the most labour-intensive activity and non-family labour may be used. Seaweed farmers in Indonesia and the Philippines tend to cluster together into villages with the same language and divide themselves into work groups. Similarly, in India, where seaweed cultivation is organized by SHGs, family labour may be supplemented by members from the same community.

In the United Republic of Tanzania, where small family farms dominate, one production cycle required about 66.5 hours of labour input and generated about 100 kg of dried seaweed (Msuya, 2013, Table 4). This implies that annual production of one tonne of dried seaweed entailed 84 person-days (assuming 8 working hours per day) of labour input and could generate 0.28 full-time equivalent jobs per year (assuming 300 working days per year). In this situation, an industry with 10 000 tonnes of annual production of dried seaweed[16] could generate 2 800 full-time equivalent jobs. As seaweed farming tends to be a part-time occupation, the number of people participating in seaweed farming tends to be much more than the number of full-time equivalent jobs.

In India, a survey of 437 households in Mandapam and Rameshwaram indicates that, on average, two family members participated in seaweed farming for 153 days per year. With an estimated 1 000 households engaged in seaweed farming in the two districts, there could be a total of 2 000 family farmers devoting half their annual working time to seaweed farming (Krishnan and Narayanakumar, 2013).

Besides farming activities, the carrageenan seaweed industry also generates jobs along the seaweed-carrageenan value chains. In the Philippines, it was estimated that

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[16] The United Republic of Tanzania produced 110 000 tonnes of fresh seaweed in 2009, which could generate about 10 000 tonnes of dried seaweed.

the seaweed industry involved 100 000–150 000 seaweed farmers, 30 000–50 000 local consolidators, and more than 20 000 small traders. The seaweed-carrageenan industry also created a large number of supportive and administrative jobs in laboratories and government offices (Hurtado, 2013).

Hired labour for laborious activities such as tying the seed tends to be low-paid jobs, especially with the availability of abundant unskilled labour. For example, in the United Republic of Tanzania, the hourly wage of seed-tying job was USD0.03/hour, much lower than the net income of family labour (USD0.19/hour and USD0.24/hour for Cases 19 and 20, respectively) (Msuya, 2013; see also discussion in Section 3.3 of this synthesis paper). In the Philippines, hired workers (mostly female) were paid USD3.00–4.25/day to remove impurities from seaweed (Hurtado, 2013).

Contribution to livelihoods

Most carrageenan seaweed farmers are coastal inhabitants without many assets. They share equipment, such as boats or drying facilities, with other families. They may be too impoverished to afford basic items such as lines, in which case they must accept them from intermediaries, as in India and the United Republic of Tanzania, in return for selling the harvest at a pre-arranged price.

Carrageenan seaweed farming requires only minimal capital and material inputs; its farming techniques are relatively easy to grasp; and it can be conducted most of the year in short production cycles. These characteristics, among others, make seaweed farming a favourable source of livelihoods in coastal communities. As a livelihood activity, it could offer relatively high and continuous incomes to families. There have been fluctuations in incomes depending on monsoon activity in certain countries but annual average incomes from seaweed culture are very attractive to coastal families in some places. Being a labour-intensive activity, it may preclude many other activities and become a substitute for, rather than a complement to, other livelihood possibilities (e.g. in the Philippines). However, its attraction is evident from the case studies and interviews with coastal families – most of whom have benefited from seaweed farming.

In Indonesia, carrageenan seaweed farming provided a stable annual average income USD5 000 to a typical nuclear family farm; for a leader farm, the annual income could be more than USD15 000. Many surveyed farmers indicated that seaweed farming contributed to most of their incomes but only cost half or even less of their time (Neish, 2013; Zamroni and Yamao, 2011).

In the Philippines, seaweed culture could offer higher returns than alternative activities. Surveyed farmers reported that income from seaweed farming had increased their annual income by USD632–1 895, helping them to meet daily needs, including children's education. Cultivation periods are a maximum of 66 days compared with several months for growing abalone, finfish or lobster, or agriculture crops, such as rice, corn and cassava (Hurtado, 2013).

In Solomon Islands, surveyed farmers deemed seaweed farming a diversified livelihood source that improved their incomes and living standards and made them more food secured. Although traditional fisheries could be more lucrative on an hourly basis, seaweed farming tends to be a more stable livelihood source, providing more income to households on an annual basis than fisheries, which relies on depleting natural resources (Kronen, 2013).

In India, seaweed farming brought higher and more stable incomes to surveyed farmers than did fishing. Income from seaweed farming has not only increased the physical consumption and wealth of farmers but also facilitated their participation in social functions such as social and religious travelling (Krishnan and Narayanakumar, 2013).

In the United Republic of Tanzania, many surveyed farmers (especially able and hard-working ones) deemed seaweed farming a beneficial economic activity that not only helped them finance their daily expenses but also enabled them to improve housing and purchase assets. However, some farmers deemed the price of *E. denticulatum* too low to be worth the effort (Msuya, 2013). Further discussion on this issue is given below.

Low income from seaweed farming

Contrary to generally positive views in the literature on the contribution of seaweed farming to livelihoods, which are generally supported by the six case studies, a recent study (Fröcklin *et al.*, 2012) brought attention to some less encouraging aspects of seaweed farming in Zanzibar (the United Republic of Tanzania). One major issue is the negative health impacts of seaweed farming, which is discussed below. Another issue is the extremely low income from seaweed farming. The median daily income of seaweed farmers ranged from USD0.5/day to USD2.4/day in seven villages being surveyed (20 farmers interviewed in each village) (Fröcklin *et al*., 2012).

As indicated in Section 3.3, with a seaweed price of USD207/tonne, the net income of family labour was USD0.19/hour and USD0.24/hour for the cases from the United Republic of Tanzania (Cases 19 and 20, respectively). Assuming eight working hours per day, the daily incomes would be USD1.5/day and USD1.9/day, which are close to the upper bound of the range of the survey results in Fröcklin *et al.* (2012).

The low seaweed price is the main cause of low income from seaweed farming in the United Republic of Tanzania, but it may not be the only reason. Given the seaweed price in the cases from Solomon Islands (USD391/tonne), the net income of seaweed farmers in the cases from the United Republic of Tanzania would have been USD0.43/hour (Case 19) and USD0.53/hour (Case 20), which would still be lower than in the Solomon Islands cases (USD0.58–1.14/hour). This indicates that a relatively low productivity could be another factor behind low income from seaweed farming in the United Republic of Tanzania.

The daily incomes of USD1.5/day and USD1.9/day are calculated based on the assumption of 8 working hours per day. However, in reality, the seaweed farmers in Cases 19 and 20 worked only part-time in a 45-day production cycle and earned about USD15 net income in total. This implies a net income of USD0.3 per day, which is far from being able to keep the farmers' livelihoods above the international poverty line of USD1.25/day currently used by the World Bank. Thus, it is not surprising that most of the surveyed farmers in Fröcklin *et al.* (2012) need to rely on additional income-generating activities.

Occupational health hazards

The survey in Fröcklin *et al.* (2012) indicated poorer health conditions for female seaweed farmers in Zanzibar (the United Republic of Tanzania) compared with women involved in other activities. Prominent health problems of the surveyed seaweed farmers include: general fatigue, musculoskeletal pains, hunger, eye soreness, asthma and other respiratory related problems, injuries by sharp shells or hazardous organisms (e.g. sea urchins), skin problems and allergies. These health problems could be caused by poor working conditions such as intensive work for long hours, handling of heavy objects, and/or exposure to sun, wind, seawater and/or toxic vapours (Fröcklin *et al.* 2012, Table 1).

Further studies should be conducted to verify whether similar health issues exist in other seaweed farming countries.

4.2 Gender

One aspect that appears from the case studies is the role of women in seaweed farming. In off-bottom cultivation in shallow water, women can tie and harvest the crop by themselves. In deeper water, where boats are necessary for raft or floating line techniques, women tend to have a smaller role, but do assist with harvesting.

In India, women were the first and primary adopters of seaweed farming, which offered them an income within a safe environment (Ramachandran, 2012; Krishnan and Narayanakumar, 2013). Most SHGs are composed exclusively of women, and they have been a major source of financing and training.

Another country where women have taken the initiative is the United Republic of Tanzania. Women are leaders both in seaweed cultivation and in adding value (Msuya, 2013). A women's group in northern Zanzibar (the United Republic of Tanzania) has started producing seaweed flour, doubling its net profits and adding new products (Msuya, 2011).

Even where women are not the majority in seaweed farming, they play an important role. One survey of seaweed farmers in Sulawesi (Indonesia) found that although all the farmers were men, the help of wives and daughters in tying the seed was crucial (Zamroni and Yamao, 2011).

In Solomon Islands, most of the work is done by men, but the role of women is critical. Women are particularly active in planting and harvesting; they also usually receive the cash. The men interviewed ranked women's involvement in the activity among the most important benefits of seaweed farming. However, women seaweed farmers often need to be away from family and hence had problems taking care of their children (Kronen, 2013). The Solomon Islands case study also showed that children were heavily involved in the seaweed family business. Children's participation in seaweed farming often resulted in their leaving school at an early stage, forgoing access to secondary and perhaps tertiary education (Kronen, 2013).

In the Philippines, women as well as children played significant roles in seaweed farming, especially in seeding and post-harvest treatments. Women accounted for about 44 percent of the regular seaweed farming labour force and were the main source of casual labour. The involvement of women and children helped reduce the cost of production. Although women were usually confined to lower-paid jobs because of gender stereotyping, the survey in Flores and Zamboanga found no evidence of women and children being exploited or abused (Hurtado, 2013).

Generally speaking, the participation of women in seaweed farming did not result in conflicts in marital relationships. In the Philippines as well as Indonesia, female seaweed farmers had equal power with their husbands in decision-making on household matters. Their role in farming business decision-making was generally consultative but with a spirit of cooperation (Hurtado, 2013; Neish, 2013).

In the study from the United Republic of Tanzania (Msuya, 2013), no serious money–power conflicts between female seaweed farmers and their husbands were observed. Albeit detaching themselves from seaweed farming as a low-paid activity unworthy of the effort required, husbands generally did not discourage their wives from engaging in seaweed farming, except occasionally complaining about the smell of dried seaweed. More supportive husbands helped with laborious tasks such as seed tying, harvesting and transportation.

As discussed above, occupational health hazards have significantly impaired the health conditions of women seaweed farmers in Zanzibar. Even though seaweed farming is not a well-paid livelihood source, many female seaweed farmers in Zanzibar kept working even when pregnant or ill in order to maintain the so-called "livelihood of the last resort" (Fröcklin *et al.*, 2012).

4.3 Other social benefits

In addition to its direct contribution to livelihoods and employment, seaweed farming offers poor coastal communities a number of other social benefits. In Solomon Islands, many surveyed farmers thought that seaweed farming had increased community cohesion through cooperation and improvement of social services such as school and church. Almost 40 percent of the surveyed farmers thought that seaweed farming had improved social networks among seaweed farming households sharing the same interest. While jealousy and petty thefts were mentioned by a few respondents, most surveyed farmers deemed competition among seaweed farmers and households constructive (Kronen, 2013).

Seaweed farmers, like many coastal people, have little formal education, so knowledge transfer is important. In Indonesia, positive social impacts of seaweed farming include access to education and training and improvements in communication (Neish, 2013).

Linked to skills are entrepreneurship and business acumen. In India, many seaweed farmers started out as being hired labour for other farmers first and then used the experience to become members of an SHG. As their operations expand, these seasoned farmers hire other people to help take care of their own plots (Krishnan and Narayanakumar, 2013). In Indonesia and the Philippines, many seaweed collectors or traders were nuclear family farmers first, then became lead farmers, and eventually ventured into the trading business (Gan, 2003, cited in Neish, 2013). In the United Republic of Tanzania, a woman seaweed farmer has succeeded in becoming a wholesaler, selling seaweed to a buyer with a 20 percent margin (Msuya, 2011).

Seaweed farming also benefits communities through multipliers. The direct value chain is often local so that cash income from seaweed culture remains in the community. Indirect and induced effects reflected in such activities as seaweed storage or consumer sales generate incomes that may exceed those generated directly in seaweed culture. The beneficial impact of spin-offs is indicated by new housing and other material assets. If income is spent on tuition, as is often the case, the long-term impacts could be significant.

4.4 Environmental externalities

Carrageenan seaweed farming can have positive effects on the environment because seaweeds could improve the benthic ecosystem, and sequester carbon, thereby offering the potential for carbon credits. Seaweed grown on rafts can also become an attractive haven for fish.

Other positive environmental externalities of seaweed farming include an alleged positive attitude towards conservation of local marine habitats, and anecdotal evidence that overexploitation of the fisheries has been reduced in some countries, because farmers have less time or inclination to fish. In Zanzibar, the United Republic of Tanzania, where low-paying seaweed farming was unattractive to men, there has been little net impact on the fishing effort; whereas the impact has been significant in India (Krishnan and Narayanakumar, 2013), the Philippines (Hurtado, 2013), and Solomon Islands (Kronen, 2013).

As mentioned above, carrageenan seaweeds tend to be an introduced species in many countries. The risk of such introductions is that they can become invasive. Introduced seaweed that do not become viable culture species could turn into an environmental nuisance (Pickering, Skelton and Sulu, 2007). To preclude potential risks in accidental or intentional introductions of alien species in carrageenan seaweed farming, quarantine and protocols are essential. These have been tested in the Pacific, where there has been only one report of cottonii becoming invasive (Sulu *et al.*, 2003).

Other negative environmental impacts of carrageenan seaweed farming include destruction of mangroves for materials (e.g. wooden stakes) used in seaweed farming, and detrimental impacts on the benthic ecosystem by clearing up the sea floor and/or the use of stakes or anchors, pollution and debris from abandoned equipment (e.g. stakes, ropes and floats), among others (Neish, 2008b).

5. GOVERNANCE AND INSTITUTIONS

Governance and institutions are critical to sustainable aquaculture development without irreversible environmental and social damage (Hishamunda *et al.*, 2012).

Poor governance and malfunctioning institutions tend to result in business disruption, environmental destruction, social mistrust and little development of the sector, in spite of positive demand and supply conditions.

5.1 The private sector

Market governance vs relationship governance

The market has become the main governance mechanism in the carrageenan seaweed industry (Neish, 2008a, 2013). Under market governance, the profit-seeking activities of self-interested stakeholders (farmers, trading agents and processors) are coordinated by the price mechanism.

As discussed above, major carrageenan seaweed farming countries (especially Indonesia and the Philippines) have recently experienced volatile market conditions. Fluctuating prices have disrupted proper functioning of the market mechanism and caused destabilizing behaviours such as harvesting crops prematurely, adding impurities to seaweed, and speculating on prices. This may be a short-term disturbance experienced by a rapidly expanding industry that could be corrected gradually through market-driven consolidation and integration. However, it seems that the disorders have induced an anti-market sentiment that favours the replacement of market governance with "relationship governance" by consolidating farmers into farm enterprises (e.g. cooperatives), promoting strategic alliances among them, and establishing direct links between farm enterprises and processors (Neish, 2008a, 2008c).

It is true that the supply chain from farmers to collectors to consolidators to traders to exporters then to processors means a mark-up at each stage and less traceability, but it remains unclear whether the intermediary and other functions of trading agents (discussed in Section 2.4) could be more efficiently internalized by farm enterprises and/or processors. Related issues include the boundaries of seaweed enterprises, the benefits, costs and sustainability of their ownership and governance structure, the governance structure, flexibility and resilience of business alliances among farm enterprises and direct business relationship between farm enterprises and processors. Further study is needed. The development of industrial organization and value chain governance in other aquaculture activities and terrestrial farming could shed light on this subject.

Contract farming

Contract farming has been widely used in carrageenan seaweed farming. In India, seaweed farming started with contract farming offered by a multinational corporation (Krishnan and Narayanakumar, 2013). In Indonesia, 45 percent of the surveyed farmers in Neish (2013) reported that they had contracts with buyers. In the United Republic of Tanzania, many seaweed farmers relied on formal or informal contractual relationships with exporters to sell their seaweed produce (Msuya, 2013).

In a typical contract farming scheme, the contractor usually provides materials (e.g. cultivars) and extension services to growers and commits to purchasing the harvest at predetermined prices. Contracted seaweed farmers are liable to deliver their produce at a satisfactory quality and avoid selling to other buyers.

In the United Republic of Tanzania, seaweed farmers often complained that exporters did not properly compensate their efforts; whereas the exporters argued that the low prices they offered were justified because they provided farming materials and extension services to farmers. The farmers often had to stick to unappealing contracts because they needed the aids provided by exporters, lacked other channels to sell their produce and/or had no alternative livelihood sources. However, they were prone to side-selling to other exporters that could offer higher prices. This caused conflicts between exporters and disruption of farming activities. On the other hand, exporters might also not honour their promises when the market was weak. In sum, it appeared that contract farming did not perform very efficiently in the United Republic of Tanzania; many farmers (especially those on the mainland) were gradually moving away the system (Msuya, 2013).

In India, the contractor (Aquagri) was concerned about farmer satisfaction and set the basic seaweed price based on their efforts. The contractor also used price incentive schemes to keep loyal and high-volume producers from being enticed away by competing companies. In addition, the contractor used other non-price arrangements (e.g. assisting farmers to meet their family and/or social obligations) to strengthen farmers' trust and loyalty. Although the temptation to breach contracts always exists when higher prices are offered, contract farming has become a generally effective mechanism that has facilitated the rapid expansion of seaweed farming in India (Krishnan and Narayanakumar, 2013).

While it is difficult to generalize, there are several factors that may help explain India's more positive experience in contract farming as compared with the United Republic of Tanzania. First, compared with seaweed exporters in the United Republic of Tanzania, the processor contractor in India may have more incentives to maintain stable seaweed supplies in order to avoid disruption of its seaweed processing business. Second, the successful SHG model in India makes contract farming easier to establish and manage. Third, the participation of financial institutions as a credit provider and contract facilitator (Krishnan and Narayanakumar, 2013) provides incentives for farmers to adopt contract farming and an assurance mechanism for the contract to be sustained.

Community-based seaweed farming

The experience in India indicates that the daily-wage corporate model is difficult to maintain for carrageenan seaweed farming because of its special characteristics such as seasonality and uneven distribution of labour requirements within a production cycle (Krishnan and Narayanakumar, 2013). In addition, in most countries, policy-makers are often reluctant to promote "big business" because of concerns over social equity. As a result, carrageenan seaweed farming has been dominated by small-scale (family) farmers.

Small-scale seaweed farming usually lacks economies of scale in both production and marketing (see the analysis in Section 3 for some evidence). Farmers groups or producer associations are a way of overcoming this disadvantage. Farmers groups allow members to share labour, materials and assets. This has been a common practice among nuclear family farms in Indonesia (Neish, 2013). In Solomon Islands, farmers hope to reduce transportation cost through community-based motorized boats (Kronen, 2013). Farmers groups could also perform the tasks of post-harvest treatments and play the roles of trading agents. In the Philippines, many famers associations have attempted to purchase fresh seaweed from member farmers, dry it and then sell it directly to a processor (Hurtado, 2013). In the Indonesia case study (Neish, 2013), 32 percent of the surveyed farmers in Nusa Tenggara Timur (NTT) sold their seaweed produce to cooperatives; all the surveyed farmers in South Central Sulawesi sold theirs to a farmer credit union. In India, one of the main advantages of the SHG model is to foster entrepreneurialism in seaweed farming as an activity with great growth potential (Krishnan and Narayanakumar, 2013).

The experiences of producer associations have not always been successful. In the United Republic of Tanzania, particularly Zanzibar, most farmers were members of cooperatives or other producer associations. Most of these associations were not formed at the initiative of farmers but rather at the behest of donor-funded programmes in order to facilitate training and implementation of aids. Interviews with farmers indicated that cooperatives were more successful in helping farmers receive aids than in enabling them to address various farming or marketing issues (e.g. die-offs from disease, and finding more reliable buyers). A lack of competent leadership was deemed a factor behind the shortcoming (Msuya, 2013). In the Philippines, direct sales arrangements through producer associations were supposed to increase farmers' profits. However, few associations have been able to accomplish their stated objectives, which raises the question of whether community-based seaweed farming is more efficient than individual farmers (Hurtado, 2013).

5.2 The public sector

Legal and policy framework

In the Philippines, under the guidance of the Philippine Fisheries Code of 1998,[17] the Bureau of Fisheries and Aquatic Resources (BFAR) establishes seaweed-related regulations and policies, while local government is responsible for issuing licences for seaweed farming (Hurtado, 2013). A primary legal document on seaweed farming is the Fisheries Administrative Order No. 146: Rules and Regulations Governing the Gathering and Farming of Seaweeds (BFAR, 1983).[18] The Administrative Order specifies issues such as eligibility for and restrictions on seaweed farming, licensing (fees, duration, procedure, etc.), and the rights and obligations of licensed seaweed farmers. The BFAR has also established a National Seaweed Development Program to gather information about the seaweed industry, to undertake research and development, and to facilitate technology transfers to farmers and processors (Ferrer, 2002).

Unlike the Philippines, other case-study countries do not have specific regulations on seaweed farming. In Indonesia, seaweed farming has been regulated as a type of "fish" under the Fisheries Law No. 31/2004.[19] However, seaweed farming in Indonesia has been governed and assisted by multiple government agencies, including the Agency for the Assessment and Application of Technology (BPPT), the Department of Oceans and Fisheries (DKP), the National Ministry of Cooperatives and Small to Medium Enterprises in Indonesia (KUKM), the Regional Body for Planning and Development (BAPPEDA), and the Indonesia Institute of Sciences (LIPI) (Neish, 2013). Decentralized government agencies have been able to manage seaweed farming closely at the village level.

In the United Republic of Tanzania, fisheries resource management has been governed under the National Fisheries Sector Policy and Strategy Statement (1997)[20] and the Fisheries Act (2003).[21] The Act has clauses on the collection/gathering, processing and marketing of aquatic flora (including seaweeds) on the mainland of the United Republic of Tanzania, but none on seaweed cultivation. The Government of the United Republic of Tanzania has been trying to update the Policy and the Act to cover more specifically mariculture and seaweed farming (Msuya, 2013). No licences are needed for seaweed farming in the United Republic of Tanzania. The use of farming areas is comanaged by coastal villagers. Seaweed farming may be conducted by outsiders under the permission of local farmers (Msuya, 2013). Tanzanian government agencies, such as the Aquaculture Department under the Ministry of Livestock Development and Fisheries in Mainland Tanzania and the Department of Fisheries and Marine Resources in Zanzibar, have been promoting seaweed farming through the Seaweed Development Strategic Plan (SDSP) as well as assistance programmers such as the Marine and Coastal Environment Management Project (Msuya, 2013).

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[17] Available at: www.fao.org/fishery/shared/faolextrans.jsp?xp_ISIS_MFN=014403&xp_faoLexLang=E&xp_lang=en

[18] Available at: www.fao.org/fishery/legalframework/nalo_philippines/en

[19] Available at: www.fao.org/fishery/legalframework/nalo_indonesia/en

[20] Available at: www.tzonline.org/pdf/NationalFisheriesSectorPolicyandStrategyStatement.pdf

[21] Available at: http://faolex.fao.org/docs/pdf/tan53024.pdf

In Solomon Islands, the Fisheries Act (1998)[22] gives the minister responsible for the administration of fisheries the power to make regulations related to seaweed farming. The Ministry of Fisheries and Marine Resources (MFMR) has been the main government agency governing aquaculture in the country. In order to ensure the reliability and financial viability of seaweed exporters, private trading companies need to obtain seaweed commercialization licences from the Aquaculture Division (established in 2000) under the MFMR (McHugh, 2006; Tinne, Preston and Tiroba, 2006; Kronen, 2013). The Solomon Islands Aquaculture Development Plan 2009–2014 (MFMR, 2009) established by the MFMR gives high priority to development of seaweed farming in the country. Seaweed farming development is also supported by other government agencies, such as Ministry of Agriculture and Ministry of Lands regarding issues related to land use, tenure and survey, and the Department of Environment for environmental assessments (Kronen, 2013).

In India, coastal aquaculture activities in saline or brackish water are regulated under the Coastal Aquaculture Authority Act (2005).[23] The Act focuses on shrimp farming, with detailed technical guidelines on shrimp farming specified in the corresponding Coastal Aquaculture Authority Rules (2005).[24] Cultivation of aquatic plants is not specifically referred to in the Act or the Rules. However, with the Coastal Regulation Zone (CRZ) extended to include 12 nautical miles of territorial waters in the recently issued Coastal Regulation Zone Notification (6 January 2011),[25] more formal regulations over seaweed farming in India could be put in place in the future. The National Fisheries Development Board (NFDB), which was chartered in 2006 for supporting fisheries and aquaculture development in India, has developed a series of "guidelines" on fisheries and aquaculture activities,[26] among which the Guidelines on Seaweed Cultivation[27] specify a government assistance scheme for the seaweed industry and its implementation procedures.

Licensing

In the Philippines, a licence is mandatory for seaweed farming in public waters. Only citizens of the Philippines or a business entity controlled (with more than 60 percent of the capital stock) by citizens of the Philippines are eligible for a seaweed farming licence. The duration of the licence is up to ten years and subject to renewal. The licence fee is PHP50 (about USD1.2) per hectare. A family is only eligible for one licence. In principle, the maximum farm size is one hectare for a family farm and 30 ha for a business entity (partnership, associations, cooperatives or corporations). These general regulations specified in the Fisheries Administrative Order No. 146 (BFAR, 1983) may be altered by local government according to special local conditions. For example, in Calatagan, the local government has limited the maximum farm area per household to 2 000 m^2 in order to provide opportunities to more potential farmers and at the same time maintain the quality of coastal waters (Espaldon *et al.*, forthcoming).

Established by government for environmental sustainability and/or social equity, regulations over seaweed farming such as those in the Philippines inevitably impose

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[22] Available at: www.fao.org/fishery/legalframework/nalo_solomonislands/en

[23] Available at: http://faolex.fao.org/docs/pdf/ind66493.pdf

[24] Available at: http://faolex.fao.org/docs/pdf/ind66500.pdf

[25] Available at: http://moef.nic.in/assets/so19e.pdf

[26] Available at: www.coochbehar.gov.in/Fishery/PDFfiles/NFDB_Guidelines.pdf

[27] Available at: http://nfdb.ap.nic.in/html/seaweed.htm

constraints on seaweed farming development. Such constraints may result in economic inefficiency. For example, more productive farmers may have difficulties in expanding their operations because of the restrictions on farm size. Studies should be conducted to evaluate the impacts of formal or informal government regulations on the economic efficiency of seaweed farming; such studies would shed light on the way of achieving optimal trade-offs among the economic, social and environmental dimensions of seaweed farming.

In Indonesia, the government has tried but failed to establish a licensing scheme to regulate seaweed farming; tenancy issues have been usually decided by community members through a participatory approach[28] (Neish, 2013). It appears that the lack of formal regulations has not deterred the rapid expansion of seaweed farming in Indonesia. However, this situation may change as competition over coastal natural resources (e.g. from the tourism industry) intensifies.[29]

In Solomon Islands, private trading companies need to acquire a licence to export raw seaweeds. Seaweed export licences were issued to six exporters in 2005, but only two licence holders actually exported seaweed during the year; and only one exporter renewed its licence in 2006 (Tinne, Preston and Tiroba, 2006). A main concern over the licensing system is that the bureaucratic system may hinder the development of the industry, especially when government lacks the capacity to manage it properly. However, proponents argue that, as the volume of the country's seaweed production is limited, the licensing system could avoid unnecessary competition and give more reliable exporters sufficient profit margins to survive and thrive (Tinne, Preston and Tiroba, 2006).

In the United Republic of Tanzania, licensing has not been a major barrier for commercial seaweed exporters entering the business because the government has generally wished that the existence of more buyers would give seaweed farmers more options to sell their produce. However, as discussed above, it appears that the "free trade" model did not help solve the problem of low seaweed prices. Indeed, instead of paying higher prices, seaweed buyers in the United Republic of Tanzania often competed for more seaweed by lowering their quality standards (MNRT, 2005). This situation raises the question of whether regulations on seaweed exporters (e.g. a more stringent licensing system similar to that of Solomon Islands) are warranted.

Quality standards

The low quality of seaweed is deemed a perennial problem in carrageenan seaweed industry. Ideally, the market mechanism could motivate farmers to improve the quality of their seaweed produce by rewarding such efforts with higher prices, but this may not be the case in practice. For example, seaweed buyers in the United Republic of Tanzania usually paid uniform prices for all seaweeds regardless of their quality (MNRT, 2005). In the Philippines, traders or processors sometimes tolerate malpractices such as adulterating seaweed with water, salt and/or other impurities, especially when seaweed is in short supply (Hurtado, 2013).

The public sector could help to improve the quality of seaweed by establishing quality standards. In the Philippines, standard-setting government agencies have established quality standards for dried raw seaweed (Hurtado, 2013). In Solomon Islands, one immediate action in its Aquaculture Development Plan 2009–2014 is

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[28] Participatory governance takes the form of self-regulation and comanagement with neighbouring (and competing) farmers working together to coordinate environmental and production measures. Compliance is enforced by peer pressure. The motivation may be altruistic, but also self-interested in order to maintain a healthy husbandry environment (Hishamunda *et al*., 2012).

[29] According to the news report "Bali seaweed farmers under threat"(http://beatmag.com/daily/bali-seaweed-farmers-under-threat/), seaweed farmers in some areas of Bali, Indonesia, need enabling regulations to help them cope with the increasing pressure from tourism and property development.

to establish seaweed quality standards (MFMR, 2009). In the United Republic of Tanzania, the Seaweed Development Strategy Plan (SDSP) has suggested several quality standards and encouraged seaweed farmers to obey and seaweed exporters (also called developers) to enforce quality standards (MNRT, 2005).

Public assistance

The case studies have documented many cases of public assistance to seaweed farming by government, development agencies, NGOs and/or research communities. Typically, public assistance includes providing seaweed farmers with farm materials (cultivars, ropes, tie-ties, etc.), training, extension, business development services, financial services, and funding supports. In the Philippines, the BFBR has also supported the establishment of seaweed nurseries to address the issue of inadequate cultivars (Hurtado, 2013). In India, the NFDB has offered funding support to establish seaweed processing plants (Krishnan and Narayanakumar, 2013). In Indonesia, 40 percent of surveyed farmers had received grants or soft loans from government agencies (Neish, 2013). In Mexico, inhabitants of Dzilam de Bravo expected public funding to help them engage in seaweed farming (Robledo, Gasca-Leyva and Fraga, 2013). In the United Republic of Tanzania, government has provided planting materials to seaweed farmers in order to reduce their dependence on exporters (Msuya, 2013). In India, seaweed farmers in Tamil Nadu have been able to obtain a partial subsidy from a rural development agency, which has subsidized up to half the cost of their investments (Krishnan and Narayanakumar, 2013).

Liaison and mediation are another type of public assistance. In Zanzibar, the United Republic of Tanzania, government has tried to facilitate farmers and exporters to sign agreements on contract farming and mediate their conflicts and disputes, but it seems that the efforts have not always been successful (Msuya, 2013). In Solomon Islands, the MFMR has been asked to negotiate with shipping companies on behalf of seaweed farmers for lower freight rates (Kronen, 2013).

Global carrageenan seaweed farming has also benefited from technical research and dissemination undertaken by research communities (Msuya, 2009). The University of the South Pacific has tested quarantine protocols for introduced seaweed and developed training manuals for prospective farmers (Sulu *et al.*, 2003; Pickering, 2006). Manuals and monographs have been published by SEAPlant.Net based in Indonesia and these are available on the Internet. In the Philippines, academic experiments have been spearheaded by the University of the Philippines as a leading research institution, the Southeast Asian Fisheries Development Center-Aquaculture Department, and Cargill Texturizing Solution SAS France, a multinational carrageenan company based in the country (Hurtado, 2013). In Mexico, the pilot project was an academic experiment, and the Center for Advanced Studies and Research (CINVESTAV) has emerged as the leading research centre in that country (Robledo, Gasca-Leyva and Fraga, 2013). The paper on Indonesia in this technical paper recognizes that much of the seaweed research in the Coral Triangle has been done in the Philippines (Neish, 2013). The India case study describes the activities of the Seaweed Research Association, the Aquaculture Foundation and other NGOs. Not only have they undertaken research, they have also assisted farmers with training, financing and collaborative development (Krishnan and Narayanakumar, 2013).

Public assistances have not always been effective. For example, in the United Republic of Tanzania, the SDSP has multiple objectives, including fostering a conducive investment environment, reducing the dependence of seaweed farmers on exporters through capacity building, expanding extension and research, increasing productivity through best management practices, and increasing awareness of the potential of seaweed farming as an income-generating business (MNRT, 2005). However, the SDSP has been mostly ineffective because of a lack of implementation.

The lack of extension officers has been one of the problems. Despite many efforts of fisheries officers, conflicts between seaweed farmers and buyers have remained a major issue, deterring the development of seaweed farming in many regions (Msuya, 2013).

Public assistance provided by development agencies and other donors is often implemented through short-term projects and, hence, faces the issue of continuity. For example, seaweed farming in Solomon Islands has relied significantly on projects funded by the European Union (Member Organization) such as the Rural Fishing Enterprise Project (RFEP) and the Commercialization of Seaweed Production in Solomon Islands (CoSPSI) project (Kronen, 2013). As the CoSPSI project was finishing in 2009, one of the immediate actions in the Solomon Islands Aquaculture Development Plan 2009–2014 was to explore ways to sustain seaweed farming development after the end of the project (MFMR, 2009).

6. LESSONS LEARNED AND THE WAY FORWARD

The above discussion attempts to provide a global review of the social and economic dimensions of carrageenan seaweed farming based on the existing literature, especially the six case studies included in this technical paper. The review has synthesized data and information on the status and trends of carrageenan seaweed farming and the seaweed-carrageenan value chain, assessed the economic and social performance of carrageenan seaweed farming, and discussed the governance and institutional aspects of the industry.

The review indicates that carrageenan seaweed farming has great potential in contributing to the socio-economic well-being of coastal communities, but it is not automatic for that potential to become reality. Various challenges and issues from the perspectives of different stakeholders were identified in the six case studies; some of which were highlighted in Section 2.4 of this synthesis paper.

The experiences of the six case-study countries indicate that commercial seaweed farming could be "jump-started" by different impetuses. The start-up process in the principal producing countries (i.e. Indonesia, the Philippines and the United Republic of Tanzania) was mostly "bottom-up". Individual farmers, encouraged by traders, began seaweed farming because of potential cash income. In Solomon Islands, seaweed farming started from development projects funded by donors that valued its livelihood benefits. In India, commercial operations began because a large (multinational) firm needed seaweed as raw material. In Mexico, seaweed cultivation was promoted by government as a strategy for reducing carrageenan imports.

One key lesson to be learned for policy-makers interested in promoting carrageenan seaweed farming is that ignoring the socio-economic aspects of seaweed farming can lead to a lack of sustainability. Many seaweed development projects have "ended in failure" because of overlooking the "human factor" that concerns not only seaweed farmers but also other stakeholders (Ask, 2001, p. 13). Not only must seaweed farming offer a comparable, even higher, income for the same effort and risk as alternative activities, but it must conform to institutional and social structures. Other coastal users, government officials, community leaders, banks, donors, NGOs and carrageenan processors as well as potential farmers must have their legitimate wants satisfied. Technical feasibility is not sufficient if farmers lack incentives, governance penalizes entrepreneurship, or social structures preclude development.

Besides technical efficiency in cultivation, the economic performance of carrageenan seaweed farming depends on various elements in seaweed-carrageenan value chains. For example, despite the good reputation of its high-quality RDS, the seaweed industry in the Pacific islands has been penalized by disadvantages such as low production scales, isolation from processors and, hence, high shipping and intermediary costs, expensive interisland transport, etc. (Luxton, 1999; McHugh, 2006).

Despite much information being provided by the existing literature, there are still substantial information and knowledge gaps that hinder the forming of a clearer vision of the future development of carrageenan seaweed farming and the formulation of more concrete and evident-based policy recommendations. Some of the gaps are highlighted as follows.

6.1 Carrageenan market

The demand for carrageenan seaweeds is derived from the carrageenan market. The demand for carrageenan is expected to continue growing because of increasing demand for processed food, driven primarily by population and economic growth in developing countries. Scientific and technological advances could also tend to broaden the uses of carrageenan as food additives and other ingredients. However, quantitatively, what will the global demand for carrageenan be in the future?

Much information on the global carrageenan market has been provided by the literature including McHugh (2003), Panlibuton, Porse and Nadela (2007), Neish (2008a), and Bixler and Porse (2011). Although data from different sources may not be completely consistent, there are some general ideas about how much carrageenan has been produced by what countries and how much carrageenan has been used in which products. However, in order to estimate the future demand for carrageenan, it would be necessary to have more detailed information on how much of what kind of carrageenan products is used by what countries in which products. Such information has not been readily available.

Another related issue is the carrageenan's own-price elasticity of demand (i.e. the sensitivity of carrageenan demand to a change in its price). A common perception is that the food industry, with generally thin profit margins, tends to be very sensitive to an increase in the price of carrageenan (McHugh, 2006; Bixler and Porse, 2011). However, there is not much information to quantify how sensitive it is.

As carrageenan may only account for a small portion of the cost of an end product, a change in its price may cause a relatively small change in the total cost and, hence, have a limited impact on its demand, especially when carrageenan is an irreplaceable ingredient. Indeed, as carrageenan may not only improve the texture of a pre-cooked meat product but also increase its yield (Bixler and Porse, 2011), the real cost of carrageenan under this situation would be the difference between its price and that of the product.

Further study should be conducted to provide more and improved information on the status and trends of the carrageenan market, including the geographic distribution of carrageenan production and production capacity, the market segments of carrageenan products (i.e. the use of carrageenan in meat, dairy, water gel and other products), and the geographic distribution of carrageenan demand across countries and products. On the basis of such information, analyses should be conducted to provide more reliable estimates of carrageenan demand and, hence, the derived demand for carrageenan seaweeds in the future. The estimation would shed light on the potential of carrageenan seaweed farming in the future, which is important information for both policy decision-making and sector management.

6.2 Carrageenan processing industry and carrageenan seaweed market

Carrageenan (seaweed) processing used to be dominated by a few large companies from developed countries. Now, carrageenan processors have become more numerous and geographically diverse. Based on the information provided in Neish (2013), an example of value addition in SRC processing in Indonesia is presented in Section 2.4 (Table 5). However, the situations in other countries (e.g. China and the Philippines) remain less clear; as do the situations of value addition in RC processing.

The carrageenan seaweed crisis in 2008 was allegedly caused by a large increase in the demand from carrageenan processors in China. What were the driving forces behind the demand hike? What will its trend be in the future? Will there be a trend of consolidation in the carrageenan processing industry in China? Will carrageenan processors from China attempt to gain more control over the sources of their raw materials through vertical integration or business alliance?

Seaweed farming countries have always been eager to extend their seaweed value chains to processing. Given time, profit-seeking entrepreneurs would make this happen, as long as seaweed processing provided profitable business opportunities. However, from a policy perspective, some issues need to be clarified in order to develop appropriate industrial policies and create an enabling environment. Despite the availability of raw materials, does a seaweed farming country necessarily have comparative advantage in carrageenan processing; what about other factors such as infrastructure, markets and human capital? What would be the minimum size for a carrageenan processing industry to be economically viable? What about the environmental impacts of carrageenan seaweed processing (e.g. nutrient-loaded effluent)? What could be done to facilitate the industry to adopt multistream processing (i.e. extracting not only carrageenan but also other nutrients [Figure 3 in Neish, 2013])? Last but not least, what could be done to increase seaweed farming countries' competitive advantage in carrageenan processing?

In Indonesia, there has been a proposal to restrict the export of raw seaweeds in order to support the development of the local processing industry.[30] Compared with other supporting policies (e.g. subsidizing the processing industry), this may incur a smaller financial burden for government to implement. However, an export quota system would distort the market and, hence, should be implemented with caution. For example, limited and uncertain seaweed supply from Indonesia under the quota system may force overseas processors to source raw materials from elsewhere, which would essentially impair the competitiveness of seaweed farmers in the home country. While the quota system may benefit the local processing industry with more abundant and cheaper raw material supply in the short term, the artificial competitive advantage may not be sustainable in the long run.

Based on the existing literature (e.g. McHugh, 2003; Panlibuton, Porse and Nadela, 2007; Neish, 2008a; Bixler and Porse, 2011), further study should be conducted to provide broader, deeper and more systematic information on the economic, social and environmental performance of the carrageenan seaweed processing industry. Considering the special situation of China (i.e. a large carrageenan processing industry depending mostly on imported raw seaweeds), further study should be conducted to understand the status and trends of its carrageenan processing industry and their implications for the global carrageenan seaweed market.

6.3 Carrageenan seaweed production

Farm sites

The availability of farming areas has not been a major constraint on carrageenan seaweed farming, but it could eventually become so. Although the six case studies and other literature (e.g. Neish, 2008b) provide some information on farming areas used in carrageenan seaweed farming, further study should be conducted to examine the status and potential of suitable farm sites in major carrageenan seaweed farming countries.

For stocktaking of existing farm sites, the information to be collected should include not only geographical and environmental parameters (e.g. location, area, temperature, depth and current) but also technical parameters (e.g. farming systems and productivity) as well as socio-economic parameters (e.g. infrastructure, labour force and economic conditions in surrounding areas). These parameters are essential for identifying potential farming sites for future development (Kapetsky, Aguilar-Manjarrez and Jenness, forthcoming).

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[30] See the news report "Indonesia plans to limit seaweed exports from 2012", available at: www.thejakartaglobe.com/business/indonesia-plans-to-limit-seaweed-exports-from-2012/366886.

Farming systems

Although there may be the temptation to compare technical and economic efficiency across different farming systems, it should be noted that conclusions drawn from such comparisons may not be rigorous and could be misleading. For example, without controlling other factors, the performance difference of two farming systems located in different areas may mainly reflect the different environmental conditions of their farm sites. Therefore, it could be misleading to claim that system A is more efficient or profitable than system B because system A may actually perform poorer than system B in the location of the latter.

Based on information provided in the six case studies, Section 3 compared the technical and economic performance (e.g. productivity, efficiency and profitability) of carrageenan seaweed farming across different farming systems. The comparisons provide useful benchmark information that indicates some patterns, e.g. floating line tends to be more cost-effective than other farming systems (off-bottom and floating raft). However, this generalized conclusion should be treated as indicative only for the reason explained above, and also because of the limited number of cases included in the comparisons.

Although the cases included in the comparisons in Section 3 contain some variations (e.g. different scales of operation, different sizes of cultivars, or different numbers of production cycles), most of them are representative cases under normal situations. These representative cases do not capture the variations in the performance of different seaweed farmers in the real world. Information on such variations is important to understanding factors affecting farmers' performance and for providing guidance on how to improve it.

Seed

Self-propagation of cultivars could be economically attractive because the value-added in the seed production could be internalized by seaweed farmers. However, one issue is the quality of self-propagated seed materials in terms of growth rate, carrageenan content, disease resilience, etc. Another issue is whether specialized seed production could be more economically efficient than self-propagation because of economies of scale.

Seed production in fish or terrestrial farming has been increasingly conducted by specialized seed producers; will seaweed farming follow a similar trend? Commercial seaweed nurseries have already appeared in Indonesia (Neish, 2013) and the Philippines (Hurtado, 2013). Most of them are part of the operations of large seaweed farms. Further study should be conducted to compare the performance of self-propagation with commercial nurseries and shed light on opportunities for and constraints on the development of commercial seaweed nurseries.

Husbandry

Seaweed farmers can improve husbandry through learning-by-doing processes facilitated by training and extension. Good agronomy practices in carrageenan seaweed farming have been documented in the literature (e.g. Juanich, 1998; Neish, 2008b). Most of the discussion focuses on the technical efficiency of seaweed farming. However, because of different costs, practices that generate higher yields do not necessarily result in greater profitability.

Further study should be conducted to evaluate the economic performance (e.g. profitability and risks) of different farming practices. Such evaluations should also consider the environmental impacts (e.g. cutting down mangroves) and social impacts (e.g. occupational hazards) of seaweed farming.

Integrated multitrophic aquaculture

Integrated multitrophic aquaculture (IMTA) has been proposed as a promising technology that could enhance seaweed farmers' incomes and reduce their risks through diversification (Neish, 2009). The ecological advantages of seaweeds are their ability to metabolize carbon dioxide and assimilate macronutrients and micronutrients. Therefore, they can be used as bioremediation in finfish culture as part of the ecosystem approach to aquaculture (Soto, Aguilar-Manjarrez and Hishamunda, 2008). Not only are there environmental advantages from combining seaweed cultivation with finfish and shellfish, but there can also be economic and social benefits (Ridler *et al.*, 2007; Barrington, Chopin and Robinson, 2009). Integrated multitrophic aquaculture has already been practised in seaweed farming; examples include IMTA of seaweeds and bivalves in China (Mao *et al.*, 2009) and growing *Gracilaria* in fish or shrimp ponds in Indonesia (Neish, 2009).

While the potential of carrageenan seaweeds in IMTA has been examined and experimented (Hayashi *et al.*, 2010), it seems that commercial IMTA of carrageenan seaweeds has yet to become substantial. Further study should be conducted to examine, especially from a socio-economic perspective, the potentials and constraints of IMTA in carrageenan seaweeds.

Summary

Based on the six case studies as well as other existing literature (e.g. Ask, 2001; Namuda and Pickering, 2006; Zamroni and Yamao, 2011; Zamroni, Laoubi and Yamao, 2011), farm surveys or censuses should be conducted to collect detailed data on carrageenan seaweed farming in each of the major carrageenan seaweed farming countries. With more detailed data, the analysis in Sections 3 and 4 could be broadened and deepened to generate more information on, and knowledge of, the socio-economic performance of carrageenan seaweed farming.

6.4 Industrial organization

Carrageenan seaweed farming has been dominated by small-scale (family) farmers. There is little disagreement that more integration is needed in the industry to overcome the disadvantages of small-scale farming (e.g. lack of economies of scale and poor traceability in both production and marketing), but the question is how to bring this about.

Large farms

Despite the benefits of economies of scale, large seaweed farms may be less favoured by government and other pro-poor stakeholders because of concerns over social equity. However, large seaweed farms can generate employment and incomes directly from own operations or indirectly from induced economic growth in local communities. Although it is neither likely nor appropriate, at least not in the near future, for carrageenan seaweed farming to be dominated by large-scale, plantation type of operations, large farms are expected to play more significant roles in seaweed farming development.

In Indonesia, large leader farmers have appeared and operated like farm enterprises (Neish, 2013). Further study should be conducted to broaden and deepen understanding of the socio-economic performance of large seaweed farms and their contributions to the development of the sector.

Farmer organizations

Formal or informal farmer organizations could consolidate the efforts of small farmers into collective actions for better economic performance. However, their success is not automatic (see Section 5.1 for some discussion). Past experiences indicate the importance of strong leadership, be it from large farmers, traders, NGOs or development agencies, to the success of farmer organizations (Vorley and Proctor, 2008). Lack of effective leadership is deemed a factor behind less-successful seaweed farmer associations in the Philippines (Hurtado, 2013) and the United Republic of Tanzania (Msuya, 2013). In

Mexico, lack of leadership that represents the interests of the community has resulted in a lack of confidence and trust among community members (Robledo, Gasca-Leyva and Fraga, 2013).

Based on the existing literature (e.g. Kassam, Subasinghe and Phillips, 2011), further study should be conducted to examine the potential and limitations of farmers organizations as a means to consolidate small-scale seaweed farmers. Special attention should be focused on how organizational and governance structures of different seaweed farming entities (farmers groups, producer associations, cooperatives, farm enterprises, etc.) affect their socio-economic performance.

Trading intermediaries

It is often taken for granted that more direct value chains between farmers and processors (i.e. less intermediation) tend to be in the interest of farmers as well as the entire industry. However, it should be clarified that reducing intermediaries does not eliminate the various services provided by trading agents (e.g. consolidation, quality control, credit provision, risk-sharing, and information exchange) but rather transfer them to the shoulders of farm enterprises, farmers organization, and/or processors. Then, the question is under what situations such internalization would be more efficient than independent commercial trading agents.

Further study should be conducted to enhance understanding of the socio-economic performance of trading agents in the seaweed industry. A good place to start could be a comparative analysis of countries' different experiences (e.g. export licensing in Solomon Islands, the free-entry policy in the United Republic of Tanzania, and the highly specialized and multilayer trading system in the Philippines[31]).

6.5 Governance and policy

Although most major carrageenan seaweed farming countries, except the Philippines, have no specific regulations on seaweed farming, detrimental environmental externalities were not cited in the case studies as a major problem of seaweed farming, nor were conflicts or disputes over natural resources among seaweed farmers or between seaweed farming and other activities. However, with increasing competition over coastal resources, it is important, especially for countries with advanced seaweed farming (e.g. Indonesia), to establish formal legal frameworks and specific regulations to ensure the sustainable development of the sector.

Notwithstanding a private-sector driven activity, the socio-economic performance of seaweed farming is affected, to a great extent, by public policy and governance structure. However, there is a general lack of information and knowledge on the design and implementation of public policies and their impacts on the socio-economic performance of seaweed farming. Further study in this regard is needed.

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[31] In the Philippines seaweed industry, the number of trading agents was about half that of the number of seaweed farmers (Hurtado, 2013).

References

Ask, E. 2001. Creating a sustainable commercial *Eucheuma* cultivation industry: the importance and necessity of the human factor. *In* A. Chapman, R. Anderson, V. Vreeland, & I. Davison, eds. *17th International Seaweed Symposium,* pp. 13–18. Oxford University Press.

Barrington, K., Chopin, T. & Robinson, S. 2009. Integrated multi-trophic aquaculture (IMTA) in marine temperate waters. In D. Soto (ed.). *Integrated mariculture: a global review*. FAO Fisheries and Aquaculture Technical Paper. No. 529. Rome, FAO. pp. 7–46.

Bixler, H. & Porse, H. 2011. A decade of change in the seaweed hydrocolloids industry. *Journal of Applied Phycology,* 23: 321–335.

Bureau of Fisheries and Aquatic Resources (BFAR). 1983. *Rules and regulations governing the gathering and farming of seaweeds*. Fisheries Administrative Order No. 146. Bureau of Fisheries and Aquatic Resources, Ministry of Natural Resources, Republic of the Philippines. (also available at www.fao.org/fishery/legalframework/nalo_philippines/en).

Buschmann, A., Varela, D., Cifuentes, M., Hernández-González, M., Henríquez, L., Westermeier, R. & Correa, J. 2004. Experimental indoor cultivation of the carrageenophytic red alga *Gigartina skottsbergii. Aquaculture,* 241: 357–370.

Espaldon, M.V., Sumalde, Z., Rebancos, C., Villanueva J. & Mercene-Mutia, M. (forthcoming). Indicators for measuring the contribution of small-scale aquaculture to sustainable rural development: Philippines pilot case studies. *In* M.G. Bondad-Reantaso, P. Bueno & T. Pongthanapanich, eds. *Indicator system for assessing the contribution of small-scale aquaculture to sustainable rural development: selected case studies*. FAO Fisheries and Aquaculture Technical Paper No. 545. Rome, FAO.

Ferrer, M.S.R. 2002. National seaweed program. *In* A.Q. Hurtado, N.G. Guanzon Jr, T.R. de Castro-Mallare & M.R.J. Luhan, eds. *Proceedings of the National Seaweed Planning Workshop held on August 2–3, 2001,* pp. 27–33. Aquaculture Department, SEAFDEC. Tigbauan, the Philippines.

Fröcklin, S., de la Torre-Castro, M., Lindström, L., Jiddawi, N.S., Msuya, F.E. 2012. Seaweed mariculture as a development project in Zanzibar, East Africa: A price too high to pay? *Aquaculture*, 356–357: 30–39.

Gan, K.T. 2003. *Strategic alliances in the tropical Asian seaweed industry: implications for development in Asia*. Adelaide, Australia, University of South Australia. 89 pp.

Hayashi, L., Hurtado, A.Q., Msuya, F.E., Bleicher-Lhonneur, G. & Critchley, A.T. 2010. A review of *Kappaphycus* farming: prospects and constraints. *In* A. Israel, R. Einav & J. Seckbach, eds. *Seaweeds and their role in globally changing environments*, pp. 255–283. Cellular Origin, Life in Extreme Habitats and Astrobiology.

Hishamunda, N., Ridler, N., Bueno, P., Satia, B., Kuemlangan, B., Percy, D., Gooley, G., Brugere, C. & Sen, S. 2012. Improving aquaculture governance: what is the status and options? *In* R.P. Subasinghe, J.R. Arthur, D.M. Bartley, S.S. De Silva, M. Halwart, N. Hishamunda, C.V. Mohan & P. Sorgeloos, eds. *Farming the waters for people and food: Proceedings of the Global Conference on Aquaculture 2010*, pp. 233–264. Rome, FAO, and Bangkok, NACA. 896 pp.

Hurtado, A. Q. 2013. Social and economic dimensions of carrageenan seaweed farming in the Philippines. *In* D. Valderrama, J. Cai, N. Hishamunda & N. Ridler, eds. *Social and economic dimensions of carrageenan seaweed farming*, pp. 91-113. Fisheries and Aquaculture Technical Paper No. 580. Rome, FAO. 204 pp.

Juanich, G. L. 1998. *Manual of running water fish culture 1. Eucheuma* spp. ASEAN/SF/88/Manual No. 2. ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1988. 25 pp.

Kapetsky, J.M., Aguilar-Manjarrez, J. & Jenness, J. (forthcoming). *A global assessment of potential for offshore mariculture development from a spatial perspective*. FAO Fisheries and Aquaculture Technical Paper No. 549. Rome, FAO. 181 pp.

Kassam, L., Subasinghe, R. & Phillips, M. 2011. *Aquaculture farmer organizations and cluster management: concepts and experiences*. FAO Fisheries and Aquaculture Technical Paper No. 563. Rome, FAO. 90 pp.

Krishnan, M. & Narayanakumar, R. 2013. Social and economic dimensions of carrageenan seaweed farming in India. *In* D. Valderrama, J. Cai, N. Hishamunda and N. Ridler, eds. *Social and economic dimensions of carrageenan seaweed farming*, pp. 163-185. Fisheries and Aquaculture Technical Paper No. 580. Rome, FAO. 204 pp.

Kronen, M. 2013. Social and economic dimensions of carrageenan seaweed farming in the Solomon Islands. *In* D. Valderrama, J. Cai, N. Hishamunda and N. Ridler, eds. *Social and economic dimensions of carrageenan seaweed farming*, pp. 147-161. Fisheries and Aquaculture Technical Paper No. 580. Rome, FAO. 204 pp.

Luxton, D. 1999. *Potential for Eucheuma "cottonii" seaweed farming in Samoa*. South Pacific Aquaculture Development Project (Phase II), Field document 17, GCP/RAS/116/JPN. Suva, Fiji, FAO. 33 pp.

Mao, Y., Yang, H., Zhou, Y, Ye, N, & Fang, J. 2009. Potential of the seaweed *Gracilaria lemaneiformis* for integrated multi-trophic aquaculture with scallop *Chlamys farreri* in North China. *Journal of Applied Phycology*, 21: 641–656.

McHugh, D.J. 2003. *A guide to the seaweed industry*. Fisheries Technical Paper No. 441. Rome, FAO. 105 pp.

McHugh, D.J. 2006. *The seaweed industry in the Pacific islands*. ACIAR Working Paper No. 61. Canberra, Australian Centre for International Agricultural Research. 55 pp.

Ministry of Fisheries and Marine Resources (MFMR). 2009. *Solomon Islands aquaculture development plan, 2009-2014*. Noumea, New Caledonia, Ministry of Fisheries and Marine Resources – Solomon Islands and Secretariat of the Pacific Community. 54 pp.

Ministry of Natural Resources and Tourism (MNRT). 2005. *Seaweed development strategic plan*. Dar es Salaam, United Republic of Tanzania, University Printing Press. 47 pp.

Msuya, F.E. 2009. *Development of seaweed cultivation in Tanzania: the role of the University of Dar es Salaam and other institutions*. EC FP7 Project. SARNISSA. 25 pp.

Msuya, F.E. 2011. The impact of seaweed farming on the socio-economic status of coastal communities in Zanzibar, Tanzania. *World Aquaculture*, 42(3): 45–49.

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 and 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.

Msuya, F.E., Shalli, M.S., Sullivan, K., Crawford, B., Tobey, J. & Mmochi, A.J. 2007. *A comparative economic analysis of two seaweed farming methods in Tanzania*. The Sustainable Coastal Communities and Ecosystems Program. Coastal Resources Center, University of Rhode Island and the Western Indian Ocean Marine Science Association. 27 pp. (also available at www.wiomariculture.org/pubs/CompSeaweedEconReport.pdf).

Namuda, M. & Pickering, T. 2006. Rapid survey techniques using socio-economic indicators to assess the suitability of Pacific Island rural communities for *Kappaphycus* seaweed farming development. *Journal of Applied Phycology*, 18: 241–249.

Neish, I.C. 2008a. *Structure and development of tropical red seaweed value chains with focus on the red algal galactan seaplants (RAGS)*. SEAPlant.net Monograph No. HB2A 1108 V2 VC. Makassar, Indonesia. 47 pp.

Neish, I.C. 2008b. *Good agronomy practices for Kappaphycus and* Euchema*: including an overview of basic biology*. SEAPlant.net Monograph No. HB2F 1008 V3 GAP. Makassar, Indonesia. 72 pp.

Neish, I.C. 2008c. *A ten-step functional framework for building ventures and alliances among Seaplant enterprises*. SEAPlant.net Monograph No. HB2C 0808 V1 VA. Makassar, Indonesia. 28 pp.

Neish, I.C. 2009. *Tropical red seaweeds as a foundation for integrated multi-trophic aquaculture (IMTA): four propositions and an action plan for this major opportunity in the Coral Triangle*. SEAPlant.net Monograph No. HB2E 1209 V3 IMTA. Makassar, Indonesia. 43 pp.

Neish, I.C. 2013. Social and economic dimensions of carrageenan seaweed farming in Indonesia. *In* D. Valderrama, J. Cai, N. Hishamunda and N. Ridler, eds. *Social and economic dimensions of carrageenan seaweed farming*, pp. 61-89. Fisheries and Aquaculture Technical Paper No. 580. Rome, FAO. 204 pp.

Panlibuton, H., Porse, H. & Nadela, E. 2007. *Seaweed/carrageenan value chain assessment: final report*. Study conducted for Seaplant.net initiative of IFC Advisory Services and for GTZ Philippines. 47 pp. (also available at: http://bimp.huniomedia.com/wp-content/uploads/downloads/2012/02/SW_Carrageenan-VCA-Report-July-2007.pdf).

Pickering, T. 2006. Advances in seaweed aquaculture among Pacific island countries. *Journal of Applied Phycology*, 18: 227–234.

Pickering, T., Skelton, P. & Sulu, R. 2007. Intentional introductions of commercially harvested alien seaweeds. *Botanica Marina*, 50: 338–350.

Ramachandran, C. 2012. “A sea of one’s own!” A perspective on gendered political ecology in Indian mariculture. *In* Gender in Aquaculture and Fisheries: Moving the Agenda Forward. *Asian Fisheries Science Special Issue*, 25S: 17–28.

Ridler, N., Wowchuk, M., Robinson, B., Barrington, K., Chopin, T., Robinson, S., Page, F., Reid, G., Szemerda, S., Sewuster, J. & Boyne-Travis, S. 2007. Integrated multi-trophic aquaculture (IMTA): a potential strategic choice for farmers. *Aquaculture Economics and Management*, 11(1): 99–110.

Robledo, D., Gasca-Leyva, E. & Fraga, J. 2013. Social and economic dimensions of carrageenan seaweed farming in Mexico. *In* D. Valderrama, J. Cai, N. Hishamunda and N. Ridler, eds. *Social and economic dimensions of carrageenan seaweed farming*, pp. 185-204. Fisheries and Aquaculture Technical Paper No. 580. Rome, FAO. 204 pp.

Soto, D., Aguilar-Manjarrez, J. & Hishamunda, N. eds. 2008. *Building an ecosystem approach to aquaculture. FAO/Universitat de les Illes Balears Expert Workshop, 7–11 May 2007, Palma de Mallorca, Spain*. FAO Fisheries and Aquaculture Proceedings No. 14. Rome, FAO. 221 pp.

Sulu, R., Kumar, L., Hay, C. & Pickering, T. 2003. *Kappaphycus seaweed in the Pacific: review of introductions and field testing of proposed quarantine protocols.* Noumea, Institute of Marine Resources, University of the South Pacific, Secretariat of the Pacific Community. 85 pp. (also available at www.spc.int/DigitalLibrary/Doc/FAME/Reports/Sulu_04.pdf).

Tinne, M., Preston, G. & Tiroba, G. 2006. *Development of seaweed marketing and licensing arrangements. technical report 1.* Project ST 98/009: Commercialisation of Seaweed Production in the Solomon Islands. Gillett, Preston and Associates. (also available at http://bluesquid.net/COSPSI/CoSPSI%20Market%20Licence%20Report.pdf).

Vorley, B. & Proctor, F. 2008. *Inclusive business in agrifood markets: evidence and action.* A report based on proceedings of an international conference held in Beijing, 5–6 March 2008. (also available at: www.regoverningmarkets.org/en/filemanager/active?fid=1059).

Zamroni, A., Laoubi, K. & Yamao, M. 2011. The development of seaweed farming as a sustainable coastal management method in Indonesia: an opportunities and constraints assessment. *In* R. Anderson & E. Beriatos, eds. *Development and planning.* Essex, UK, WIT Press.

Zamroni, A. & Yamao, M. 2011. Coastal resource management: fishermen’s perceptions of seaweed farming in Indonesia. *World Academy of Science, Engineering and Technology*, 60: 32–38.

Social and economic dimensions of carrageenan seaweed farming in Indonesia

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1. INTRODUCTION

This chapter is an assessment of the social and economic dimensions of seaweed aquaculture in Indonesia. It focuses on the development of sustainable seaweed farmer livelihoods in the context of regional and global value chains. The analysis was carried out in conformity with the frameworks of Scoones (1998) and Scoones *et al.* (2007). These frameworks were placed in a value chain context according to the model of Gereffi, Humphrey and Sturgeon (2005). Data were analysed from farmer surveys conducted by Seaplant.net in the period May 2007 – January 2008 and again in September 2009. In addition, several value chain players were informally interviewed.

From 1985 to 2009, Indonesian seaweed farm development was driven by farmers and local traders/collectors in a reflexive, "bottom-up" manner. A market need was made known to prospective seaweed farmers by value chain stakeholders on the demand side; farmers were exposed to the simple technology that was involved in growing seaweeds and, with facilitation from a variety of organizations, seaweed farmers were able to build their businesses within the context of village norms, mores and structures. Seaweed farming became integrated into the social fabric of farmer villages to the point where it now appears to be a traditional economic activity even though it did not begin until the mid-1980s or later.

Since 1985, seaweed farming has been generally expanding in Indonesia; by 2008, it provided an average annual income of the order of USD5 000 to an estimated 20 000 farm families working on a part-time basis. The most diligent farmers have been able to make from two to three times that amount by working full time or by employing the "leader model" approach to farming. Such earnings are well above the poverty level. Interviewed farmers generally asserted that seaweed farming was by far their most lucrative economic activity.

Seaweed farming has also been complementary and compatible with other village economic activities such as fishing and farming land crops. Ready cash from seaweed farming has also had a noticeable multiplier effect. Shops, support services for seaweed farming and village infrastructure have all benefited visibly from seaweed cash flowing through local village economies.

2. CARRAGEENAN SEAWEED PRODUCTION AND VALUE CHAIN

Indonesia is located in the Coral Triangle region of Southeast Asia, north of Australia and south of East Asia (TNC, 2004). The country has a tropical marine climate. Seashores are typified by fairly uniform air and sea temperatures averaging in the range of 25–30 °C. There is high humidity and moderate to heavy rainfall. There are no typhoons but seismic activity can produce tsunamis and earth tremors.

Most cultivated seaweeds from Indonesia are of the red algal galactan seaweeds (RAGS) genera *Kappaphycus* (commonly known by its commercial name cottonii), *Eucheuma* (commonly known as spinosum) and *Gracilaria*. Those genera are sources of the hydrocolloids known respectively as kappa carrageenan, iota carrageenan and agar.

2.1 Production and trade

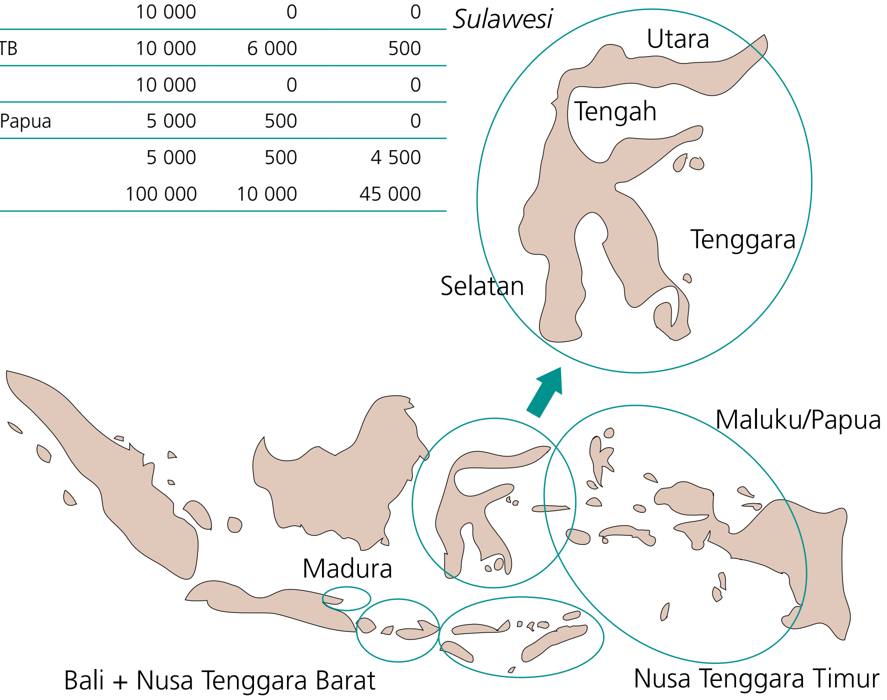
National production of seaweed in Indonesia has increased dramatically. According to FAO Statistics (FishStat), cultivated carrageenophyte seaweed production in Indonesia was 197 277 tonnes (wet weight) and worth USD21.7 million in 2000; by 2010, production had approached 3.4 million tonnes, worth USD1.1 billion. By 2010, Indonesia accounted for more than two-thirds of world tonnage and value.

Seaweed farming in Indonesia first reached commercial production in Bali in the mid-1980s but the technology rapidly spread to other parts of the country; since then, Sulawesi has become the centre of seaweed production (Figure 1). Major seaweed farming peoples included the Balinese, Madurese, Bajo, Bugis, Makassar,

FIGURE 1

Estimated annual production of RAGS, 2009 (tonnes in dry weight)

Location	**Cottonii**	**Spinosum**	***Graciliria***
Sulawesi Selatan	20 000	1 500	40 000
Sulawesi Tenggara	35 000	1 500	0
Sulawesi Tengah	4 000	0	0
Sulawesi Utara	1 000	0	0
Madura	10 000	0	0
Bali + NTB	10 000	6 000	500
NTT	10 000	0	0
Maluku/Papua	5 000	500	0
Other RI	5 000	500	4 500
Total RI	100 000	10 000	45 000



Sources: Seaplant.net; JaSuDa farmer network.

Luwuk, Banggai, Muna and Buton. Some of these peoples have lived in their ancestral homelands for centuries. Sea peoples such as the Bugis, Buton and Bajo have also migrated to establish seaweed farms in eastern regions such as Nusa Tenggara Timur (NTT) and Maluku.

Large areas of Indonesia, especially in East Indonesia, were still available for seaweed farm development as of late 2009. The less-developed regions included the Java Sea, the Sulawesi Sea, Lesser Sundas (including NTT), Banda Sea, Halmahera and Papua, but most other regions still had expansion potential as well. If all areas were developed, at least a three-fold increase in Indonesian RAGS production could probably be accomplished.

Indonesia's export of RAGS has increased significantly since 2000, thanks primarily to the increase in its cottonii and spinosum exports from about 40 000 tonnes (worth USD20 million) in early 2000 to 100 000 tonnes (worth more than USD110 million) in 2008 (Figure 2).[1] Its exports of *Gracilaria* remained fairly constant at an annual average of about 16 000 tonnes with a value of USD8 million.

About 55 percent of Indonesian exports have gone to China, where the market for RAGS products has steadily grown in the past decade (Neish, 2009). The JLJ Group

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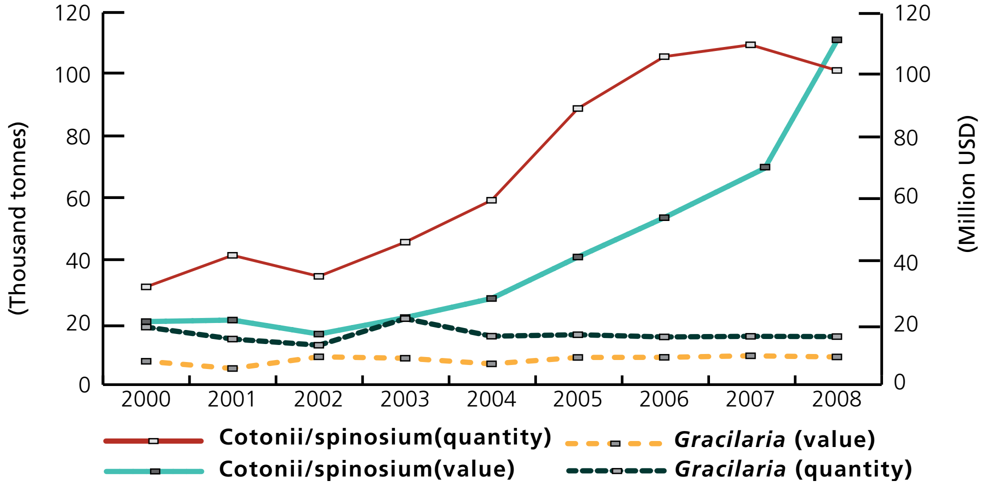
[1] The two species were generally not disaggregated in the trade data but their joint exports were estimated to contain about 90 percent cottonii.

FIGURE 2

Indonesian seaweed exports, tonnage (raw dried equivalent) and value, 2000–08



Source: Author's calculation based on data from Indonesian Customs and Excise Department.

(2006) estimated that about 95 percent of the China market consisted of meat, jelly and soft candy applications and that the market could grow at more than 10 percent per year.

Based on supply, demand and prices criteria, the situation for RAGS as of late 2009 was that the markets for spinosum, *Gracilaria* and their extracts were steady but the markets for cottonii and kappa carrageenan made from cottonii were in an uncertain state. The high cottonii farmgate prices led to unprecedented high carrageenan prices and a reduction in the demand for kappa carrageenan. By November 2009, all processors were reporting business down by as much as 50 percent. The general consensus among processors interviewed during the present study was that a free-on-board (f.o.b.) price in the range of USD1 000–1 200/tonne for export-grade cottonii would lead to steadily growing markets while still giving a good return to farmers.

Seasonal variability between regions, within years and between years was commonly cited by farmers as a causative factor for variability in seaweed production;[2] however, comprehensive scientific studies of cause-and-effect relationships remain to be undertaken. Interviewed farmers reported that, on average, worst yields were about 23.4 percent of best yields (standard deviation = 17.5). Ten successful farmers in South Sulawesi reported an average monthly harvest exceeding 1 170 kg in the best seasons, 425 kg overall, and 178 kg in the worst seasons. Exports of RAGS products from Indonesia also showed a distinct seasonality pattern in the period 2000–2008. The first quarter was usually the lowest season (19.7 percent of the annual export), followed by the second quarter (23.9 percent), the third quarter (27.5 percent) and the highest in the fourth quarter (28.9 percent).

Various actions were taken by seaweed farmers in response to seasonal changes. In South Sulawesi and NTT, most farmers had more than one farming site and shifted

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[2] Weather changes in Indonesia are driven by the West Monsoon (generally from October to March) and the East Monsoon (generally from April to September). Seasonal variations in wind patterns and rainfall are a fact of life that has great impact on Indonesian seaweed farmers. Most farmers refer to "good" or "bad" farming conditions with reference to rainfall. In some locations, production is best during the "rainy season" and in others during the "dry season". Some locations are good for seaweed farming all year round although there may be seasonal variations in productivity. Many locations can only support seaweed farming in a limited season of the year. Seasonality can vary even within nearby areas. In some cases (e.g. Bulukumba), seasons are different even for farms located a few kilometres apart.

sites seasonally. In South Sulawesi, they also tended to change their cultivar mix by growing more spinosum in times when cottonii did not grow well. Farming effort remained constant throughout the year in Sulawesi Tenggara (South Central Sulawesi) but effort was concentrated more towards the best seasons in other areas. Almost all farmers reported that drying was not a major seasonal constraint although rainy weather made crop drying more difficult. However, all farmers reported that seasonal effects on growth were a major factor affecting farming effort.

2.2 Value chain

The history of the seaweed-to-carrageenan value chain has been reflected through changes in value chain linkages. While Indonesia is the largest carrageenan seaweed farming and exporting country, the history of its seaweed farming development was intimately connected with development in other countries, especially the Philippines. A brief discussion on the development of RAGS value chains from a global perspective is provided below to facilitate the understanding of the seaweed value chain in Indonesia.

Development of RAGS value chains: a history of different governance models

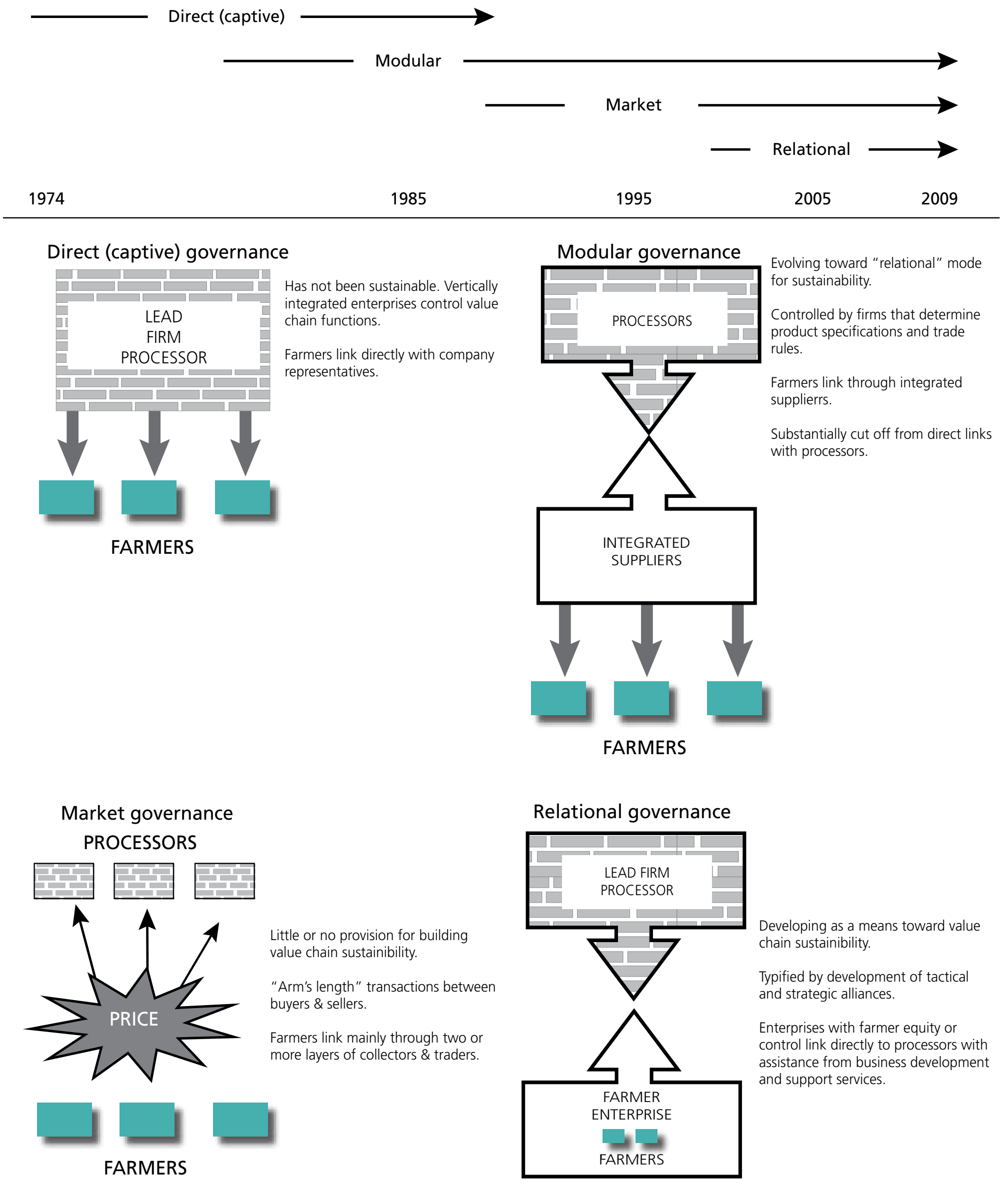
The first phase of extensive tropical seaweed aquaculture was launched in 1974, when commercial quantities of cottonii were first produced in the south of the Philippines. Direct governance predominated as vertically integrated enterprises controlled value chain functions. This resulted in an oligopsony (many small sellers and few major buyers). Cultivation of tropical RAGS and the extraction of RAG gums rapidly went from experimental trials to fully developed value chains owing to innovations in process technology and seaweed farm development driven by the "big three" innovative transnationals that dominated the carrageenan business (Marine Colloids, Auby and CP). These firms collaborated with local entrepreneurs to develop farms through direct investment. Substantial benefits were realized given the strong market position and robust strategic alliances built by the transnationals. Standards systems were facilitated by Marinalg, a trade association that included the "big three". Farmer linkages were directly to company representatives including trainers, extension workers and staff of company-operated buying stations. Direct governance value chains did not prove to be sustainable. They have evolved towards a "relational" mode in order to enhance sustainability as depicted in Figure 3.

The second phase of RAGS value chain development occurred from the mid-1980s until the mid-1990s as modular governance substantially displaced direct governance. Processors still determined product specifications and trade rules but they operated through integrated suppliers. The availability of cultivated *Kappaphycus* made it possible to introduce a novel technology by 1980 known as semi-refined carrageenan (SRC). This low-cost, low-energy product was initially developed by collaboration among established producers and end users in the petfood industry. The original process technology was copied as new industry players entered the SRC business and recruited former employees, consultants and equipment suppliers of previously established manufacturers. As a result, innovation in the industry stagnated. Major traders became processors while farm development became farmer- and trader-funded. The Philippines lost its effective monopoly because Indonesia and the United Republic of Tanzania developed as significant RAGS sources. Standards systems were still facilitated by Marinalg but they were weakening. Farmer linkages were through integrated suppliers, i.e. farmers were substantially cut off from direct links with processors.

The third phase of value chain development occurred by the mid-1990s as market governance began to displace direct and modular governance. "Arm's length" transactions between buyers and sellers became common as large volumes of seaweed were sold on short-term contracts or on the spot-market. As supply sources developed

FIGURE 3

Governance models of tropical (carrageenan) seaweed value chains



Has not been sustainable. Vertically integrated enterprises control value chain functions.

Farmers link directly with company representatives.

Evolving toward “relational” mode for sustainability.

Controlled by firms that determine product specifications and trade rules.

Farmers link through integrated supplierrs.

Substantially cut off from direct links with processors.

Little or no provision for building value chain sustainibility.

“Arm’s length” transactions between buyers & sellers.

Farmers link mainly through two or more layers of collectors & traders.

Developing as a means toward value chain sustainibility.

Typified by development of tactical and strategic alliances.

Enterprises with farmer equity or control link directly to processors with assistance from business development and support services.

in less accessible island locations, multiple levels of trading proliferated. Although they added little value, agents and officials were in a position to collect rents and gain trading advantage through their possession of capital and information. Competition for reliable *Kappaphycus* sources intensified greatly as market demand could not be met by seaweed supplies. Market-driven value chains functioned poorly for performance ingredients such as carrageenan. Systems that once enabled third-party buyers to trace and control quality broke down. Farmers were substantially cut off from direct links with processors and to some extent they were also isolated from integrated suppliers. Most market links were through two or more layers of collectors and traders. Market governance has tended to be “of the moment” and has not supported mechanisms leading towards sustainability. At the time of writing, at least 88 substantial processors in at least 18 countries were capable of producing carrageenan and/or agar. Few of these companies have built direct or modular value chain links. The disintegration of exclusive value chain relationships caused side-selling to become a major problem both for the original "big three" companies and for subsequent entrants as well. Investments in process and farm development were curtailed by the mid-1990s because investments could no longer be protected and internalized by private investors. By 2008, it became clear to many in business, government and aid organizations that something was broken in the seaweed-to-hydrocolloid value chains. Supply and demand disconnects in the cottonii trade led to unprecedented instability and high prices for cottonii. Prior to 2008, prices had been fairly stable. Prices fluctuated markedly in the period 2008–09.

Phase four of RAGS value chain development evolved as relational governance showed promise for building value chain sustainability. Relational value chains are typified by development of tactical and strategic alliances. Development has been facilitated by aid agencies and business development services (BDSs) since about 2003 when the International Finance Corporation – Program for Eastern Indonesia SME Assistance (IFC-PENSA) programme began. Aggregation of farmers into enterprise units such as cooperatives enabled them to acquire the critical mass necessary for participating in regional and global value chains. Meanwhile, the processing sector consolidated in China even as new processors began to move value addition towards Indonesia. Market pressure towards sustainability and fair trade increased the need for transparent links from source to solution and that, in turn, stimulated the development of relational linkages. At the time of writing, farm development and processing were beginning to move towards integrated systems. Transparent standards were developing regionally and globally. Enterprises with farmer equity or control were beginning to link directly to processors with assistance from BDSs.

Characteristics of seaweed value chains in Indonesia

Basic post-harvest treatment procedures for RAGS seaweed farmers are covered in Neish *et al.* (2009). Cottonii and spinosum are dried before shipment to further-processing facilities. Industry standard is about 38 percent moisture. Individual transactions may involve specifications as low as 30 percent or as high as the trading environment permits. Attempts at finding better and more cost-effective all-season drying options are a persistent industry preoccupation. Depending on weather conditions and plant density, cottonii and spinosum can typically be dried in 2–3 days under tropical conditions. Plants must be turned over frequently. Wet-to-dry ratios vary between species and locations but generally range from 6:1 to 9:1. Cottonii and spinosum are almost universally dried under the sun before they are packed and shipped for further processing. The basic rules for producing raw dried seaweed (RDS) of export quality are: clean the materials properly; dry the material to below 38 percent moisture; do not salt the crop; do not play "trading games" such as adding water and contaminants.

During cleaning and re-drying there are some steps that are generally applicable and others that are optional. Raffia, rope and other materials used during farming activities can cause processing problems and product contamination, so they should be removed. Seaweeds other than the desired crop ("junk weed"), debris and other contaminants or adulterants should be removed as much as possible, especially if they can have critical effects on quality (e.g. a spinosum + cottonii mix may be useless for processing). Sand and stones cause equipment fouling, wear and tear, so they must be removed. Mud, dirt and other particulate contaminants should also be removed. Seaweed salt removal is optional. The natural potassium chloride in cottonii has a role in processing so it can be left in the crop.

In Indonesia, almost all seaweed is dried under the sun. Four main types of drying apparatus are employed and all are suitable provided that the seaweed is kept clean during the drying process. The types of apparatus are: concrete slabs sloped so they have good drainage; tarpaulins or plastic placed on flat ground; platforms or flakes ("para-para") made from wood or bamboo and covered with fine netting; and wooden or bamboo racks that are used to hang lines with the cuttings still attached.

The functions of local trading and collecting are performed by local entrepreneurs, farmers groups, farmers cooperatives or farmers credit unions. All farmers interviewed during the present study sold their seaweed to buyers located in their village of residence. Overall, 88 percent said that they usually sold to the same collector, 59 percent sold to independent collectors, and 41 percent sold to their cooperative or credit union (Table 1).

Price was cited by 52 percent of farmers as a major factor in choosing buyers but 68 percent said that the buyer was a friend or relative and 45 percent said they had contracts with buyers (Table 1).

TABLE 1
Selling practices of 66 farmers interviewed in 4 provinces of Indonesia in 2007–08

	Sell to					Buyer choice by			
	Collector	**Co-op**	**Credit union**	**Exporter**	**Same buyer**	**Price**	**No QC**	**Friend**	**Contract**
South Sulawesi (N = 8)									
Sum	8	0	0	1	6	8	2	7	1
%	100	0	0	13	75	100	25	88	13
Bali (N = 8)									
Sum	8	0	0	0	4	3	1	6	1
%	100	0	0	0	50	38	13	75	13
NTT (N = 34)									
Sum	23	11	0	0	32	24	1	17	12
%	68	32	0	0	94	71	3	50	35
South Central Sulawesi (N = 16)									
Sum	0	0	16	0	16	0	0	16	16
%	0	0	100	0	100	0	0	100	100
Total (N = 66)									
Sum	39	11	16	1	58	34	4	45	30
%	59	17	24	2	88	52	6	68	45

Note: QC = quality control.
Source: Seaplant.net survey.

The first link in seaweed-based value chains is usually from farmers to collectors. As indicated in Table 1, all farmers in South Sulawesi and Bali sold their seaweed to collectors. Most collectors were entrepreneurs from the villages where they bought seaweed. Many were or had been active seaweed farmers. Most financed their operations with their own capital although some had cash advances from seaweed processors or traders.

Farmers' responses indicated that trust and commitment were important components of the link between farmers and collectors. In the survey, 66 farmers were interviewed using methods similar to those used in a study by Gan (2003) on farmer-to-collector links in tropical seaweed aquaculture in Asia.[3] The results indicate, in general, a high degree of trust and commitment between farmers and collectors (Table 2).

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[3] The Gan (2003) study showed that seaweed collectors in Indonesia (as well as the Philippines) tended to deal with farmers from the same ethnic backgrounds and home villages that they came from. Many were current or former seaweed farmers who developed as lead farmers, then as collectors. It appears that in the seaweed industry of Indonesia, trust–commitment mechanisms have led to value chain development within established local communities.

TABLE 2
Overall farmer trust and commitment to the collector

Trust and commitment	SS (N = 8)		Bali (N = 8)		NTT (N = 34)		SCS (N = 16)		Overall (N = 66)	
	Av.	SD	Av.	SD	Av.	SD	Av.	SD	Av.	SD
Trust										
I can always trust the buyer	7.00	0.00	5.00	1.69	6.15	1.46	7.00	0.00	6.32	1.34
The buyer has high integrity	7.00	0.00	5.13	0.99	6.09	1.46	7.00	0.00	6.30	1.25
The buyer keeps promises	6.25	1.39	5.75	1.75	5.68	1.63	7.00	0.00	6.08	1.48
When making an important decision, the buyer also considers my interests	7.00	0.00	5.00	1.31	5.62	1.92	5.13	0.50	5.59	1.57
The buyer is always honest with us	6.25	1.39	5.50	1.77	5.68	1.65	7.00	0.00	6.05	1.50
High level of trust has been developed between me and the buyer	6.25	1.39	5.50	1.20	5.74	1.68	7.00	0.00	6.08	1.45
The buyer considers it important that I am successful	6.63	1.06	4.88	1.73	5.82	1.49	7.00	0.00	6.09	1.42
There is no reason for me to be suspicious of the buyer	5.88	1.55	3.75	2.05	5.56	1.56	7.00	0.00	5.73	1.69
Commitment										
I have a strong commitment to this buyer	7.00	0.00	5.50	1.41	5.85	1.60	7.00	0.00	6.23	1.37
I intend to maintain and develop this relationship	7.00	0.00	6.50	0.76	6.41	1.13	7.00	0.00	6.64	0.89
This relationship requires maximum effort and involvement	7.00	0.00	6.13	0.99	6.76	0.70	7.00	0.00	6.77	0.65
I am fully open and honest in the relationship with the buyer	7.00	0.00	6.38	1.41	5.97	1.38	7.00	0.00	6.39	1.19
The buyer spends enough energy in our relationship	7.00	0.00	6.38	0.74	3.91	0.79	7.00	0.00	5.33	1.61
I often feel satisfied in the cooperation with the buyer	7.00	0.00	4.75	2.31	6.59	1.02	7.00	0.00	6.52	1.26

Notes: SS = South Sulawesi; NTT = Nusa Tenggara Timur; SCS = South Central Sulawesi; Av. = average; SD = standard deviation. A seven-point Likert scale is used: 1 = strongly disagree; 4 = neither disagree nor agree; 7 = strongly agree.
Source: Seaplant.net survey.

Generally, several collectors fed into a central trading centre where seaweeds were weighed, bagged and shipped. As an example, the operation of a major local trader in Bulukumba, South Sulawesi, is summarized as follows and in Table 3:

- The volume of business for this trader averaged about 100 tonnes per month (maximum 200 tonnes and minimum 80 tonnes).
- Seaweed from farmers was received by 11 collectors and also at the central trading centre.
- Cash advances totalling about USD25 000 were distributed by the trader to 66 people (both collectors and farmers). The source of funds was the trader's own capital and also some cash advances from buyers.
- Advances were repaid in the form of seaweed. At each delivery, about 10 percent was allocated to cash advance repayment. The same price was paid to farmers whether or not they had a cash advance.
- People were paid on a piecework basis to sort and stuff sacks (average capacity of 60 kg) at a rate of USD0.50 per sack. The cost of each sack was about USD0.20, thus the total cost of sorting and sacking was about USD12/tonne.
- The cost of loading a truck and sending 5 tonnes of seaweed to Makassar was about USD20/tonne.
- Remuneration received by collectors and traders was variable but generally not more than 5 percent of seaweed price. At low, average and high price levels, trader

TABLE 3
An example of monthly seaweed volume, capital requirement and added costs from farmgate to market for a local trader in South Sulawesi

Scenarios	Low price	Medium price	High price
Trader volume and capital			
Cottonii purchased per month (tonnes)	100	100	100
Seaweed farm gate price (USD/tonne)	500	850	1 200
Monthly cash to buy seaweed (USD)	50 000	85 000	120 000
Advances to farmers and collectors (USD)	25 000	25 000	25 000
Costs per tonne marketed (USD/tonne)			
Cost of sorting and sacking	12	12	12
Cost of transport to market	20	20	20
Collector and trader fees	25	43	60
Shrinkage from sorting and re-drying	50	85	120
Cost of baling	25	25	25
Total added costs	**132**	**185**	**237**
All-in costs per tonne (USD/tonne)	**632**	**1 035**	**1 437**
Added costs as a percentage of total cost (%)	**21**	**18**	**16**

and collector fees would therefore have amounted to about USD25, USD43 and USD60 per tonne, respectively.

- Export prices or prices to processing plants generally specified a moisture content averaging not more than 38 percent. Seaweeds delivered with higher moisture levels had to be re-dried by traders; typical shrinkage was of the order of 10 percent. Shrinkage costs at low, average and high price ranges would therefore have been of the order of USD50, USD85 and USD120/tonne, respectively.
- Most export shipments were packaged in compressed bales averaging 100 kg in weight at a cost of about USD25/tonne.
- Based on this example, the added costs of bringing seaweeds from farm to market at low, average and high price ranges was USD132, USD185 and USD237 per tonne, or 21, 18 and 16 percent of the all-in production cost of cottonii.

Most Indonesian cottonii and spinosum are currently exported as sun-dried seaweeds to be used as raw material for making refined or SRC.[4] This means that most of the value added in the seaweed processing has yet to be captured by the country. Indeed, as no significant economies of scale occur until the final milling, blending and laboratory testing steps of carrageenan production, a large portion of value addition in the seaweed processing can be realized in places close to seaweed cultivation areas, especially in locations where low-cost labour is available.

Keeping track of materials and energy balances is key to good carrageenan or agar process control. This requires effective testing and quality assurance programmes. Seaweed raw material is usually the major contributor to production costs, and optimizing raw material use is an exercise in balancing process inputs and outputs. A large shrinkage in weight and volume can occur as RAGS move along the value chain.

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[4] An overview of these processes is presented in Neish (2008b). In the past 30 years, a variety of trade names has been used for the alkali-modified "gel-mode" products of RAGS. The term "SRC" (semi-refined carrageenan) came into general use in the marketplace around 1978 and it is still commonly used in the trade. The defining characteristic of SRC is that it is reduced to final product form without being dissolved in water; hence, without having fibre removed. This type of process enables the product to be recovered using low-cost water-removal methods. The SRC process is an attenuated version of processes used in the manufacture of some kinds of clarified agar and carrageenan extracts. It is one of a family of processes in which alkaline modification is done while the gum is in a gel (frozen) state rather than a sol (melted) state. The two types of processes are referred to as "gel-mode" and "sol-mode" processes.

It has been estimated that about 23 percent of cottonii is recovered as SRC, with the balance lost during processing. Almost all "waste" from this process can be utilized as agricultural nutrients and/or can be recycled to the SRC process. It is this phenomenon that introduces complexities into trading dynamics and process economics and provides an incentive for ongoing innovation and optimization of value-chain structure. An examination of cost partitioning provides further insight into the drivers behind such developments.

In Indonesia, SRC for pet food or human food usage is the most common form of carrageenan manufactured. At the time of writing, the cost of SRC production for a typical Indonesian factory was about USD1 500/tonne, excluding the cost of seaweed. In the past five years, the price of RDS cottonii to local processors has ranged from a low of about USD500/tonne to a high of about USD1 600/tonne. Assuming a 25 percent yield from RDS to SRC,[5] the cost of making SRC would be about USD3 500/tonne and USD7 900/tonne with an RDS cost of USD500/tonne and USD1 600/tonne, respectively. Thus, cottonii represents 57 percent of production cost at the low RDS price and 81 percent of production cost at the high RDS price.

Transportation costs and a proliferation of collecting or trading links can boost RDS cost significantly. At the time of writing, shipping baled RDS (at 20 tonnes per 20-foot [6-m] container) cost in the order of USD30/tonne from Indonesia to the south of China, and about twice that amount to Europe. Moreover, local shipping in Indonesia can add substantially to RDS cost. Moving RDS from feeder hubs to major hubs can cost more than shipping from major hubs to overseas destinations. In addition, with each step in the chain, there is a high risk of losses, shrinkage and trading games. In addition, some jurisdictions impose levies on RDS transported through their ports or roads; unofficial rent-seeking activities can also add appreciably to RDS cost.

If effective technology and quality controls are in place, economics favour the production of SRC near seaweed sources. The following comparative advantages can amount to hundreds of US dollar per tonne. The advantages of source-based processing are: shortening supply lines can save tens of US dollars per tonne on all-in RDS costs, which can easily translate to several hundred US dollars per tonne in SRC chips or powder cost, near-source processors can minimize trading games, seaweed sources are usually in areas with low-cost labour and abundant sunlight that is useful for drying, processing near sources minimizes handling and process steps associated with drying and packing.

At the time of writing, at least 16 processing plants in Indonesia were capable of making SRC or refined carrageenan (RC). It remained to be seen whether Indonesia could follow the pattern of the Philippines and evolve towards exporting value-added products rather than RDS. The major determinant will be the commercial connections to China. China cannot grow substantial quantities of tropical RAGS such as cottonii. As of 2009, China imported tropical RDS and extracted carrageenan from them in China. Indonesian RAGS producers must find a way to sell carrageenan rather than selling raw seaweed in China if they aspire to progress up the value chain.

The worldwide distribution of plant capacity is difficult to determine accurately because most companies keep capacity information confidential. Based on McHugh (2003) and data collected by Seaplant.net, the approximate distribution as of 2009 is shown in Table 4. The data indicate substantial plant overcapacity for SRC, refined kappa carrageenan and agar. Because the same process lines can be configured to produce both agar and kappa carrageenan, agar factories represent latent kappa carrageenan capacity.

Links between the supply and the demand ends of seaweed-to-hydrocolloid value chains are being developed to increase resilience in the face of external value-chain

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[5] With good quality RDS, the yield could be as much as 35 percent.

TABLE 4
Estimated distribution of process plant capacity for agar and carrageenan as of 2009

Type	Europe	Africa	Americas	Indonesia	Philippines	China	Other Asia	Total
	(tonnes/year)							
Agar	780	1 050	3 000	4 000	200	4 000	1 500	14 350
RC	13 100	0	8 050	750	2 700	10 000	1 000	35 600
SRC	500	0	1 100	11 080	19 600	3 000	2 000	37 280

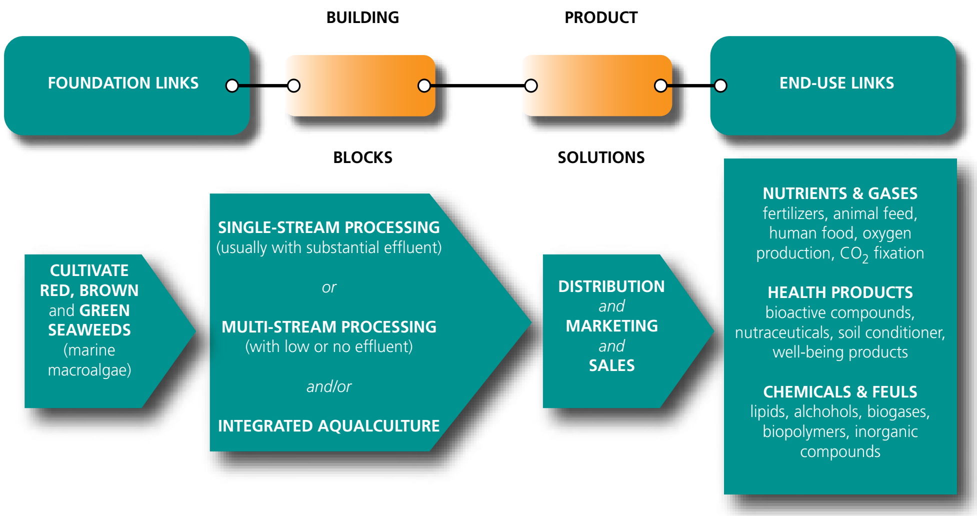
Source: Adapted and updated from McHugh (2003).

shocks such as unstable price and quality related to supply and demand imbalances. Such linkages are also being strengthened in order to make sure that seaweed products remain competitive against competing products in the world marketplace in uncertain economic times.

As of 2009, single-stream processing was the norm for cottonii, spinosum and *Gracilaria*. Seaweeds were generally dried and shipped as a raw product; typical gum yields ranged from as low as 8 percent to as high as 30 percent or more. About 70–92 percent of seaweed weight shipped entered waste streams at the site of processing. Multistream processing is an innovation that could have positive impacts on the competitiveness of tropical seaweed products. Processing could involve the use of small-scale facilities and appropriate technology in places near farms. This would ensure that very little would go to waste. The nutrient component of seaweeds could be extracted for local use or processed for export. The gum component could be shipped as a high-yielding, low-waste concentrate or could be processed into finished form in "mini-factories" (Figure 4).

Seaweed-to-hydrocolloid value chains were opaque and farmers had little knowledge of the value chains they sold to until the advent of cell phones and the Internet. In the past decade, farmers have become connected to the world through cell phones and computers so a wide range of knowledge, information, tools and solutions (KITS) is available to them, including open price information online at www.jasuda.com. Seaweed processors can now buy directly from farmer enterprises in a fully traceable manner if they wish to do so.

FIGURE 4
Evolution of processing



Source: Neish (2008a).

Since June 2008, the seaweed Web sites www.seaplant.net and www.jasuda.net have been operated by Seaplant.net Foundation as Web-based BDS platforms. The sites were able to undertake commercial transactions for sale of items such as e-books; however, seaweed was never sold through the sites. Rather, contacts made through the site were the means by which seaweed transactions took place.

Within Indonesia, logistics networks that connected farmers to market centres were mainly sea-based and were well developed. Seaweeds were transported along centuries-old trade routes. Ethnic groups prominent in seaweed farming were also among those with a historical role in sea transport, notably the Bugis, Makassar and Buton.

South Sulawesi and Bali are examples of regions where land transport brings seaweeds to market. In both cases, roads were near to seaweed farms and trucking services were readily available. In South Sulawesi, seaweed farms were visible from the highway at many locations and seaweed could be seen drying beside the road.

Many value chain stakeholders complained that domestic freight was too expensive along some trade routes, especially on short-haul local connections by sea. As a result, some seaweed enterprises such as farmer cooperatives were undertaking transport functions themselves.

3. CARRAGEENAN SEAWEED FARMING: ECONOMIC AND SOCIAL PERFORMANCE

3.1 Economic performance

Technology and productivity

Almost all cottonii and spinosum farm systems involve attaching cuttings to lines made from ropes, strings or strappings, which can be suspended in the sea using habitats with a variety of configurations and orientations. In the case of *Gracilaria*, it is common to place cuttings loosely in terrestrial ponds (“tambak”).

In the areas of focus for the present study: (i) farmers in South Sulawesi and NTT generally utilize rafts at or near sea surface suspended by bamboo frames or plastic floats; (ii) farmers in Bali generally use off-bottom horizontal “short-stake” systems or small bamboo rafts (about 5-m long); and (iii) farmers in South Central Sulawesi utilize horizontal long-stake systems. The spacing of cuttings on lines is generally about 10–20 cm in all regions but varies substantially between regions. The norm is 20 cm in Bali and more than 1 m in NTT.

The average production of farms under survey was about 6.3 tonnes per year and 1.1 tonnes per kilometre of lines or 10.9 tonnes/ha.[6] The scale of operation varied across regions from an average of 2.7 km of lines for the surveyed farms in South Central Sulawesi to 10.8 km in South Sulawesi, as did the productivity from average 0.55 tonnes/km of lines in South Sulawesi to 1.68 tonnes/km in NTT. In terms of area, the average farm size varies from about 0.11 ha in Bali to 0.99 ha in South Sulawesi; and the productivity from 6 tonnes/ha in South Sulawesi to almost 60 tonnes/ha in Bali (Table 5).

It has been proposed in theory and demonstrated in practice (Neish *et al*., 2009) that large cuttings yield higher productivity per kilometre of line than small cuttings, provided that plants are harvested before they become so large as to break up. The use of large cuttings (about 150 g) is widespread in the Philippines and some parts of Indonesia (e.g. NTT and Bali) but other regions of Indonesia, notably South Sulawesi, tend to use small cuttings, sometimes with an average size of less than 50 g. The

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[6] An average floating farm in South Sulawesi utilized 442 lines with an average length of 24 m and had lines spaced 93 cm apart. A farm such as this would occupy about almost 1 ha of sea surface. In NTT, an average farm had 101 lines with an average length of 37 m spaced 135 cm apart. Such a farm would occupy about 0.5 ha of sea surface. In Bali, lines were short and spaced closely. The average Balinese farm had 1 107 lines with an average length of 5 m spaced only 20 cm apart and occupying about 0.1 ha. In South Central Sulawesi, an average farm had 62 lines with an average length of 58 m spaced 100 cm apart. Such a farm would occupy about 0.4 ha of sea surface.

TABLE 5
Productivity of surveyed cottonii farmers in Indonesia

Region	Farming system	Annual farm production (tonnes/ year)	Average scale of operation		Average productivity	
			Km of line	ha	Tonnes/km of lines	Tonnes/ha
South Sulawesi	Floating	5.9	10.8	0.99	0.55	6.0
Bali	Off-bottom (short-stake)	6.6	5.3	0.11	1.25	59.6
Nusa Tenggara Timur (NTT)	Floating	5.7	3.4	0.50	1.68	11.3
South Central Sulawesi	Off-bottom (Long-stake)	3.1	2.7	0.36	1.15	8.6
All		6.3	5.8	0.58	1.09	10.9

reason given by farmers in South Sulawesi was that they tended to pay workers on a piecework basis computed against lines planted. When there is insufficient biomass to enable the use of large cuttings, they use small ones in order to keep the pieceworkers (usually close female relatives of the farmers) content.

There are several reports of RAGS productivity in the literature (Neish *et al*., 2009). In regions with their best growth during the east monsoon, yields peaked in June and July, and the inverse occurred with regions with the best growth during the west monsoon; yields peaked in December and January.

Capital costs

Most Indonesian seaweed farms are "shoestring" operations that employ an absolute minimum of capital. They borrow, share or rent the more expensive items required for seaweed production. For *Gracilaria*, the predominant method is to place cultivar biomass as a by-crop in ponds constructed for growing prawns or milkfish. The following discussion therefore focuses on cottonii.

Lines, floats and anchors

Substrate is a major capital item for seaweed farms in Indonesia. Polypropylene (PP) line is the predominant material used. The cost of PP line depends on its diameter, so farmers tend to use the smallest diameter (usually 4–6 mm). Because PP lines degrade under direct sunlight, they are submerged or protected as much as possible (lasting from one to three years depending on care of use). Plants are generally attached to the main lines using loops made from 1mm PP strings (Table 6).

Farm equipment and facilities

In Indonesia, most nearshore areas are public property not available for outright ownership. The same applies to farm locations in the sea. Farm sites and foreshore work areas are made available to local farmers by agreement among citizens of the village claiming jurisdiction over the sites. In general, there is no formal system of leasing.

Most farms in Indonesia are in close proximity to the villages where farmers reside. It is common practice for houses to be built on stilts with a work and storage area underneath; it is in these areas where farm activities (e.g. attaching cuttings to lines) are carried out. Such activities can also be carried out under a tented lean-to or a tarpaulin or leaf-covered open-sided shelter. The cost of such shelters for a typical farm with 6 km of lines is about USD200 (Table 7).

Drying is done on net-covered platforms (also known as "flakes" or "para-para"), on tarpaulins spread over the ground, or on bamboo racks about 2 m high. The cost of drying facilities per 6 km of planted lines (one average farm) is about USD150 (Table 7).

TABLE 6

Initial Investment for one kilometre of line for a floating habitat system

Item	Number	Units	USD/unit	Total cost (USD)	Life span (years)
1 km (13.6 kg) of 5-mm PP line	1	km	34.00	34.00	2
0.2 km (11 kg) of 10-mm PP line	0.2	km	136.00	27.20	2
0.2 km (9 kg) of 8-mm PP line	0.2	km	114.00	22.80	2
1 km of 1-mm PP line (for loops)	1	km	1.00	1.00	2
Plastic bottles as floats	500	pieces	0.03	15.00	2
Sandbag anchors	50	pieces	0.15	7.50	2
Total investment for 1 km of line				**107.50**	
Live cuttings as initial biomass	**800**	**kg**	**0.24**	**192.00**	

TABLE 7

Farm equipment and facilities reported by farmers interviewed in South Sulawesi in September 2009

Item	Number	Units	USD/unit	Total cost (USD)	Life span (years)
A nuclear farm (6 km of lines)					
Vehicle and equipment				**650**	
- 9-m canoe with 5.5-hp motor	1	unit	500.00	500	5
- Miscellaneous tools and equipment	1	set	150.00	150	5
Shelter and post-harvest treatment				**366**	
- Drying facilities	1	set	150.00	150	5
- Shelter for shade while working	1	set	200.00	200	5
- Sacks	200	pieces	0.08	16	2
Total				**1 016**	
A leader farm (30 km of lines)					
Vehicle and equipment				**1 600**	
- 9-m canoe with 5.5-hp motor	2	unit	500.00	1 000	5
- 6-m canoe with no motor	2	unit	150.00	300	5
- Miscellaneous tools and equipment	2	set	150.00	300	5
Shelter and post-harvest treatment				**2 264**	
- Drying facility	4	set	150.00	600	5
- Shelter for shade while working	2	set	800.00	1 600	5
- Sacks	800	pieces	0.08	64	2
Total				**3 864**	

It was observed that shelters and post-harvest treatment facilities were used not only for seaweed farming but also for other economic activities, including drying fish and land crops such as maize, rice, fruits, vegetables and coconuts (copra). It was also observed that these facilities were shared among individuals within farmer groups (Table 7).

Seaweed farms in Indonesia rarely include vehicles as part of their capital equipment. Some farmers own motorcycles for their personal use but seaweeds are transported using hired vehicles. Seaweed buyers usually pick up the dried crop from farmers. Most farmers own small boats or canoes ("sampan"). Boats are used for other activities in addition to seaweed farming, notably for fishing and transport. The two most common classes of boats are 6–9 m unpowered canoes and 8–12 m powered canoes. Generally, the unpowered canoes cost less than USD300 while powered boats cost about USD500 (Table 7).

Most family farms have little or no expenses on energy or handling equipment. Electricity is available in many farm villages for at least part of each day but appliances, equipment and tools powered by electricity play no direct role in seaweed farming. Handling and weighing equipment is generally supplied by firms that perform the collection, trading and processing functions. Farmers usually own simple tools with which to perform maintenance functions and two or three jerry cans for storing fuel. The total cost of such miscellaneous tools and equipment was about USD150 for an average farm with 6 km of lines (Table 7).

TABLE 8
Capital investments of two floating seaweed farms based on farmer interviews in South Sulawesi in September 2009

Items of capital investments	Initial investment		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)
A nuclear farm (6 km of lines)						
Farming system (lines, floats and anchors)	645	39	323	61	108	54
Vehicle and equipment	650	39	130	24	108	22
Shelter and post-harvest treatment	366	22	78	15	61	13
Total	1 661	100	531	100	277	89
A leader farm (30 km of lines)						
Farming system (lines, floats and anchors)	3 225	45	1 613	67	108	54
Vehicle and equipment	1 600	23	320	13	53	11
Shelter and post-harvest treatment	2 264	32	472	20	75	16
Total	7 089	100	2 405	100	236	80

Note: Numbers may not add up due to rounding.
Source: Calculation and amortization based on Table 6 and 7.

Summary

Based on Tables 6 and 7, the capital investments for a 6-km nuclear farm and a 30-km leader farm under survey are summarized in Table 8. The results indicate that the farming system (including lines, floats and anchors) costs about USD54 per kilometre. They represent a main capital investment, accounting for 39 percent and 45 percent of the total initial investments of the 6-km farm and 30-km farm, respectively. As the life span of the farming system (2 years) is shorter than other capital investments (generally 5 years), the share of farming system in the amortized annual capital cost (61 and 67 percent for the 6-km and 30-km farms, respectively) is higher than its share in the total initial investment.[7]

Variable costs

Material cost

Live seaweed cuttings that are "planted" on the farming system is the main variable cost of a seaweed farm. For example, farmers in South Sulawesi reported that initial seaweed biomass per kilometre of planted line was about 800 kg at the cost of USD0.24/kg or so. Thus, the cost of live seaweed cuttings of a newly planted line is about USD192/km, which is more than two times of the annual capital cost per kilometre indicated in Table 7 (USD89/km and USD80/km for the 6 km and 30 km farms, respectively).

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[7] The share of farming system in annual capital cost would be even higher considering the fact that vehicles, shelters and drying facilities are also used for non-seaweed farming activities.

A typical farmer would usually purchase enough replanting biomass to stock about 1 km of line and propagate cuttings from that initial biomass. Under this situation, the cost of seaweed cuttings would be the same (i.e. USD192) for seaweed farms with different scales of operation. The problem with this approach is that insufficient quantities of seaweed are available for sale at the time that biomass is being built up. In fact, cultivar biomass was in chronic short supply for several years. Most farmers have developed their farms to full size gradually over 2–3 years by starting with a small quantity of cultivars. In several areas, it has been possible for farmers to maintain sufficient cultivar biomass all year round so they have not had to buy cultivars once their farms were up and running. Some of these farms have been able to act as "nurseries" and sold cultivars to farmers from more seasonal locations.

Other notable material costs include costs for fuel and maintenance, which were about USD134 for the 6 km farm under survey (Table 9) and USD450 for the 30km farm (Table 10).

TABLE 9
Initial cash costs for starting a 6 km floating nuclear model seaweed farm based on interviews of farmers in South Sulawesi in September 2009

Cost items	Number	Units	Unit cost (USD/unit)	Initial costs (USD)	Initial cost per kilometre (USD/km)
Cash costs for materials (1)				**326.4**	**54.4**
- Initial live cuttings	800	kg	0.24	192.0	
- Fuel per boat	12	months	1.20	14.4	
- Maintenance per boat	12	months	5.00	60.0	
- Other farm maintenance	12	months	5.00	60.0	
Cash costs for labour (2)				**288.0**	**48.0**
- Attaching cuttings to lines	6	km	48.00	288.0	
Variable cash cost (3)				**614.4**	**102.4**
Fixed cash cost (4)				**1 661.0**	**276.8**
Total cash cost (5)				**2 275.4**	**379.2**

Notes: (3) = (1) + (2); (4) from Table 8; (5) = (3) + (4). Numbers may not add up due to rounding.

Labour cost

Labour is another main variable cost of farm operations. Because most farms in the survey were nuclear family businesses, labour was usually compensated by a share in farm proceeds. In some areas (e.g. Bali), it is normal practice for farmers to tend their plots personally with help from nuclear family members or friends and to plant and harvest small portions of the farm several times per month.

At the other extreme, notably in South Sulawesi, it is common practice for farmers to plant their entire farm area – or a large portion of it – at one time, then to harvest the entire amount at the end of the cropping cycle (usually reported to be 45 days). In such cases, it is common for farmers to hire people on a piecework basis for the attachment of cuttings to the lines.[8]

The normal labour cost for attaching cuttings to the lines is USD0.15 per line, which translates to USD6/km per cropping and USD48 per annum per kilometre over 8 annual cropping cycles of 45 days each. Therefore, the annual labour cost for a 6 km farm that hires people to attach cuttings to the lines is USD288/year (Table 9).

In the case of "leader model" farms, all labour-intensive tasks (e.g. attaching cuttings to lines, placing lines in sea, removing lines from sea, and drying the crop) were paid for on a piecework basis (Table 10).

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[8] In several cases, farmers in groups share labour rather than paying piecework wages.

TABLE 10

Initial cash costs for starting a 30 km floating nuclear model seaweed farm based on interviews of farmers in South Sulawesi in September 2009

Cost items	Number	Units	Unite(USD/ unit)	Initial costs (USD)	Initial cost per kilometre (USD/km)
Cash cost for materials (1)				**640.8**	**21.36**
- Initial live cuttings	800	kg	0.24	192.0	
- Fuel (2 boats)	12	months	2.40	28.8	
- Maintenance (2 boats)	12	months	10.00	120.0	
- Other farm maintenance	12	months	25.00	300.0	
Cash cost for labour (2)				**4 320.0**	**144.00**
- Attaching cuttings to lines	30	km	48.00	1 440.0	
- Placing lines in sea	30	km	32.00	960.0	
- Removing lines from sea	30	km	32.00	960.0	
- Drying the crop	30	km	32.00	960.0	
Variable cash cost (3)				**4 960.8**	**165.36**
Fixed cash cost (4)				**7 089.0**	**236.30**
Total cash cost (5)				**12 049.8**	**401.66**

Notes: (3) = (1) + (2); (4) from Table 8; (5) = (3) + (4). Numbers may not add up due to rounding.

Initial cash costs

Tables 9 and 10 summarize the first-year cash costs for starting a 6 km and 30 km farm, respectively. The results indicate that it would cost about USD2 275 to finance the first year operation of a 6 km nuclear farm (USD379/km on average) and USD12 050 to finance a 30 km leader farm (USD402/km on average).

Revenues and cash flows

The average productivity of the farms under survey is 6.3 tonnes per year (Table 5), which could generate gross revenues of about USD3 200, USD5 400 and USD7 600 for low price USD500/tonne, medium price USD850/tonne and high price USD1 200/tonne, respectively.

Annual revenues (gross receipts) calculated for the exemplary 6 km nuclear farm and the 30 km leader farm are shown in Table 11. Based on these calculations, budgets were developed and cash flow estimates were generated for year 1 and years 2 to n. These examples assumed that a farmer built up biomass and that the farm reached full production during the first year of operation, with the same production level being maintained from the second year on.

Table 12 shows calculated cash flow summaries for six farm management cases. Cases 1–5 assume a nuclear model farm with 6 km of planted lines and annual production averaging 6.6 tonnes of raw dried cottonii. Case 6 is based on a leader model farm with 30 km of planted lines and annual production averaging 33 tonnes of raw dried cottonii. Differences among cases are explained below:

- Case 1: All labour supplied by the family, and cuttings biomass self-generated starting in year 1.
- Case 2. All labour supplied by the family, and cuttings biomass self-generated after year 1 (i.e. the farm buys start-up biomass).
- Case 3. All labour supplied by the family, and cuttings biomass self-generated after year 1. Cost of floating structures, equipment and facilities assumed to be 50 percent higher than the budgeted examples in Tables 5 and 6.
- Case 4. All labour supplied by the family, and cuttings biomass self-generated after year 1. Cost of floating structures, equipment and facilities assumed to be 50 percent lower than the budgeted example.

TABLE 11
Annual sales of floating seaweed farms based on interviews conducted in South Sulawesi in September 2009

Item	Type of farm	
	Nuclear	Leader
Total length of planted lines (km)	6	30
Number of 45-day cycles per year	8	8
Annual farm yield (tonnes)	6.6	33
If crop price was 500 USD/tonne, then annual total sales (USD) were	3 300	16 500
If crop price was 850 USD/tonne, then annual total sales (USD) were	5 610	28 050
If crop price was 1 200 USD/tonne, then annual total sales (USD) were	7 920	39 600

Note: Sales are shown for low (USD500/tonne), average (USD850/tonne) and high (USD1 200/tonne) farm price levels observed in 2007–09.

TABLE 12
Annual cash balance for six farm management cases, assuming low, average and high price levels as observed in 2007–09

	Year 1			Year 2…n			Farm model
	USD500/ tonne	USD850/ tonne	USD1 200/ tonne	USD500/ tonne	USD850/ tonne	USD1 200/ tonne	
Case 1	837	2 801	4 764	2 498	4 462	6 425	nuclear
Case 2	-315	1 649	3 612	2 498	4 462	6 425	nuclear
Case 3	-1 105	858	2 822	2 538	4 502	6 465	nuclear
Case 4	476	2 440	4 403	2 459	4 422	6 386	nuclear
Case 5	–633	1 331	3 294	1 988	3 952	5 915	nuclear
Case 6	-4 776	5 041	14 859	8 073	17 890	27 708	leader

- Case 5. Outside labour used to attach cuttings; biomass augmented by purchases from nurseries each year.
- Case 6. Outside labour used for attaching cuttings, placing lines, harvesting and drying. Biomass self-generated after year 1.

The cases highlight the following cash flow aspects of seaweed farms:

- Case 1 represents the most common situation in Indonesia for a nuclear model farm where all labour is supplied by the family and cuttings biomass is self-generated from cuttings provided by a third party such as relatives, friends, government or aid agencies. The farm covers all costs during the first year of operation and has a positive cash flow at all price levels.
- In case 2, the farm buys start-up biomass, which causes negative cash flows at the lowest prices in year 1 but positive cash flow at average or high prices.
- Cases 3 and 4 examine cash flow sensitivity to capital items. Conditions other than capital costs are the same as in Case 2. The average used in the examples was representative from floating systems in South Sulawesi, which are at the high end of farm system costs in Indonesia. If the cost of capital items increased by 50 percent (case 3), year 1 would yield a negative cash balance of more than USD1 000 in year 1 at the lowest price level. If capital costs were halved (Case 4), there would be a positive cash flow at all price levels in year 1.
- Case 5 generates a negative cash balance for year 1 at the low price but positive cash flow for the other price levels. In general, cash flows are lower than those observed under Case 1.
- Case 6 also assumes that the entire farm is initially stocked with purchased biomass in year 1. The lowest-price scenario generates a negative cash flow in year 1; nevertheless, higher prices lead to positive cash flows.

In sum, the above cash flow analysis indicates that seaweed farming in Indonesia is a highly profitable business.[9] Provided farmers can obtain enough funding to start the business, they can recover their initial investments in the second year in all the six cases discussed above even in the situation of relatively low seaweed prices. In Cases 1 and 4, they would be able to recover the initial investments in the first year. In the situation of medium and high prices, farmers would be able to recover their initial investments in the first year under all the six cases.

Financial resources

Sources of finance for 72 farmers interviewed for the present study are shown in Table 13. Use of own funds is the primary means of financing for these farmers. Government is another important funding source – about 40 percent of farmers had received grants or soft-money loans from government agencies such as the Department of Oceans and Fisheries (DKP). One-quarter of the interviewed farmers also obtained funding from friends and relatives. Credit unions or cooperatives provided funding to 19 percent of the interviewed farmers, while only 1 percent of the farmers received bank loans despite the fact that many farmers have bank accounts and electronic banking is readily available.

Some microfinance was made available to farmers by non-governmental organizations (NGOs) such as CARE in NTT and by the Indonesian government institution Permodalan Nasional Madani (PNM), which provides finance to micro, small and medium enterprises (MSMEs). Important financial support also comes in the form of grants and soft loans from the Indonesian government through DKP. Much of that assistance supports biomass purchases; it may also consist of donations of cultivar biomass.

One of the major obstacles for farmers seeking finance is their lack of collateral. Seaweed farm assets and seaweed crops are not viewed as satisfactory collateral by lending institutions; in addition, few farmers own real estate that can be used as collateral.

Crop insurance for seaweed is hardly available in Indonesia. However, in some cases, farmers have provided new biomass to other farmers that have lost their crops due to flooding. The Seaplant.net initiative of IFC-PENSA has mediated in such situations.

3.2 Social performance

Livelihoods

Average annual production of cottonii in farms surveyed in this study was 6.3 tonnes. If this number is taken as an average for all seaweed farms in Indonesia, then there are almost 20 000 farm units contributing seaweed for exports. Generally, each farm unit provided annual income to a family at an average level of about USD5 500 (gross) and

TABLE 13
Finance sources for 72 farmers interviewed during the present study

	Self	Friends or relatives	Coop or credit union	Collector or trader	Government	Bank
Number	72	18	14	6	29	1
Percentage	100	25	19	8	40	1

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[9] Cash flows do not exactly reflect profitability from an accounting perspective. However, for Indonesian seaweed farming, profitability was most appropriately viewed in cash flow terms because capital investments are relatively low; and floating structures as the main capital investment tend to have relatively short life span. Hurtado *et al.* (2001) examined the economics of seaweed farming in the Philippines and evaluated farm profitability in terms of return on investment.

USD4 500 (net), for an average monthly net income of USD375. These are substantial income earnings for part-time work by a rural farm family, equivalent to the wages of a university-educated person working in a mid-level position in a government office. Not only was average annual income of interviewed farmers USD5 000, but the income was stable. In the best cultivation regions, crop production can take place year round. Harvesting and cash sales occur virtually every day.

The income from seaweed is accessible to marginalized segments of society. Many seaweed farming activities require light labour that can be undertaken near the farmers' residences. This creates income opportunities for both women with care-giving responsibilities, and old people. Seaweed farming and related value-adding activities are inherently suitable for MSMEs.

For those households that chose to rise above the average and made seaweed farming their dominant occupation, a monthly farm income of USD1 000 or higher could be achieved at average prices. High prices prevalent in 2008–09 resulted in substantial windfalls for many farmers but led to market uncertainty. For farmers that expanded into a "leader" model of operation, annual net incomes of the order of USD15 000–20 000 were achievable for operations about five times larger than the average nuclear farms. Such farms also tended to serve as nurseries to provide biomass for planting to other farmers.

It is difficult to quantify the degree to which seaweed farming has affected the socio-economic conditions of coastal communities because baseline studies pre-dating seaweed farming were unavailable at the time of writing. Anecdotal accounts by farmers indicate that seaweed culture was a major addition to their income. The presence of new houses, new motorcycles and other material possessions gave tangible indications of this added income. Other livelihood options available to these communities have tended to remain static or have declined during the time when seaweed farming developed. For example, nearshore fishing from small boats declined to the point of being viewed as a subsistence activity with reduced potential for generating cash income (Maarif and Jompa, 2007).

Economic returns from seaweed aquaculture compared with those of competing or complementary economic activities were not quantified in the present study; however, almost all farmers interviewed for the present study stated that seaweed provided most of their cash income despite the fact that it only took half or even less than half of their time.

Women and children

Women generally play an important role in seaweed farming. As a result, they sometimes become the main earner in the household, even if initially they had very little income. This can potentially lead to marital tensions. However, studies on impacts of seaweed farming indicate that such marital problems were few (Neish *et al.*, 2009). Another possible concern is the use of child labour. As in most agriculture, it is common practice for children to participate in farming activities. One must ensure that they are not exploited in this capacity.

Communication

The spread of cellular phone and Internet connectivity has virtually eliminated the isolation of seaweed farmers from global communication. Even a decade ago, most seaweed farmers had little connection to the outside world. As of 2009, seaweed farming generated enough revenue that most farm families had access to mobile phones. Cellular telephone connections were widespread throughout Indonesia and were developing steadily.

Internet connectivity has followed the development of mobile telephone technology so many seaweed farmers were able to connect either through their mobile phone or through available computers. From 2004 until 2008, the IFC-PENSA Seaplant.

net initiative developed peer-to-peer connections among Indonesian farmers by sponsoring workshops and by installing computer terminals at several locations in east Indonesia. Other aid agencies and NGOs supported similar efforts. Seaplant.net made KITS available globally through the English language Web site www.seaplant.net. KITS and farmer peer-to-peer communication tools were made available through the Bahasa Indonesia Web site www.jasuda.net. JaSuDa is an acronym of Jaringan Sumber Daya, which means "source net" in English. Both of these Web sites were continuing to serve seaweed farmers and other seaweed-based value chain stakeholders as of late 2009.

Education and training

Seaweed farming has provided access to education and training to poor coastal inhabitants. In the interviews, 44 farmers stated their level of formal education. Among that group, 1 farmer had no formal education, 24 had primary education, 9 had intermediate education and 10 had graduated from high school. The younger farmers tended to have more formal education than the older ones.

Since 2005, scientific and technical knowledge and information has been provided to seaweed farmers through the www.seaplant.net and the www.jasuda.net Web sites. Developed by the IFC-PENSA Seaplant.net Initiative, the Web sites have been operated by the Seaplant.net Foundation since 2008. Science and technology information and knowledge products have been available for downloading. The Web site content was developed subsequent to a meeting sponsored by the IFC and AusAID in Bali in May 2004. At that meeting, 138 seaweed farmers from all over Indonesia received IT training; the JaSuDa Web site has served since then to link Indonesian farmers together in a virtual community.

The Government organizations – including the BPPT and DKP – and seaweed-oriented NGOs such as APBIRLI, ASPERLI and the Indonesian Seaweed Society Association have also promoted community development among seaweed farmers. All of these entities joined together for the Seaweed International Business Forum and Exhibition held in Bali in October 2007 and the Indonesia Seaweed Forum held in Makassar, South Sulawesi, in October 2008. The Makassar forum attracted seaweed buyers from all over the world and also included special sessions for seaweed farmers.

The Seaplant.net training tools have been complemented with materials developed by other agencies, including INI RADEF, LIPI, DKP and BPPT. These materials have been used in farmer training programmes supported by several agencies, including AusAID, CARE, the CIPSED project of the Canadian International Development Agency (CIDA), the AMARTA project of USAID, GTZ, JICA, DKP, BPPT and PNM. Support for farmer training was also provided by the private sector. The GTZ promoted the development of research and development (R&D) linkages in the BIMP-EAGA region and also promoted the development of coordinated quality infrastructure systems in the region. These initiatives were mediated through the Seaplant.net Web site.

During industry gatherings and interviews for the present study, the need for ongoing technical training for farmers and peer-to-peer networking among farmers was recognized by stakeholders at all levels of seaweed-to-hydrocolloid value chains. Several governmental organizations, NGOs and private businesses continue to seek means for continuing education.

4. GOVERNANCE AND INSTITUTIONS

Farming of RAGS in Indonesia is an example of livelihoods being developed largely by seaweed farmer groups on their own initiative. Farms were built in response to strong "market pull" from biopolymer manufacturers who sought the cultivated raw seaweed sources essential to supplement limited wild-harvest sources. A reflexive, iterative approach to seaweed farm development occurred in Indonesia in concert with decentralization policies of the Government of Indonesia and traditional "adat"[10] forms of village government. Iterative cycling of information combined with reflexive action at the level of farmer groups brought about strong market linkages. These linkages, in turn, catalyzed rapid value chain initiation and extensive farm development.

Seaweed farms are planted along seashores in locations that are common property of all Indonesians. With respect to property issues, the government has attempted to regulate allocation of farm sites and to issue permits or titles; however, communities of farmers have generally sorted out tenancy issues among themselves at the village level.

4.1 Government, regulations and standards

Indonesia is divided into administrative entities in accordance with the provisions of Article 18 of the country's constitution. These entities are a manifestation of the decentralization principle, which has led to a transfer of responsibilities from the central government to regional governments. Decentralization policies support subnational entities as they regulate and manage their own affairs. The decentralization policy is complemented by a deconcentration policy that delegates responsibilities from the central government, governors, mayors and local offices of ministries to their officers at subnational levels.

The government organizations that deal most directly with seaweed farmers are the BPPT, DKP and KUKM. Others include BAPPEDA and LIPI. For seaweed farmers at the village level, decentralization and deconcentration policies have enabled them to interact with government units close to their homes. With due oversight from the responsible government agencies, village-level governing bodies have been able to implement substantial management over the seashores adjacent to their villages. In most villages where seaweed farming is undertaken, it has evolved into a major economic activity. The management of seaweed farming rights and operations is therefore integrated into the fabric of village life.

RAGS value chains in Indonesia are subject to two categories of regulations and standards that affect seaweed farmers, one on aquaculture in general and the other on carrageenan/agar processing specifically (Neish and Julianto, 2008).[11] Although standard protocols on aquaculture are at their inceptive stages, there are already some initiatives for RAGS value chain stakeholders, including: (i) EUREPGAP – Euro Retailer Produce Working Group (EUREP) on standards and procedures for the development of good aquaculture practices (GAPs) in conventional agriculture (general regulations, control points and compliance criteria for integrated aquaculture assurance); (ii) FAO Guidelines for Aquaculture Certification (under development at the time of writing); and (iii) quarantine protocols for tropical seaweeds such as those proposed by Sulu *et al.* (2004).

For RAGS products, legally defined product standards must be met; failure to comply means that products cannot be sold to customers or jurisdictions where the standards apply. Important regulatory documents include:

- European Union (Member Organization): European Union standards for E407a (Processed *Eucheuma* Seaweed) and E407 (Carrageenan);
- JECFA – FAO/World Health Organization: standards for Processed *Eucheuma* Seaweed and Carrageenan;
- Codex FAO;
- USFDA;
- HACCP Hazard Analytical Control Points requirements;

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[10] The term "adat" is roughly translated as "custom" or "tradition".

[11] The online version of the document provides links to current documents and sources.

- ISO 9001: 2000, Quality Management System;
- ISO 14001: 2004, Environmental Management System;
- ISO 22000: 2005, Food Safety Management;
- OHSAS 18001.

It is recognized that many RAGS standards are "commercial standards" that are best left to definition between buyers and sellers. In such cases, standards should not be imposed but guidelines can be of use. Examples include:

- PNCS – Philippine National Carrageenan Standard (under development), which is proposed as the basis for a BIMP-EAGA harmonized standard;
- CAC/GL 60-2006: Principle for Traceability/ Product Tracing as a Tool within a Food Inspection and Certification System;
- CAC/GL 38-2001 Rev.1-2005: Guidelines for Generic Official Certificates Formats and the Production and Issuance of Certificate;
- *Basic manufacturing practices for raw-dried seaweed and semi-refined carrageenan from* Eucheuma *and* Kappaphycus (Seaplant.net Monograph no. HB2G 1008 V2 BMP).

This is a starting point towards developing good manufacturing practice guidelines, especially for process steps that occur near seaweed sources and fall into the category of "post-harvest treatment" (Neish, 2008b).

4.2 Business alliances

With a supply that is globally dispersed and a demand that is globally diffuse, there are compelling reasons for the formation of business alliances among seaweed-related enterprises. Strategic alliances are trusting relationships that are often the only feasible option for MSMEs building long-term competitive advantages while retaining independence. Business alliances are essential for the profitable operation of seaweed farms and other functioning MSMEs within seaweed-to-hydrocolloid value chains. Although the formation of alliances can be costly and risky, such relationships can become important unique resources for MSMEs. A guide to alliance formation was available as a free download from Seaplant.net (Neish, 2008c). During farmer training programmes, it was the policy of Seaplant.net and IFC-PENSA to foster alliances between farmer groups and seaweed processors. That trend is ongoing as some kind of relational governance in seaweed value chains.

Seaweed MSMEs tend to be owned and operated by close associates and family members who build long-term business relationships. Thus, bonds of personal trust, once established, can be smoothly transferred through managerial generations. The formation of trust in alliances is a function of person-to-person relationships, which entail a great deal of time, effort and expense to foster. As time and effort are among the most limited and valuable assets of MSME managers, the cost of forming trust relationships can be a major investment. In the present study, it was found that trust/ commitment relationships were the norm among farmers and buyers.

4.3 Research institutes and NGOs

Universities in Indonesia that have undertaken work with RAGS include UNHAS, UNSRAT and Udayana University. Government departments such as the BPPT, DKP and LIPI have provided research and education services to seaweed farmers. Much of the seaweed research in the BIMP-EAGA region has taken place in the Philippines.

Business development services (BDSs) and financial services have been provided to seaweed farmers by several private and international organizations (Seaplant.net, Swiss Contact, IFC-PENSA, GTZ, AusAID, USAID, JICA, CARE and ADB) in tandem with Indonesian government organizations (BPPT and DKP) and government-supported associations such as APBIRLI, ASPERLI and ISSA. Similar organizations have emerged from time to time during the years of seaweed farming development.

Several aid agencies have provided microfinance or other forms of financial support to farmers either directly or through Indonesian government agencies. For example, the PNM is a state-owned investment firm that has funded farmer training and provided finance products to seaweed farmers.

4.4 Farm structures

In Indonesia, seaweed farming was found to be primarily a village-based family business.[12] Two distinct approaches to farm management were encountered in the present study. The most common one was a "nuclear family" model, where spouses share work and income among themselves, their children, their parents and other first-degree blood relations. The other approach was the "lead farmer" model, where one person or a small team of people own the enterprise, are actively involved in the day-to-day operations, assume responsibility for managing the farm enterprise, and undertake marketing and selling of the crops produced. Farm labour generally consists of extended family members and neighbours who provide labour on a piecework basis.

The most common real property structure of Indonesian seaweed farming enterprises is a "proprietary" model where the farm enterprise directly owns physical farm assets and holds the rights to farm in the locations where it operates. The nuclear family model predominated among farmers surveyed during the present study; however, sharing of labour and assets among farmers was a common occurrence. In Indonesia, this practice is known as "gotong royong" or "kerja bakti". Usually, kerja bakti takes place among farmers that belong to the same farmer group ("kelompok"). Labour sharing generally occurs during periodic instances of intense activity such as farm construction, harvesting, drying and attaching of cuttings to lines. Shared physical assets generally include drying platforms, boats and work shelters.

An uncommon structure was the "tenant" model, where the farm enterprise pays fees for the right to use physical farm assets and/or to farm in the locations where it operated. Also uncommon was the "sharecropper" model, where the farm enterprise pays rent as a percentage of crop yields for the right to use physical farm assets and/or to farm in the locations where it operated. One approach that has been tried and failed several times is the "estate farm" model, whereby the farm is owned by individuals not active in day-to-day operations while actual management and operation are undertaken by people on salary. Substantial village-level control of seashore utilization has certainly been an impediment for any estate farming approach because aquaculture sites are generally sought after by many village members.

5. CHALLENGES AND THE WAY FORWARD

Indonesia has made great strides in the past decades in developing essential infrastructure, goods and services that have had a positive impact on seaweed farmers. There are still remote regions in east Indonesia that have not caught up with areas near urban centres, but the gap is closing. Education, health care, social services, communication and transport systems have undergone steady improvement in Indonesia since the 1970s and the law-and-order situation has been calm in most seaweed farming regions since the industry began. Generally, all value chain stakeholders can travel to the farming regions without fear of kidnapping or violence.

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[12] Whether they operate near their ancestral home base or whether they have migrated, seaweed farmers in Indonesia have tended to cluster into village units that retain their native languages and customs. Within villages, farmers tend to cluster into work groups ("kelompok") built around family ties.

5.1 Issues perceived by farmers

The major sustainability issues perceived by farmers revolve around seasonality impacts on crop productivity of cottonii and the price instability that accompanied seasonal variations in seaweed supply. Specific issues are:

- the need for robust cottonii cultivars that have similar growth characteristics to spinosum cultivars, especially with respect to growth during all seasons of the year;
- the need for cottonii cultivar biomass in sufficient quantities for seasonal replanting;
- the need for finance to cover the purchases of biomass for replanting;
- means for prevention or control of "ice-ice" malaise, *Neosiphonia* infestation and other seasonal maladies;
- access to fair trade and market links;
- access to knowledge and information on technologies appropriate to the different seaweed farming regions.

5.2 Issues perceived by processors

Processors have been exposed for several years to cottonii supplies that fell short of demand. The problem became especially critical in 2008–09 when short supplies resulted in high and unstable prices that resulted in the loss of carrageenan market share to other food ingredients. As of late 2009, the carrageenan market remained weak. Processors were uncertain as to whether that was caused by price instability or was a reflection of the global economic recession. There was a general consensus that stable, affordable cottonii supplies were essential to sustainable carrageenan markets.

Marinalg International is a worldwide association that promotes the image and use of seaweed-derived hydrocolloids in food, pharmaceutical and cosmetics industries. Many of the world's largest processors of RAGS belong to Marinalg. Specific issues of interest to the industry have been addressed by Marinalg in position papers posted on its Web site (www.marinalg.org). One persistent issue addressed by Marinalg deals with recent attempts to have carrageenan banned as a food additive (Tobacman *et al.*, 2008). Another problem is connected with reports describing how introduced RAGS have established alien and invasive populations in coral reef habitats in Hawaii (Parsons *et al.*, 2008), Kiribati (Pala, 2008) and Tamil Nadu in India (Tobacman *et al.*, 2008; Chandrasekaran *et al.*, 2008). Marinalg responded to these reports with a position paper and a protocol for introducing non-indigenous seaweeds.

5.3 Issues perceived by governments

The multilayered, decentralized structure of government agencies in Indonesia has led to integration and coordination concerns by officials in the several government agencies that deal with seaweed farmers. They are aware of the concerns of farmers and processors and also of the need to balance uses of the marine foreshore. Government officials have also complained about inadequate budgets and diffusion of funds through layers of government and agencies. As a result, information such as crop production statistics cannot be collected and disseminated comprehensively.

Government organizations at the provincial and regency level have viewed seaweed farms and processing plants as sustainable development options for much of coastal Indonesia. Efforts are under way in many regions to develop financial support programmes for seaweed farmers. The training of human resources and the need for BDSs are perceived as necessary conditions for sustainable development.

5.4 Issues perceived by development agencies and NGOs

Numerous aid agencies, international financial institutions and NGOs have become involved directly or indirectly with seaweed farmers in Indonesia since the mid-

1980s. Generally, such agencies have worked either through government agencies or in coordination with them. The perceived needs of farmers and processors have been addressed with training and farmer finance initiatives tied to generally rigorous monitoring and evaluation efforts to ensure the proper use, disbursement and management of funds and the prompt submission of reports. Initiatives by IFC-PENSA, Swiss Contact, AusAID, CIDA and USAID have emphasized the development of BDS providers. Seaplant.net Foundation is one example of a BDS provider that has received support from all of those agencies.

5.5 Concluding remarks

Seaweed farming has been expanding in Indonesia since 1985; by 2008, it provided an average annual income on the order of USD5 000 to an estimated 20 000 farm households working on a part-time basis. The most diligent farmers were able to make 2–3 times that amount by working full time or by employing the "leader model" approach to farming. Such earnings were well above the poverty level. Interviewed farmers generally asserted that seaweed farming was by far their most lucrative economic activity.

Seaweed farming is also complementary and compatible with other village economic activities such as fishing and farming land crops. Ready cash from seaweed farming has also had a noticeable multiplier effect. Shops, support services and local infrastructure have benefited visibly from seaweed cash flowing through local village economies.

The spread of mobile communication technology, Internet connectivity and satellite television has been facilitated by the earnings from seaweed farming. Communication links, in turn, have facilitated the acquisition of knowledge, information, tools and solutions by seaweed farmers even in the more remote regions of Indonesia. The reflexive approach to Indonesian seaweed farm development has been driven by farmers and local traders/collectors in a "bottom-up" manner. A market need was revealed to them by value chain stakeholders on the "demand" side; farmers were exposed to the simple grow-out technologies; and with facilitation from a variety of organizations, seaweed farmers were able to build their businesses within the context of village norms, mores and structures.

Seaweed farming has never been imposed on farmers using a "top-down" approach; in addition, the simplicity of farming techniques has meant that technology transfer has been readily accomplished. Seaweed farming has rapidly become integrated into the social fabric of farmer villages to the point where it now appears to be a traditional economic activity even though it did not exist until the mid-1980s or later.

Opportunities for seaweed aquaculture intensification and integrated multitrophic aquaculture are considerable.

References

Chandrasekaran, S., Nagendran, N.A., Pandiaraja, D., Krishnankutty, N. & Kamalakannan, B. 2008. Bioinvasion of *Kappaphycus alvarezii* on corals in the Gulf of Mannar, India. *Current Science*, 94(9): 1167–1172 (also available at www.ias.ac.in/currsci/may102008/1167.pdf).

Gan, K.T. 2003. *Strategic alliances in the tropical Asian seaweed industry: implications for development in Asia*. Adelaide, University of South Australia. 89 pp.

Gereffi, G., Humphrey, J. & Sturgeon, T. 2005. The governance of global value chains. *Review of International Political Economy*, 12(1): 78–104 (also available at www.global-production.com/scoreboard/resources/sturgeon_2005_governance-of-value-chains.pdf).

Hurtado, A.Q., Agbayani, R.F., Sanares, R. & de Castro-Mallare, M.T. 2001. The seasonality and economic feasibility of cultivating *Kappaphycus alvarezii* in Panagatan Cays, Caluya, Antique, Philippines. *Aquaculture*, 199: 295–310.

JLJ Group. 2006. *Preliminary study – Chinese market for seaweed and carrageenan industry*. Shanghai, China.

Maarif, S. & Jompa, J. 2007. *The Coral Triangle and coastal community development through sustainable integrated aquaculture*. Sustainable Integrated Mariculture Meeting and Workshop. Makassar, Indonesia, Seaplant.net. (also available at http://seaplant.net/index_mbr.php?page=sea_publications).

McHugh, D.J. 2003. *A guide to the seaweed industry*. FAO Fisheries Technical Paper No. 441. Rome, FAO. 105 pp. (also available at ftp://ftp.fao.org/docrep/fao/006/y4765e/y4765e00.pdf).

Neish, I.C. 2008a. *Tropical red seaweeds as a foundation for integrated multi-trophic aquaculture (IMTA): four propositions and an action plan for this major opportunity in the Coral Triangle*. Seaplant.net Monograph no. HB2E 1008 V1 IMTA. Makassar, Indonesia. (also available at http://seaplant.net/bimpeaga/page_12.php).

Neish, I.C. 2008b. *Basic manufacturing practices for raw-dried seaweed and semi-refined carrageenan from Eucheuma and Kappaphycus*. Seaplant.net Monograph no. HB2G 1008 V2 BMP. Makassar, Indonesia. (also available at http://seaplant.net/bimpeaga/page_10.php).

Neish, I.C. 2008c. *A ten-step functional framework for building ventures and alliances among seaplant enterprises*. Seaplant.net Monograph no. HB2C 0808 V1 VA. Makassar, Indonesia. (also available at http://seaplant.net/bimpeaga/page_12.php).

Neish, I.C. 2009. *An analysis of world production and trade in tropical red seaweeds; with focus on the Philippines and Indonesia*. Makassar, Indonesia, Seaplant.net.

Neish, I.C. & Julianto, B.S. 2008. *A practical guide to quality assurance, governance systems and good practices for tropical seaweed-to-carrageenan value chains: with focus on developing harmonization and transparency in the BIMP-EAGA region of ASEAN in the Coral Triangle*. Seaplant.net Monograph no. HB2D 1108 V1 GTZ. Makassar, Indonesia. (also available at http://seaplant.net/bimpeaga/download_gtz.php).

Neish, I.C., Hurtado, A.Q., Julianto, B. & Saragih, D. 2009. *Good aquaculture practices for Kappaphycus and Eucheuma. A compilation of nine training modules for seaweed farmers*. Seaplant.net Monograph no. HB2F 0909 V4 GAP. Makassar, Indonesia.

Parsons, M.L., Walsh, W.J., Settlemier, C.J., White, D.J., Ballauer, J.M., Ayotte, P.M., Osada, K.M. & Carman, B. 2008. A multivariate assessment of the coral ecosystem health of two embayments on the lee of the island of Hawai‘i. *Marine Pollution Bulletin*, 56(6): 1138–1149.

Scoones, I. 1998. *Sustainable rural livelihoods: a framework for analysis*. IDS Working Paper no. 72. Brighton, UK, Institute of Development Studies, University of Sussex. 22 pp. (also available at www.ids.ac.uk/files/Wp72.pdf).

Scoones, I., Leach, M., Smith, A., Stagl, S., Stirling, A. & Thompson, J. 2007. *Dynamic systems and the challenge of sustainability*. STEPS Working Paper 1. Brighton, UK, STEPS Centre. 68 pp. (also available at www.stepscentre.org/PDFs/final_steps_dynamics).

Sulu, R., Kumar, L., Hay, C. & Pickering, T. 2004. *Kappaphycus seaweed in the Pacific: review of introductions and field testing proposed quarantine protocols*. Noumea, Secretariat of the Pacific Community. 85 pp. (also available at wwwx.spc.int/coastfish/sections/reef/Library/Reports/Sulu_04.pdf).

Tobacman, J.K., Bhattacharyya, S., Borthakur, A. & Dudeja, P.K. 2008. The carrageenan diet: not recommended. *Science*, 321(5892): 1040–1041.

The Nature Conservancy (TNC). 2004. *Delineating the Coral Triangle, its ecoregions and functional seascapes: report on an expert workshop, held at the Southeast Asia Center for Marine Protected Areas, Bali, Indonesia (April 30 May 2, 2003)*. Bali, Indonesia, The Nature Conservancy, Southeast Asia Center for Marine Protected Areas. 26 pp. (also available at www.southchinasea.org/docs/Nature%20Conservancy-Coral%20Triangle.pdf).

Social and economic dimensions of carrageenan seaweed farming in the Philippines

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ACKNOWLEDGEMENTS

This study would not have been completed without the warm support of several people in the industry who shared their time, effort and information. I am truly grateful to the seaweed farmers I interviewed in Marupo and Marcilla, Coron Palawan; Guindacpan Island, Tubigon, Bohol; Panyam Look, Layag-Layag and Arena Blanco, Zamboanga City; Pondohan (Sipangkot, Sapagamat 1 & 2, Baligtang) Sitangkai, Tawi-Tawi. I thank Ms Jacqueline Corrosco, Hadji Adam Omar, Hadja Saada Omar, Munib Joe, Arnel Kalugdan, Richard Radier, Benson Dakay, Antonio Yuri Yap, Farley Baricuatro, Dinah Sayam, Philip Parado, José Arturo Evalle, and Dr Jumelita Romero for invaluable information given.

1. INTRODUCTION

Philippine seaweed aquaculture is currently dominated by the cultivation of red algal galactan seaweeds (RAGS) that serve as raw materials for the biopolymers known as agar and carrageenan. This study considers three RAGS genera that comprise most crop production, namely the genera *Eucheuma* (known commercially as spinosum), *Gracilaria* and *Kappaphycus* (known commercially as cottonii). Hurtado *et al.* (2001) stated that "*Kappaphycus* farming in the Philippines is nearly synonymous with the seaweed industry of the country since 85–90 percent is dominated by farming, processing and marketing of this seaweed". Thus, the present study focuses primarily on cottonii farming that links to kappa-carrageenan value chains. Nevertheless, the author proposes that sustainability for seaweed-based value chains requires development far beyond synonymy with *Kappaphycus* farming.

The long history of seaweed farming (*Kappaphycus* in particular) in the Philippines is a manifestation of the strength of this industry. The activity has generated employment to, and uplifted the socio-economic status of, tens of thousands of coastal families in the country. The roles played by government and non-government agencies, academia, business partners, and national and international institutions have been instrumental to the development of the industry. However, there is still a need to link strongly the institutional research and development (R&D) programmes to meet the problems and concerns of seaweed farmers, especially on production and productivity. Similarly, a direct link to and transparent transactions in the market are much needed.

This chapter assesses the social and economic dimensions of seaweed aquaculture in the Philippines by focusing on the development of sustainable livelihoods in the context of regional and global value chains. A comprehensive evaluation of the socio-economic dimensions of seaweed farming in the Philippines was carried out to assess the sustainability of seaweed farming as a livelihood strategy. Data gathering and analysis were conducted for the four major production areas in the country: ARMM (Sitangkai), Region IV-B (Palawan), Region IX (Zamboanga City) and Region VII (Bohol).

2. CARRAGEENAN SEAWEED PRODUCTION AND VALUE CHAIN

2.1 Physical conditions

Geographic location and climate

The Philippines is an archipelago comprising 7 107 islands with a total area of 300 000 km^2 and a coastline area of 36 289 km. The Philippines has a tropical wet climate with alternating rainy and dry seasons. The summer (southwest) monsoon brings heavy rains to most of the archipelago from May to October, whereas the winter (northeast) monsoon brings cooler and drier air from December to February. Monsoon rains, although hard and drenching, are not normally associated with high winds and waves. However, because the Philippines sits astride in the typhoon belt, it suffers an annual onslaught of dangerous storms from July to October. These are especially hazardous for northern and eastern Luzon and the Bicol and Eastern Visayas regions. The Philippines is prone to about 18–21 typhoons per year; however, western Mindanao – the Sulu archipelago in particular – is not known for typhoons.

Seasonality

Seasonal variability between regions, within years and between years is commonly cited as a causative factor for variability in seaweed production, but comprehensive scientific cause-and-effect studies remain to be undertaken. Varieties and farming techniques may also vary according to seasons (Table 1). The difficulty of drying during the southwest monsoon also explains the lower production volumes.

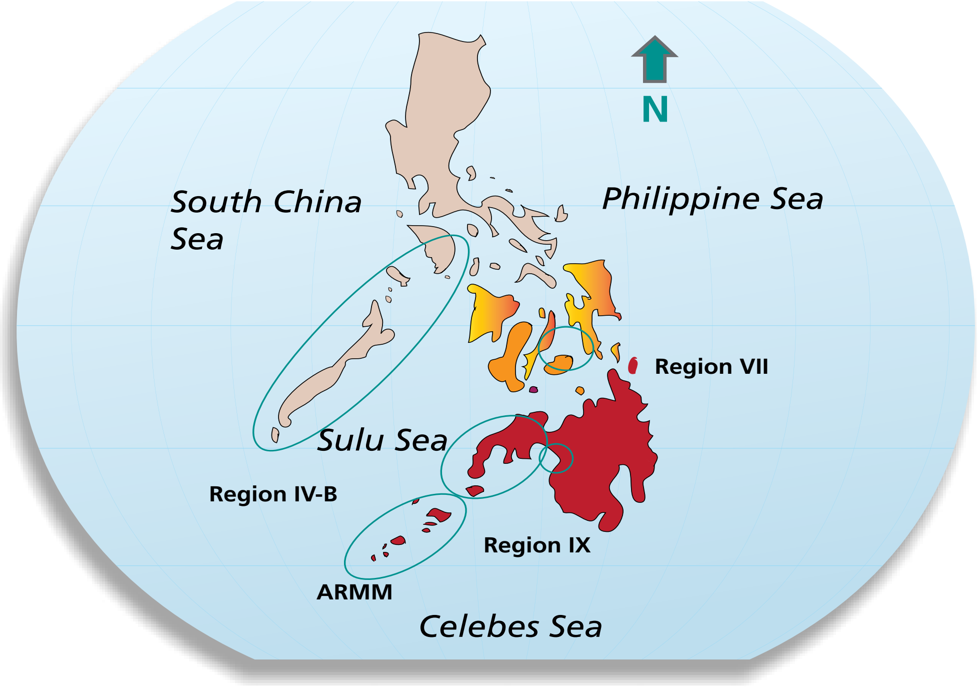
TABLE 1
Seasonality of *Kappaphycus* varieties and farming techniques adopted in Tawi-Tawi, ARMM

Season	Farming technique	Variety
Southwest monsoon (June–October)	Spring and free-swing	*K. alvarezii* var. *tambalang*
Northeast monsoon (November–May)	Fixed-off-bottom Spring and free-swing	*K. striatum* var. *sacol* *K. alvarezii* var. *tambalang*

Cultivation areas

It is difficult to gather information on the total cultivation area and production of each municipality or province as government agencies do not maintain substantial records for these purposes. Nevertheless, approximate estimates can be obtained from the four key production areas in the country: ARMM, Region IV-B, Region IX, and Region VII (Figure 1).

FIGURE 1
Major seaweed farming areas in the Philippines



Source: Seaweed Industry Association of the Philippines (2009).

It is estimated that ARMM, consisting mostly of Maguindanao, Lanao del Norte, Sulu and Tawi-Tawi, has about 24 000 ha under production. Using current farming techniques such as fixed off-bottom, hanging long-line and swing at 4–4.5 m depth, there are about 20 750 ha available for expansion in Tawi-Tawi. However, geographic information system (GIS) studies have revealed that, if seaweed faming were expanded to a depth of 15 m in Sitangkai[1], about 102 885 ha would be available for expansion. These estimates are indicative of the large potential for further industry growth in the area.

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[1] Sitangkai in Tawi-Tawi was the single largest seaweed producing area in the Philippines in 2009, but Palawan is the now the largest single seaweed producing province (as of 2011).

2.2 Production and trade

Production

Total cultured seaweed production in the Philippines was 1.7 million tonnes in 2009; about 85 percent of which came from ARMM (39 percent), Region IV-B (26 percent), Region IX (13 percent), and Region VII (7 percent) (Table 2).

TABLE 2
Seaweed farming production in the Philippines

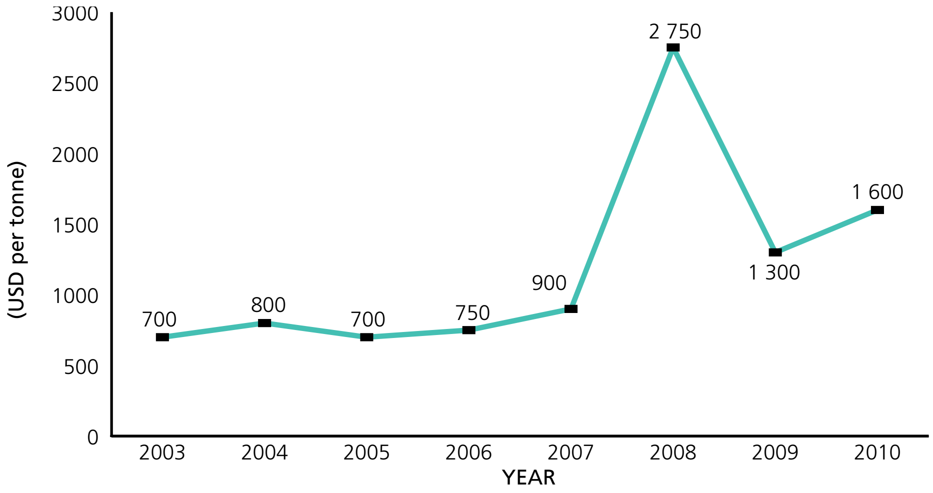
Region	2004	2005	2006	2007	2008	2009
	(1 000 tonnes, fresh weight)					
ARMM	473	510	561	618	657	683
IV-B	329	359	401	365	447	451
IX	155	177	211	202	222	225
VII	83	107	94	108	111	121
Other regions	165	186	203	212	229	260
Total	**1 205**	**1 339**	**1 470**	**1 505**	**1 666**	**1 740**

Source: BAS (2010).

Cultured seaweed production in the Philippines grew stably at about 8 percent annually in the period 2004–07. However, production doubled from 1.5 million tonnes (wet weight) in 2007 to 3.3 million tonnes in 2008, driven primarily by strong demand from China, which drove the price of dry cottonii in the Philippines from USD900/tonne in 2007 to almost USD3 000/tonne in 2008 (Figure 2). The "seaweed rush" lasted only one year – the price dropped to USD1 300/tonne in 2009.

This incident exemplifies the cyclic nature of seaweed farming in the Philippines owing to the instability of prices. Generally, when strong demand for dry seaweeds drives up the price, seaweed farmers tend to increase their planting efforts and/or harvest immature crops. However, if the price is low, seaweed farmers tend to reduce production, which creates sourcing difficulties for the local processors. Indeed, the shortage of local supplies has forced local processors to source dry seaweeds abroad

FIGURE 2
Representative cottonii seaweed export prices (f.o.b. Cebu City, the Philippines), annual average



Source: Dakay (2010).

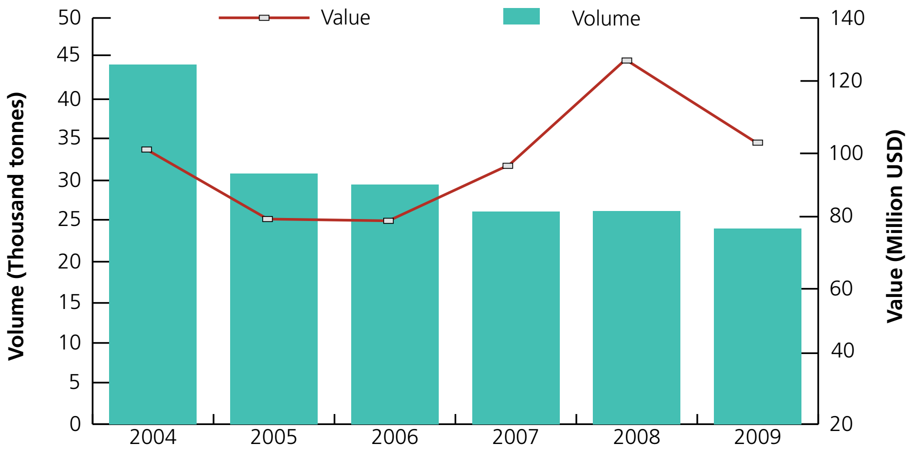
(e.g. from Indonesia). It is estimated that a total of 4 340 tonnes was imported in 2007 (Dakay, 2008).

Trade

Exports of seaweed and seaweed products from the Philippines reached almost 45 000 tonnes, worth more than USD120 million in 2004, but the export volume has been on a downward trend since 2005. Despite the decline in the export volume, the export value has been on an upward trend since 2006 (Figure 3).

FIGURE 3

Export of Philippine seaweed and seaweed products in volume and value (f.o.b.)



Source: NSO (2010).

Exports of dry seaweed from the Philippines have been concentrated on three major markets: China (including China, Hong Kong SAR), France and the United States of America. However, imports by the United States of America declined significantly in 2009. The Republic of Korea and Spain were major markets in 2004 but drastically reduced their purchases afterwards. Thailand seems to have been consistently importing dry seaweeds from the Philippines in recent years. Brazil increased its import substantially in 2009 (Figure 4).

Compared with the situation of dry seaweeds, export markets of carrageenan and other colloid products from the Philippines are more diversified; the major markets are in North America (the United States of America and Canada) and Europe (France, Germany, Belgium, Spain, the United Kingdom of Great Britain and Northern Ireland, and Denmark) (Figure 5).

Local seaweed processors in the Philippines also import dry seaweeds from abroad (primarily Indonesia) as raw materials (Figure 6).

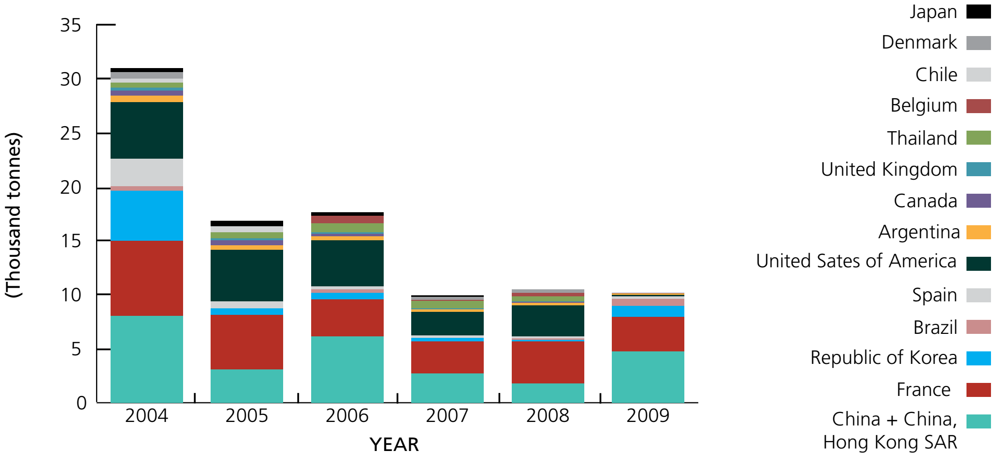
2.3 Value chain

Marketing of seaweed in the Philippines starts at the shoreline. Generally speaking, there are two marketing channels connecting farmers to processors. Both channels are important; and the role of every stakeholder in the value chain is significant and symbiotic.

One channel is through consolidators and traders. A local consolidator who usually works for a small trader buys the seaweed in either fresh or dried form. At the time of writing, the price of fresh *K. striatum* var. *sacol* is USD0.12–0.13/kg. Normally, the local consolidator dries the seaweed for 2–3 days to a moisture content (MC) of

FIGURE 4

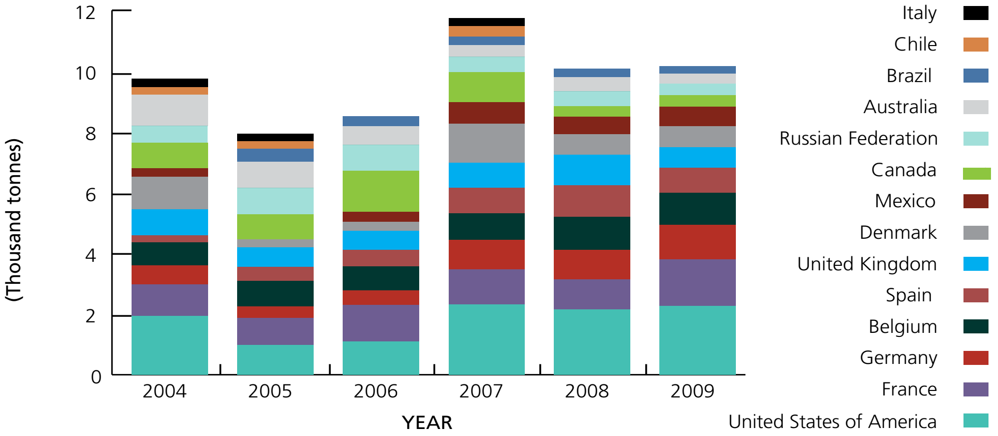
Major export markets of dry seaweed from the Philippines



Source: NSO (2010).

FIGURE 5

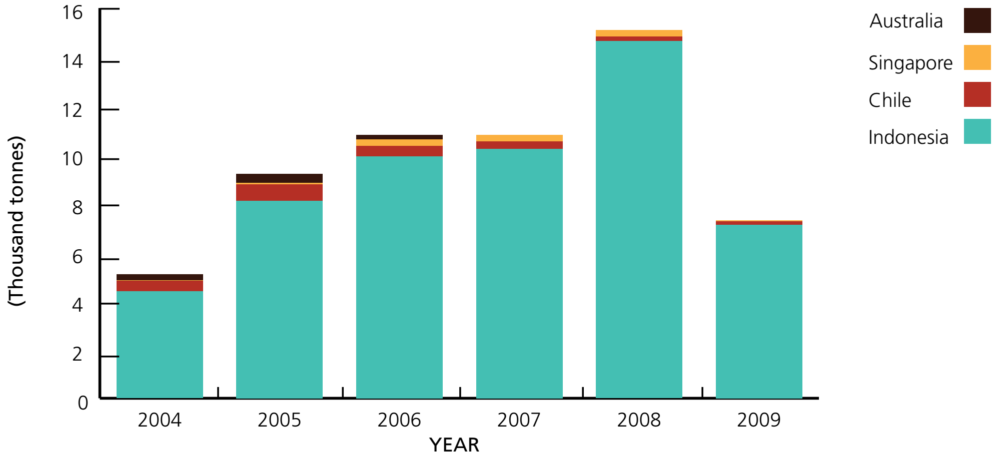
Major export markets of carrageenan and other colloid products from the Philippines



Source: NSO (2010).

FIGURE 6

Philippine imports of seaweed



Source: NSO (2010).

50–55 percent and later sells it to a small trader in the community, who in turn sells it to a larger trader, owner of a warehouse. The consolidator usually earns USD0.01–0.02/kg while the small trader earns USD0.02–0.03/kg. Generally, the larger trader further sun dries the seaweed to 42–45 percent MC, then packs it in sacks or in 100–120 kg bales. Under this channel, seaweed prices are negotiated between processors and farmers through larger traders. Prices change daily or weekly.

Another channel is through farmers associations. Seaweed farmers, especially those in island communities or in the "pondohans" of Tawi-Tawi, are organized into associations, e.g. the Sipangkot Seaweed Planters Association in Sipangkot, Sitangkai, Tawi-Tawi.[2] Members sell their products directly to their own associations, which dry and then sell them directly to a processor through the assistance of a business development service (BDS) or a non-governmental organization (NGO). This scheme eliminates one or two layers of trading/marketing and hence increases profit margins for the growers.[3] As an association can hoard large volumes (e.g. 375–415 tonnes/week in peak months [January to March] or 225–300 tonnes/week in lean months [April–December]), it is in a position to demand a premium price, provided the moisture content, percentage of impurities and seaweed age are within the specifications of the processor. Despite the obvious benefits of operating through associations, some farmers do not follow consistent marketing strategies, selling instead to local traders in small volumes; hence, they cannot negotiate good prices.

The lack of high-quality dry seaweed is a perennial problem in the industry. Although there are government standards – prepared in cooperation with the processors and academia – they are not implemented and adhered to consistently. Some adverse factors are: (i) farmers harvest prematurely (i.e. prior to 45 days of culture); (ii) a high percentage of impurities (presence of soft "tie-ties" and undesirable seaweeds); (iii) high MC; and (iv) sand–salt adulteration. Farmers harvest their seaweed prematurely mostly for economic reasons – because they need cash daily to meet basic needs, extending the culture cycle beyond 30 days entails a long waiting period.

The above-mentioned malpractices are sometimes tolerated by larger traders and processors, especially when there is a scarcity of raw dried seaweed (RDS). However, traders and processors are advised by the government to enforce the standards strictly. Processors could reject RDS that do not meet their standards and specifications and purchase only good-quality seaweed at a premium price. In times of scarcity, if the delivered RDS is not within their standards and specifications, processors could simply deduct 15–20 percent of the current price.

There were 19 semi-refined carrageenan (SRC) and 3 refined carrageenan (RC) processors in the Philippines in 2005 (Hurtado, 2005). By 2008, the number of SRC processors had declined to 12 (Dakay, 2008). Large transnational SRC companies are still active in the Philippines, whereas a number of smaller companies have succumbed to international competition and insufficient supplies of RDS. Very few national companies in the Philippines are involved in the marketing of dried seaweed.[4]

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[2] A "pondohan" is a group of families (20–30 families) residing in the middle of the sea in stilt houses as a cluster. They are primarily engaged in seaweed farming.

[3] This scheme is being practised in a small island community whose association (Pangapuyan Seaweed Planters Association, Pangapuyan Island, Zamboanga City) is directly involved in the purchase of fresh seaweed.

[4] An exception is Marcel Carrageenan, which supplies RDS to its partner Cargill Texturizing Solutions in Canlubang, Laguna.

3. CARRAGEENAN SEAWEED FARMING: ECONOMIC AND SOCIAL PERFORMANCE

3.1 Business structure and farming system

Business structure

The management and operation of seaweed farms in the Philippines follow a village-based family business model. Two distinct approaches to farm management are encountered: (i) the "nuclear family" ("mom and pop") model, where spouses share the farm work and income among themselves, their children, their parents and/or other first-degree blood relations; and (ii) the "lead farmer" model, where one person or a small team of people own the enterprise, are actively involved in day-to-day operations, assume responsibility for managing the farm enterprise, and undertake the marketing of the crops produced. Much farm labour is undertaken by extended family members and neighbours who provide labour on a piece-work basis.

The most common real property structure in the Philippines is a "proprietary" model, in which physical farm assets such as farmhouses and motorized and non-motorized boats are owned directly by the farm enterprise. The seaweed farmer holds the rights to farm and operate the area. Although the Philippine Fisheries Code 1998 (known as Republic Act 8550) requires licences for farming seaweed, unlicensed farming is currently taking place in a number of island communities and in some areas in the "pondohans".

An uncommon structure is the "tenant" model, in which the farm enterprise pays cash rent for the right to use physical farm assets and/or to farm in the locations where it operates. This model applies only if the farm area is legally acquired. Another uncommon arrangement is the "sharecropper" model, in which the farm enterprise pays a percentage of the harvest as rent for the right to use physical farm assets and/or to farm in the location where it operates.

One approach that has been tried but has failed several times is the "estate" or "corporate farm" model, whereby the farm is owned by individuals or a group of individuals not active in the day-to-day operations and farm management is undertaken by agents on salary. Substantial village-level control of seashore utilization is an impediment for any estate farming approach because aquaculture sites are generally sought after by village members.

Farming system

Different farming techniques are employed throughout the country. These vary from simple long lines such as fixed-off-bottom (FOB) and hanging long line (HLL) to complex structures such as the multiple raft long line (MRLL) and the spider web (SW). Generally, techniques are chosen according to the depth of water at the lowest tide: FOB is chosen in shallow water ranges (0.25–0.50 m); HLL is used in intermediate water ranges (1–5 m); whereas MRLL and SW are selected in deep water ranges (> 5 m).

The FOB technique of culturing *Kappaphycus* is the simplest and most traditional since seaweed farming was introduced in the Philippines in the early 1970s. Farmers use flat binders or polyethylene ropes as cultivation lines, plastic soft strips to tie the propagules, and wooden stakes to peg both ends of the cultivation line. As the FOB technique is normally used in shallow waters, a non-motorized boat is needed for planting, monitoring and harvesting.

The MRLL and SW techniques are innovative approaches to seaweed farming in deeper waters and are being implemented in Zamboanga City. These two techniques usually require much higher capital investment than the FOB method.

3.2 Economic performance

The economic performance of six farms that adopt the four commonly used seaweed farming systems in the Philippines is examined below. The basic information of these farms is summarized in Table 3.

TABLE 3
Basic information on the six farms under study

Farm	Farming system	Species	Location	Operation scale
1	FOB	*K. striatum* var. *sacol*	Zamboanga City, Tigtabon Island	100 lines; 18 m/line
2	FOB	*K. striatum* var. *sacol*	Tawi-Tawi, Sitangkai, Baligtang pondohan	90 Lines; 18 m/line
3	HLL	*K. alvarezii* var. *tambalang*	Palawan, Marcilla Coron	90 lines; 30 m/line
4	HLL	*K. alvarezii* var. *tambalang*	Tawi-Tawi, Sitangkai, Sipangkot Island	100 lines; 30 m/line
5	MRLL	*K. striatum* var. *sacol*	Zamboanga City, Layag-Layag,	10 m × 50 m
6	SW	*K. alvarezii* var. *tambalang*	Zamboanga City, Arena Blanco	30 m × 90 m

Note: FOB = fixed-off-bottom; HLL = hanging long line; MRLL = multiple raft long line; SW = spider web.

Capital costs

The initial capital investment as well as corresponding amortized annual capital costs (i.e. depreciation) of the six farms are summarized in Table 4. The results indicate that:

- Investments in farming system and vehicle (boat) are two primary items of capital cost.
- The farming systems (stakes, lines, floats, weights, etc.) of FOB and HLL had relatively low requirement of initial investments. The costs of the farming systems of Farm 2 (FOB), Farm 3 (HLL) and Farm 4 (HLL) were USD28/km of lines, USD34/km and USD53/km, respectively. However, the FOB system of Farm 1 was more expensive (USD115/km) because of the money it paid for wooden stakes, which cost virtually nothing for the other three farms.
- The farming systems of MRLL and SW were more expensive in terms of total capital costs. The farming systems of Farm 5 (MRLL) and Farm 6 (SW) accounted for 47 and 81 percent of their total capital costs, respectively. It should be noted that the capital costs of MRLL and SW in Table 4 are not directly comparable with those of FOB and HLL because the former were measured by area they occupied while the later by the length of lines they used. However, a rough estimation can be used to show that MRLL and SW are more expensive. As mentioned above, Farm 1 (FOB) had the most expensive farming system among the four farms using FOB or HLL. Assuming 20 cm line space for Farm 1 (FOB),[5] then its area would be about 20 m × 18 m = 360 m^2. Thus, its capital cost on the farming system would be USD5 750/ha, which is much lower than Farm 5 (USD11 440/ha) and Farm 6 (USD9 956/ha).
- Capital cost per kilometre of lines or per hectare of area was calculated to facilitate comparisons across the specific farms under study. However, the unit cost so calculated should not be used to extrapolate investment requirements for operations at different scales. For example, the 0.05-ha Farm 5 (MRLL) invested USD646 in a boat, which means a capital cost of USD12 920/ha. However, this does not mean that a 1-ha MRLL farm would need to invest USD12 920 in boats; the amount is the value of 20 boats.

Variable costs

The cash operating costs for the first production cycle of the six farms are summarized in Table 5. The results indicate that:

- Generally speaking, the cost of seeds is the main expense in the first cycle for all the farms under examination. Farmers usually purchase a small quantity of seeds

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[5] Line space is 20 cm for the off-bottom system used in Bali, Indonesia.

TABLE 4

Initial capital investment and amortized annual capital costs of various seaweed farming systems in the Philippines

Items of capital investment	Initial investment		Amortized annual capital cost		Capital cost*	
	Total cost	Share of total cost	Annual cost	Share of annual cost	Total	Annual
	(USD)	(%)	(USD/year)	(%)	(USD/km or ha)	(USD/km or ha)
Farm 1: FOB (Zamboanga, 100 lines; 18 m/line)						
Farming system	207	63	94	70	115	52
Vehicle (boat)	120	37	40	30	67	22
Total	327	100	134	100	182	74
Farm 2: FOB (Tawi-Tawi, 90 lines; 18 m/line)						
Farming system	46	28	15	27	28	9
Vehicle (boat)	120	72	40	73	74	25
Total	166	100	55	100	102	34
Farm 3: HLL (Palawan, 90 lines; 30 m/line)						
Farming system	92	15	31	23	34	11
Vehicle (boat)	526	85	105	77	195	39
Total	619	100	136	100	229	50
Farm 4: HLL (Tawi-Tawi, 100 lines; 18 m/line)						
Farming system	159	23	70	40	88	39
Vehicle (boat)	526	77	105	60	292	58
Total	686	100	175	100	381	97
Farm 5: MRLL (Zamboanga, 10 m × 50 m)						
Farming system	572	47	204	58	11 440	4 080
Vehicle (boat)	646	53	145	42	12 920	2 900
Total	1 218	100	349	100	24 360	6 980
Farm 6: SW (Zamboanga, 30 m × 90 m)						
Farming system	2 688	81	944	87	9 956	3 496
Vehicle and equipment	646	19	145	13	2 393	537
Total	3 335	100	1 089	100	12 352	4 033

* Measured by per kilometre for FOB and HLL, by per hectare for MRLL and SW.
Notes: USD1 = PHP47.50 (September 2009). Numbers may not add up due to rounding.
FOB = fixed-off-bottom; HLL = hanging long line; MRLL = multiple raft long line; SW = spider web.

in the first cycle; then a portion of the harvest in one cycle is separated and used as seeding materials for the ensuing cycle. Therefore, the initial expense on seeds can vary among different farmers. For example, expenditure by Farm 2 expense on seed (USD21) was much lower than that by Farm 1 (USD442) although their farming systems were very similar. Under such self-propagation schemes, seed expenses would tend to be less after the first cycle.

- Fuel and maintenance of engine are a minor expense, but fuel costs are higher for farm sites located far away from the coastline, such as deep-sea farms in the area of Zamboanga peninsula (e.g. Farm 5 and Farm 6).
- Labour expenses depend on how much family or other non-cash labour is used. Generally speaking, family labour is often used for relatively simple works such as seeding, harvesting and drying. However, workers may need to be hired for relatively large-scale operation (e.g. Farms 1, 5 and 6). More sophisticated tasks such as the construction or installation of the farming system tend to entail hired labour, especially for more sophisticated systems such as MRLL (Farm 5) and SW (Farm 6). However, bayanihan-style[6] of wooden-post staking and culture

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[6] "Bayanihan" is a Philippine term referring to a spirit of communal unity or effort to achieve a particular objective without the benefit of monetary compensation.

TABLE 5

Cash operating costs in the first production cycle for various seaweed farming systems in the Philippines

Farms	Farm 1 (FOB)	Farm 2 (FOB)	Farm 3 (HLL)	Farm 4 (HLL)	Farm 5 (MRLL)	Farm 6 (SW)
Location	**Zamboanga**	**Tawi-Tawi**	**Palawan**	**Tawi-Tawi**	**Zamboanga**	**Zamboanga**
Material costs (USD)	**455**	**31**	**671**	**350**	**517**	**1 367**
- Seed	442	21	568	263	421	1 263
- Plastic strip (soft tie-tie)	13	10	20	11	30	38
- Fuel and engine maintenance	–	–	83	76	66	66
Labour costs (USD)	**126**	**16**	**–**	**25**	**152**	**630**
- Seeding	42	16	–	14	35	115
- Harvesting & drying	–	–	–	–	28	84
- Construction/installation of farming system	84	–	–	11	89	431
Variable cost (USD)	**581**	**46**	**671**	**375**	**669**	**1 998**

Notes: USD1 = PHP47.50 (September 2009). Numbers may not add up due to rounding.
FOB = fixed-off-bottom; HLL = hanging long line; MRLL = multiple raft long line; SW = spider web.

line installation were available in some places, which helps farmers to save on installation expenses. Some farmers (e.g. Farm 3) did not use hired labour but relied on family labour to install lines.

Revenue, cost and profit

The revenues, costs and profits of the six farms are summarized in Table 6. The results indicate that:

- All six farms have positive profits. Their profit margins vary from 22 percent (Farm 5 MRLL) to 82 percent (Farm 3 HLL).
- The break-even prices (i.e. costs per unit of production) vary from USD171/tonne (Farm 3 HLL) to USD834 (Farm 5 HLL).
- The returns on investment (ROI) vary from 1 075 percent (Farm 3 HLL) to 56 percent (Farm 5 MRLL).
- Almost all of the six farms can recover their initial capital investments in less than one year. Farm 5 MRLL, as the only exception, can recover its initial capital investment in about 1.2 years.
- For Farm 1, the FOB technique used requires relatively low capital investment compared with the other three farming systems. However, the farm used more hired labour than Farm 2, which used a similar system and hence had higher variable costs. The use by Farm 1 of a slow-growing species, *K. striatum* var. *sacol,* resulted in relatively low production volumes. The operation may not be economically viable if affected by severe episodes of "ice-ice" and/or *Neosiphonia* infestation during extreme weather conditions (low and high temperature – salinity readings).
- Farm 2 also used the FOB system and was a typical family farm that entailed very low initial capital investment as well as low initial seed expense. The farm relied mostly on family labour and hence had relatively low variable costs. The low capital and variable costs gave Farm 2 a relatively high profit margin, which made it more resilient to unfavourable conditions. One shortcoming of this low-input-low-cost operation is the prolonged waiting period associated with the splitting of propagules following the harvest (usually 15–21 days). In addition, the net profit of Farm 2 was lower than that of Farm 1 although they had a similar total length of lines.
- Farm 3 used the HLL system and appeared to be the most profitable among the six farms studied. The use of family labour and "bayanihan" lowered its

TABLE 6
Profitability analysis for four seaweed farming systems in different locations in the Philippines

Farms	**Farm 1 (FOB)**	**Farm 2 (FOB)**	**Farm 3 (HLL)**	**Farm 4 (HLL)**	**Farm 5 (MRLL)**	**Farm 6 (SW)**
Location	**Zamboanga**	**Tawi-Tawi**	**Palawan**	**Tawi-Tawi**	**Zamboanga**	**Zamboanga**
Farming species	***K. striatum* var. *sacol***	***K. striatum* var. *sacol***	***K. alvarezii* var. *tambalang***	***K. alvarezii* var. *tambalang***	***K. striatum* var. *sacol***	***K. alvarezii* var. *tambalang***
Scale of operation						
- Total length of lines (km)	1.8	1.62	2.7	1.8		
- Farm area (m^2)					500	2 700
Capital investment (USD)	**327**	**166**	**619**	**686**	**1 218**	**3 335**
Initial seed expenses (USD)	**442**	**21**	**568**	**263**	**421**	**1 263**
- Unit seed expense (USD/km)	246	13	210	146		
- Unit seed expense (USD/ha)					8 420	4 678
Dry seaweed produced (kg)	**2 143**	**900**	**8570**	**2 750**	**2 850**	**8 500**
- 1st crop (kg)	429	180	1714	550	570	1 700
- 2nd–5th crops (kg)	1 714	720	6 856	2 200	2 280	6 800
Productivity (tonne/km of lines)	**1.19**	**0.56**	**3.17**	**1.53**		
Productivity (tonne/ha)					**57**	**31**
Revenue (USD)	**2 346**	**966**	**8 119**	**2 953**	**3 060**	**9 126**
- 1st crop (USD)	469	193	1 624	591	612	1825
- 2nd–5th crops (USD)	1 877	773	6 495	2 362	2 448	7 301
Price of dry seaweed (USD/tonne)	**1 093**	**1 072**	**947**	**1 075**	**1 074**	**1 074**
Cost (USD)	**1 422**	**324**	**1 465**	**996**	**2 376**	**6 024**
- Fixed cost (depreciation) (USD)	134	55	136	175	349	1 089
- Variable cost (USD)	1 288	268	1 329	821	2 027	4 936
1st crop (USD)	581	46	672	375	669	1 998
2nd–5th crops (USD)	707	222	657	446	1 358	2 938
Cost per unit of production, i.e. break-even price (USD/tonne)	**664**	**360**	**171**	**362**	**834**	**709**
Net profit	**923**	**643**	**6654**	**1957**	**684**	**3102**
Profit margin (%)	39	67	82	66	22	34
Profit per km of lines (USD/km)	513	397	2 464	1 087	–	–
Profit per ha of area (USD/ha)					13 680	11 489
Return on investment (%)	**282**	**387**	**1 075**	**285**	**56**	**93**
Pay-back period	**0.31**	**0.24**	**0.09**	**0.32**	**1.18**	**0.80**

Notes: USD1 = PHP47.50 (September 2009). Numbers may not add up due to rounding.
FOB = fixed-off-bottom; HLL = hanging long line; MRLL = multiple raft long line; SW = spider web.

production costs of the HLL technique. In addition, the use of the fast-growing species, *K. alvarezii* var. *tambalang*, led to high production volumes. The farm had the highest net profit (in terms of both magnitude and profit margin), the highest ROI, and the shortest payback period.

- Farm 4 had an operation similar to Farm 3, which used the HLL system and had a relatively high profit margin. However, the use of hired labour increased its variable costs and reduced its profitability. Nevertheless, with a profit margin as high as 66 percent, the operation tends to be economically viable even under unfavourable conditions.
- Farm 5 (MRLL) and Farm 6 (SW) used farming systems for deeper water. The topography of the Zamboanga peninsula requires deep-sea farming techniques because of the scarcity of shallow intertidal areas as compared with Sitangkai,

Tawi-Tawi.[7] Both techniques are capital- and labour-intensive as propagules need to be tied to the structure. The use by Farm 5 of the slow-growing species, *K. striatum* var. *sacol,* led to a relatively low production volume and hence resulted in a relatively low net profit and long payback period. The relatively low profit margins of these two operations suggest that they may not be economically viable under unfavourable conditions such as severe episodes of "ice-ice" and/or *Neosiphonia* infestation.

3.3 Social performance

Seaweed farming has contributed to improving the socio-economic status of coastal communities in the Philippines through: (i) generating employment and hence steady incomes for tens of thousands of coastal families; (ii) providing diversified livelihoods to meet basic family needs such as food, shelter, education of children, and health care, among others; (iii) enhancing community cohesion through cooperation among farmers; (iv) strengthening stewardship of marine environment and resources; (v) promoting development of and enhancing viability of small and medium enterprises; and (vi) contributing to the local and national economies.

However, seaweed farming in the country has been subject to various limitations and shortcomings, such as: (i) lack of capital investment for many farmers (especially for small-scale farmers) to benefit from the economies of scale of more intensified seaweed farming; (ii) low incomes for some farmers because of seasonal and unstable production and low productivity; (iii) poor market linkages that deprive seaweed farmers of benefits of the seaweed value chain; (iv) community development hindered by lack of good leadership; and (v) farming environment threatened by indiscriminate discharge of domestic effluents.

Employment

Seaweed farming is a labour-intensive activity entailing a large workforce and, hence, it provides a good source of employment in the coastal communities and at the "pondohans". Figure 7 illustrates the estimated number of workers and companies involved in the seaweed farming value chain in the Philippines.

Although no specific figures are given in Figure 7, a large force of supporting or auxiliary workers is involved in sorting, cleaning, re-drying, baling, transporting, tracking, and many other activities along the trading and processing stages. In addition, the seaweed carrageenan industry employs a large number of staffs in its laboratories and offices.

Livelihoods

The contribution of the seaweed industry to improving living conditions has been recognized in the literature (Jain, 2006). Although seaweed farming is a demanding physical activity, the economic returns make the hard labour worthwhile. With production cycles spanning only 45 days (60–66 days if the initial 15–21 days of the nursery phase are included), harvests are produced rapidly compared with other aquaculture activities such as finfish cage culture (7–8 months), abalone culture (8–10 months), lobster cage culture (6–8 months) or agricultural crops such as rice, corn and cassava (90–120 days).

Experiences in the Philippines indicate that seaweed farming can be the primary source of livelihoods in some places such as Sitangkai (Tawi-Tawi), where 90–95 percent of farmers' time is spent in the preparation of propagules (selection and tying), harvesting and drying–packing. It can also be part of diversified livelihood sources. For example, seaweed farmers in Marupo, Coron, Palawan, who had diversified sources of livelihoods

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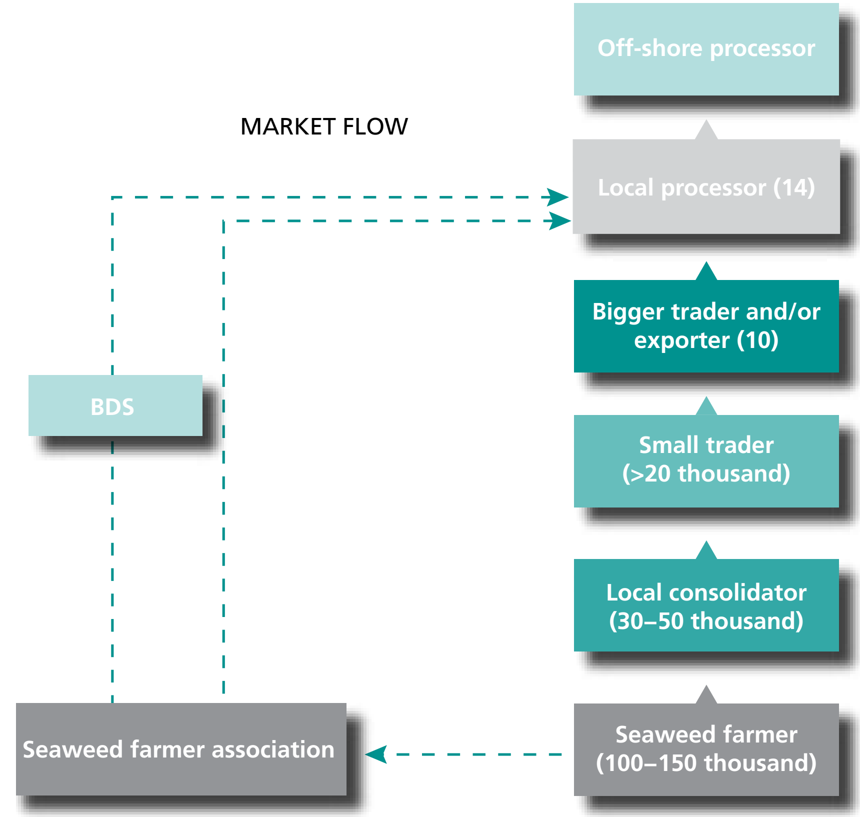
[7] MRLL was practised in Layag-Layag while SW was more common in Arena Blanco.

FIGURE 7

Number of persons or organizations involved with the seaweed farming industry in the Philippines



Note: BDS = Business Development Service.

such as planting of vegetables, cassava, rice and fishing, claimed that life would be much more difficult without seaweed farming, which increased their annual income by USD632–1 895 and helped them meet basic family needs, including children's education. The motorized boats of seaweed farmers were sometimes used to transport passengers.

Education

Generally, older seaweed farmers (> 40 years old) in the Philippines reached the elementary level but were not able to finish Grade 6. On the other hand, the younger generations (15–40 years old) either reached or finished the secondary level, or even go to college (up to the third year). The Sipangkot seaweed farmers have an important advantage over the other "pondohans" in Sitangkai in that their youths have been able to finish their secondary education in a national high school located in the island. Some families have had remarkable success with the education of their offspring. A family in Baligtang with seven children has been able to see five of them through college, who are now all employed in the Philippines or abroad. The two younger children still attend elementary school on Sipangkot Island. This family is also known for home-schooling their children through Grades 1 and 2. When the pupils reach Grade 3, they travel to the main island of Sipangkot, which is one hour away by motorized boat.

According to an earlier survey of the pondohans of Sitangkai (Hurtado, unpublished data), school-age children whose houses are close to the main island of Sitangkai attend elementary and secondary school. One of the pondohans runs a day-care centre for 2–5-year-olds. Some families can afford to send their children to colleges in Bongao, Tawi-Tawi or Zamboanga City.

Women and children

In order to comprehend fully the inner workings of seaweed farming in the Philippines, which is basically a family-based enterprise, gender issues are explored based on the results from earlier reports (Aming, 2004; Hurtado, 2005). Social impacts of seaweed farming were reviewed in Module 1 of Neish *et al.* (2009). A gender analysis for seaweed farming small and medium-sized enterprises (SMEs) was undertaken by the author and others in Indonesia and the Philippines in connection with the East ASEAN Initiative Business Development Services (EAI-BDS) Project of AusAID in 2008. The Philippine study focused on the seaweed farming regions of the Zamboanga peninsula.

The studies revealed that, in the seaweed farming communities of Flores and Zamboanga, women and children were neither exploited nor abused in so far as their rights as members of the family and community were concerned. Women farmers were equally involved with their husbands in the decision-making process on matters pertaining to household and seaweed farming activities. However, their involvement in decision-making pertaining to farming activities was generally consultative in nature. Men and women were generally found in scenes of cooperation and coproduction rather than in competition and conflict.

The studies also revealed that both men and women were active among accommodation providers with ecotourism potential. These activities are also run as family businesses. It was estimated that women represented about 44 percent of the regular labour force and were more prominent than men as casual labour; however, gender stereotyping was confining them to the lower-paid jobs.

The family-oriented cultivation of *Kappaphycus* involves the father, mother and all children over 6–7 years old. Generally, all unmarried adult offspring in a family are participants in this endeavour (Barraca and Neish, 1978). Preparations for planting such as the knotting of nylon cords, insertion of "tie-ties" to the cultivation line, and seaweed cluster tying are usually performed by wives and women (Hurtado and Agbayani, 2002). Children join their mothers in these tasks. As the head of the family, the father usually carries out the toughest tasks such as installation of stakes, deployment of anchors and preparation of rafts. Wives generally accompany their husbands in these activities, helping to load and unload the materials their husbands will use in the field. If in a family the father has died, his widow will usually take charge of all tasks, from preparation of seedlings and support materials to planting and hauling.

Women and children are involved in seaweed cluster tying in Tictauan Island, Pangapuyan, Panyam, Layag-Layag, and Arena Blanco, Zamboanga City, where deep-sea farming is practised. Women usually assist men in the harvesting of seaweeds grown in deeper areas – an activity normally conducted by men – by collecting the untied cultivation lines and placing them in the boat. However, women can harvest the crop by themselves if seaweeds have been planted in shallow areas. Widows are always assisted in these tasks by their unmarried male children.

One of the most critical stages in seaweed production is post-harvest management. The market price of seaweed is determined after this process is completed. Sun-drying (including turning over) of the harvested seaweed over fishnets on a platform or on the ground is normally undertaken by women with the assistance of children. Aggregating, packing and storing the dried seaweed are carried out jointly by women and men. However, some farmers have recently opted to sell their harvested crops immediately to traders in fresh form or in semi-dried form (55–60 percent MC) so that they can attend immediately to their next farming activities. These farmers claim that sun-drying of seaweed is laborious and time-consuming (3–4 days for an MC of 40–45 percent).

Seaweed for export and for SRC and RC processing must ideally be free from unwanted seaweed (epiphytes), dirt, "tie-ties", shells and other impurities. Women provide the workforce at this stage on a daily wage basis (USD3.00–4.25/day) while schoolchildren are hired on weekends, holidays or summer vacations on a per-basket wage basis.

Seaweed farming is a labour-intensive endeavour. The inclusion of women and children in the workforce, especially for the preparation of seedlings and planting materials and cleaning and sorting of dried seaweed, plays a significant role. This is mainly done in order to save on labour costs. It is widely perceived that the labour output will increase with the number of children in the family.

Stewardship of marine resources

Seaweed farming has contributed to reduce overexploitation of fishery resources. Although claims made by Sievanen *et al.* (2005) in the sense that "increased income provided by seaweed farming may even be invested in capital improvement of fisheries business" may hold true in Bohol and Bais Bay, Negros Oriental, the introduction of seaweed farming in Sitangkai in the early 1970s did result in reduced fishing effort, including destructive fishing practices. Seaweed aquaculture in this area has emerged as the major livelihood activity, leaving farmers with little time to engage in overexploitation of marine resources. Moreover, the income derived from seaweed farming is sufficient for them to meet their daily needs.

Community development

As mentioned above, seaweed farming in the Philippines is approached as a family endeavour; hence, benefits (food, shelter, education, health services, etc.) are shared among all family members. The strong family ties of the Filipinos (the Tausug ethnic group in particular) are exemplified by the fact that homes are normally inhabited by grandparents, uncles, aunts, grandchildren, etc., in addition to the nuclear family members.

Migratory flows have played an important factor in the development of the seaweed farming industry. Increased production in Sitangkai has been made possible by the migration of tens of thousands of Joloanons who originally came from Sulu. This migration started in the 1970s and has continued to the present time. In search of better opportunities, Filipino seaweed farmers have migrated to nearby Sabah (Malaysia), where they currently account for 90–95 percent of the seaweed industry workforce.

Success stories

A number of interviews were conducted in several seaweed farming sites to document the socio-economic impacts of seaweed farming in the Philippines. The results of these interviews are exemplified in the three case studies presented below.

Case 1

Gorgonio Pulilan from Marcilla, Coron, Palawan, married with a five-year-old child, re-initiated seaweed farming in the Mataya Reef in 2006, following the closure of a nearby pearl farm. He understood that seaweed farming in the area could not be made profitable as long as the pearl farm operated because its effluents negatively affected the growth of seaweeds.

In 2005, the Shell Foundation conducted a three-day training course on seaweed farming as part of their corporate social responsibility (CSR) programme. Upon completion of the course, Mr Pulilan and 89 other trainees were given planting materials such as ropes, soft straws, and propagules. These materials gave Mr Pulilan the opportunity to farm once again *K. alvarezii* var. *tambalang*. Mr Pulilan has succeeded despite problems such as the occurrence of "ice-ice" from January to March and grazing by herbivorous fish from June to August. Initially, he owned 42 30-m lines and had an income of USD145 (June–July) resulting from the production of 800 kg of dry seaweed. At present, he operates 68 HLLs and 42 nursery lines. His income from seaweed farming has allowed him to acquire a modest house on the mainland, a farmhouse with a drying platform worth USD135, a motorized boat and a dugout boat. Mr Pulilan confidently claims that seaweed farming has dramatically improved the living conditions of his family.

Case 2

Ibrahim Ibno migrated from Jolo, Sulu, to Sipangkot Island, Sitangkai, Tawi-Tawi, at the age of ten years in 1985. His father and relatives had migrated to Sipangkot ten years earlier to begin a seaweed farming business. Today, Ibrahim is not only a seaweed farmer but also one of the largest traders in the area. He currently owns 153 8.75-m lines planted with *K. striatum* (kab-kab). Mr Ibno plants *K. striatum* during the southwest monsoon and *K. alvarezii* during the northwest monsoon, which is common practice in Sitangkai. The grow-out cycle normally lasts 45 days, generating about USD947 and USD459 in gross and net revenue, respectively. Mr Ibno owns two motorized boats and a semi-permanent modest house; in addition, his family owns a 10-hp generator and one of the largest television sets in the village (including a parabolic antenna and DVD player). He is the president of the Sipangkot Seaweed Planters Association; in this role, he oversees the harvesting and drying schedules for all members. He is also responsible for taking the entire harvest of RDS to the processing centres in Bongao or Zamboanga.

Case 3

In 2007, the Philippine Development Assistance Program (PDAP), an NGO supported by the Canadian International Development Agency (CIDA), sponsored the Sitangkai Seaweed Productivity Enhancement through Education and Extension (SPE3) programme in three pondohans in Sitangkai, Tawi-Tawi: Sipangkot, Tinambak and Sikulan. The author of this chapter shared her expertise as a lecturer-trainer on all aspects of *Kappaphycus* farming, including: (i) taxonomy, distribution and biology–physiology–ecology; (ii) farming; (iii) crop management (diseases and epiphytism); (iv) post-harvest management; (v) marketing; and (vi) product applications. At the end of the training course, an experimental farm was established to demonstrate science-based farming of *Kappaphycus*. The experience of Ummik Sabun, one of the successful seaweed youth farmers coming out from SPE3, is presented below.

Ummik Sabun was able to implement carefully the science-based knowledge imparted in the training programme. Mr Sabun successfully harvested a crop worth USD2 105 from an initial capital of only USD21. Because of seaweed farming, he was able to acquire two small motorized boats, a 10-hp generator, a television set, a sari-sari store,[8] and is now the primary income earner in his family. Mr Sabun explained that he was hardly able to obtain good harvests prior to the SPE3 training because the "ice-ice" malaise and *Neosiphonia* infestations would spoil his crops. The SPE3 training programme gave him the opportunity to improve his seaweed farming skills through proper crop management (selection of cultivar and farming technique according to the season) and post-harvest management (drying facilities and moisture content). Prior to the SPE3 training, he used to plant 600 lines that ultimately would be plagued with diseases. Currently, he is able to avoid the occurrence of these diseases, which allows him to manage an additional 100. Nowadays, Mr Sabun is considered one of the wealthiest seaweed farmers on his island and has become a provider of good-quality cultivars and propagules to other seaweed farmers.

Many graduates of the SPE3 training programme are providing extension advice to farmers in other pondohans.

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[8] A sari-sari store is a type of convenience store found in the Philippines. Most sari-sari stores are privately owned shops and are operated inside the shopkeeper's house.

4. GOVERNANCE AND INSTITUTIONS

4.1 Government and international agencies

Seaweed farming is perceived by the Philippine government, especially the local government units, as a means to generate employment and alleviate poverty in coastal communities. Seaweed is a multimillion-dollar export commodity that generates high revenues to the national economy.

The Bureau of Fisheries and Aquatic Resources (BFAR) under the Department of Agriculture (DA) has provided various supports to the seaweed industry, including: (i) giving farmers cultivars, ropes and soft ties; (ii) supporting the establishment of nurseries in order to overcome the seed constraint; and (iii) coordinating extension services to farmers.

The Government has also established policy and regulations to promote sustainable development of the sector. For example, in a recent policy (formulated as of 14 September 2009), standards and guidelines were established to ensure the quality and safety of seaweed products (Table 7).

TABLE 7
Quality standards for farmed seaweed in the Philippines

Class	Moisture content	Clean anhydrous seaweed*	Impurities	Sand and salt	Colour
	(%)				
Kappaphycus					Definitely not black
Class A	≤ 35	≥ 52	≤ 3	≤ 10	
Class B	36–39	48–51	≤ 3	≤ 10	
Class C	≤ 40	≥ 47	≤ 3	≤ 10	
Eucheuma					Definitely not black
Class A	≤ 30	≥ 57	≤ 3	≤ 10	
Class B	31–34	53–56	≤ 3	≤ 10	
Class C	≤ 35	≥ 52	≤ 3	≤ 10	

* Clean anhydrous seaweed refers to seaweeds that have been removed of moisture, salt, sand and other impurities.
Source: PNS/BAFPS (2009).

Using a top-to-bottom approach, the Government of the Philippines has formulated a National Seaweed Development Program to look into the priority concerns, issues and problems of the seaweed industry in the country. Only the province of Bohol has developed a local policy for its seaweed industry, but all local governments are responsible for issuing licences and permits to seaweed farmers within their respective areas.

International agencies have also played active roles in seaweed farming development in the Philippines by financing projects, providing technical assistance, and conducting training or other capacity-building activities, among others. For example:

- The IFC-ADB established two seaweed nurseries in Zamboanga City (Arena Blanco and Manicahan) in June–September 2007.
- The Seaplant.net-AusAID-EAI project established a BDS for the seaweed farmers of Zamboanga City.
- The GTZ/Seaplant.net/AusAID-EAI project delivered training courses on good aquaculture practices (GAPs) to LGUs, MAOs and state colleges and universities in Mindanao and Palawan;
- USAID and the International Youth Foundation (IYF) have become collaborators in the SPE3 programme promoted by the PDAP.

4.2 Civil societies and research communities

A number of local and international NGOs have played a vital role in the development of seaweed farming in the Philippines.[9] The constant delivery of training courses and workshops by these NGOs has exposed seaweed farmers to an entire range of concepts related to GAPs and empowered them to become more capable and responsible members of their communities. For example, in collaboration with the CIDA and the Consuelo Foundation,[10] the PDAP harnesses the capabilities of out-of-school youth to help them become active players in the improvement of the seaweed industry of Sitangkai. On-site training courses on the basic biology, ecology and physiology of *Kappaphycus* as well as farming, crop management, post-harvest management, marketing and product applications, have been hosted as part of the programme.

Producers normally organize themselves in associations for the purpose of sourcing financial and technical assistance from both government organizations and NGOs. As noted above, farmers associations buy fresh seaweed, then dry it and sell it directly to a processor through the assistance of a BDS[11] or an NGO. This scheme eliminates one or two layers of trading/marketing, thereby increasing profit margins for the growers. However, it is noted that few associations are successful in attaining their stated objectives. As a result, some industry observers have concluded that individual farmers may obtain better results than groups of farmers working communally.

Education plays a significant role towards improving the production capabilities of seaweed farmers. The Philippine Council for Aquatic and Marine Research and Development – Department of Science and Technology has been responsible for conducting and funding seaweed R&D through different state colleges and universities. Within this context, the University of the Philippines – Marine Science Institute has emerged as the lead centre for seaweed R&D in the country, being supported in this role by the regional state colleges and universities. A number of local and international NGOs also support the various seaweed R&D programmes in the country.

Cross-visits of farmers to other production areas and research institutions are additional avenues to increase and improve farmers' capabilities. The exposure and interaction with scientists and experts achieved through collaborative research projects have also generated very positive feedback. For example, the association between the Kasanyangan Nursery Seaweed Enterprise and the Manicahan Pearl Diving Multi-Purpose Cooperative in Zamboanga City under the ADB-IFC seaweed nursery project in 2007 was fruitful not only in terms of the acquisition of new technologies, but also in terms of the learning of entrepreneurial skills. The experimental farm jointly run by the youths of the Sipangkot Seaweed Planters Association and the Tinambak Seaweed Planters Association in Sitangkai (with the support of PDAP-SEAFDEC-ISDA) demonstrates also the significance of implementing science-based technologies to enhance productivity. The experience and knowledge acquired by youths in these two "pondohans" has allowed them to act as extension leaders in other "pondohans".

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[9] The local NGOs include the PDAP, KFI, ISDA, LGSP and PBSP; the international NGOs include GTZ, CIDA, ASL, Seaplant.net, and Cargill Texturizing Solutions.

[10] The Consuelo Foundation is a philanthropic organization focused on relieving the suffering of neglected and abused children and women in the Philippines and Hawaií (the Unites States of America).

[11] The concept of BDS in the seaweed industry is relatively new; hence, only two BDS are known to date. The BDS link farmers directly to the market. Support from BDS providers is best mediated through producer organizations, networks and alliances.

5. CHALLENGES AND THE WAY FORWARD

Sustainable development of seaweed farming in the Philippines entails efforts from various stakeholders to overcome a number of constraints on the economic, social, environmental and governance aspects of the seaweed value chain. Some major issues and requirements identified by different stakeholders are summarized below.

Important issues and requirements in terms of production include:

- expansion of farming areas to deeper waters;
- appropriate site selection and zoning arrangement;
- development and access to farming technologies suitable to the farming location;
- development of, access to, and proper use of high-quality cultivars (e.g. fast-growing and disease-resistant);
- prevention or control of "ice-ice" malaise and *Neosiphonia* infestation;
- establishment of nurseries in strategic areas nationwide.

Important issues and requirements in terms of seaweed processing, marketing and trade include:

- access to good-quality dry seaweeds by local processors;
- access to fair trade and market links by seaweed farmers and processors;
- more efficient value chain through minimizing layers of trading and eliminating illegal traders;
- establishment of well-functioned BDSs to link farmers associations directly to processors;
- further development of markets for carrageenan products.

Important issues and requirements in terms of R&D and financial services include:

- close interaction and collaboration between seaweed farmers and research communities;
- access to local bank loans by farmers, especially small-scale farmers.

5.1 Trade and marketing

A number of trade and marketing issues must be addressed to ensure continued growth of the industry:

- Brand management: Each segment in the value chain has to develop and protect its own brand to maintain and increase its market share. Awareness of culture practices that relate to product quality and food safety must be enhanced and linked with market requirements.
- Adding value near crop sources: This practice would provide a higher income and diversify sources of livelihood to the seaweed farmer.
- Secure electronic transaction systems: Appropriate in places where information and communication technology is accessible.
- Traceable transactions and product flows: Ecolabelling could play an important role as it would provide valuable information about the product.
- Testing, verification and certification: A duly certified laboratory could examine the RDS and provide certification for a number of attributes, MC in particular.
- Market knowledge and information: producers need to be linked with proper agencies that could provide accurate price information.
- Product innovation and development: Processors need to engage in continuous R&D in order to meet the changing needs of the end users.
- Marketing and sales tools and services: Aggressive and effective marketing strategies, along with excellent customer service, need to be undertaken by processors.
- Electronic buy–sell systems: The fastest and simplest means of buying and selling carrageenan is via electronic mails. Business transactions are performed in a few minutes and can be closed in a day. Among farmers, the Short Message Service

(SMS) and Multimedia Messaging Service (MMS) are powerful tools for the buying and selling of RDS. A farmer or trader can e-mail a picture of the RDS to larger traders, exporters or processors for preliminary assessment.

- Education and training systems: Continuing education on GAPs for seaweed farmers and training on quality control for workers and managers in processing plants are essential.
- Regional collection and distribution hubs: The establishment of these networks is essential to carrageenan processors for efficient sourcing of RDS and for local and offshore marketing of the final product.

5.2 Education and R&D

Further advancement of seaweed farming in the Philippines will require scientific and technological support. Farmers need to receive continuous education to keep them abreast of the latest technology and to update their knowledge of seaweed biology, physiology and ecology to understand better how seaweeds interact with their environment.

The R&D programmes in a country must be designed with the needs of its various industries in mind. Although basic research is important, applied research must be given greater weight. In the case of the seaweed industry, only a limited number of academic and non-academic institutions in the Philippines have been involved in R&D, which has resulted in the lack of human resources available to assist the industry with emerging production, technological and marketing challenges.

Most R&D in the Philippines and the BIMP-EAGA region has been focused on *Kappaphycus* and *Eucheuma* simply because of the commercial importance and the "flagship" status of *Kappaphycus*. However, it is also important to take advantage of the Philippines' rich endowment in different seaweed species to explore and develop the potential of other economically important seaweeds such as *Gracilaria* as a source of agar and agarose, *Sargassum* as a source of alginates, and *Caulerpa* as a sea vegetable. Similarly, it is advisable to conduct research on rare species that could potentially yield new pharmaceuticals.

Except for SRC and RC, the seaweed industry in the Philippines has failed to develop significant product applications in the last 40 years. Additional uses for seaweed need to be identified. For example, research conducted in other countries has shown that seaweed fertilizer could be derived from the sap of *Kappaphycus.* This application could potentially be developed in the Philippines.

5.3 Expansion, intensification and diversification

Expansion of seaweed farming areas is feasible in some locations. For example, GIS-generated maps have revealed plenty of areas suitable for seaweed farming in Sitangkai (up to 15 m deep). Intensification of activities can be achieved in certain locations, particularly in areas where production is seasonal. However, intensification carries the risk of bringing imbalances for farming areas that have reached the limits of their carrying capacity.

Polyculture, i.e. the farming of two or more different commodities within the same culture environment, has distinct advantages over monoculture, including the potential for earning higher revenues. In particular, the integration of finfish, molluscs, crustaceans and seaweed, commonly known as integrated multitrophic aquaculture (IMTA), provides an environmentally friendly farming system with the potential to increase profitability in aquaculture by enabling the production of additional marine crops.

As it is currently practised, the potential contribution of seaweed farming to diversified livelihoods in coastal communities has yet to be fully exploited. In the majority of places visited during this study, seaweed farming was undertaken as the primary source of livelihoods, which was particularly true for the larger farmers. Seaweed farming is a labour-intensive endeavour that requires great dedication and focused efforts from producers, leaving them little time for other activities. Farmers slow down occasionally only during planting owing to the unavailability of propagules. It is the author's opinion that seaweed farmers could benefit from the diversification of marine aquaculture in order to generate additional sources of income. This is particularly important in view of the problems that occasionally beset seaweed culture.

The richness of the marine resources of Tawi-Tawi, Zamboanga Peninsula and Palawan could bring greater opportunities to the coastal inhabitants. However, these opportunities need to take advantage of the new technologies developed at the research institutions. In this regard, the expertise of SEAFDEC/AQD in Tigbauan, Iloilo, could be tapped to introduce marine aquaculture technologies to the seaweed coastal communities. In Sitangkai, pen culture of abalone could be introduced, while cage culture of grouper, Napoleon wrasse and lobster could be promoted in Pangapuyan Island, Zamboanga. In general, sound IMTA systems could be introduced in the culture areas, which would have *Kappaphycus* or *Gracilaria* as one of the major components.

Seaweed farmers currently engage in the gleaning of sea urchins (Arena Blanco and Look Panyam, Zamboanga City), gathering of abalones (Sitangkai), and gathering of wild juveniles of groupers and Napoleon wrasse (Pangapuyan Island, Zamboanga City; Tandu Banak, Sibutu, Tawi-Tawi). These activities are only seasonal and conducted on a very small scale, but they acquire greater importance in times of low seaweed prices. International buyers (Chinese from both China, Hong Kong SAR and mainland China) have begun to purchase live grouper and Napoleon wrasse in Tandu Banak, Sibutu. This trade has not emerged as a result of an introduced science-based technology; instead, it is a product of the seaweed farmers' own ingenuity. However, production could be increased provided farmers are given the opportunity to adopt technologies developed from research.

5.4 Infrastructure and services

Frequent and reliable connection to the different elements of the value chain and stakeholders in the industry play a significant role in upgrading and improving the marketability of crops. Internet connectivity is the key factor to facilitate timely communication and information exchanges among stakeholders.

Periodic workshops and meetings are important in order to keep stakeholders (especially farmers) abreast of the latest information on market conditions (prices) and farming technologies and management.

Transportation systems (especially in remote islands) must be improved to allow convenient and fast access to the markets. A fast-craft service from Sitangkai to Bongao, Tawi-Tawi, or operating in other places such as Agutaya, Palawan and Cagayancillo, Palawan, would increase farm productivity.

Access to financial services has been one of the weakest links that needs improvement. Seaweed farmers in the Philippines usually rely on own funds for investment and operation, which not only hinders their development but also makes them less resilient to negative shocks. Farmers must have access to the financial institutions to avail themselves of capital as well as financial services such as crop insurance and electronic banking.[12]

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[12] Traditionally, seaweed farmers trust their cash to relatives who are traders. Whenever they need cash, farmers just go back and obtain it from their relatives. Farmers repeatedly state that having cash at the pondohan is not a safe practice; therefore, they need to be taught how to use bank services.

References

Aming, N. 2004. *Participation of Filipino Muslim women in seaweed farming in Sitangkai, Tawi-Tawi, Philippines*. University of the Philippines in Los Baños. (PhD dissertation)

Barraca, R.T. & Neish, I.C. 1978. *A survey of Eucheuma farming practices in Tawi-Tawi. I. The Sitangkai, Sibutu, Tumindao Region*. Report submitted to Marine Colloids, Inc. 65 pp.

Bureau of Agricultural Statistics (BAS). 2010. *Bureau of Agricultural Statistics* [online]. Quezon City, Philippines, Department of Agriculture. [Cited 9 January 2013]. www.bas.gov.ph/.

Dakay, B.U. 2008. Developing a partnership between the Philippines and Indonesia in the seaweed industry. Makassar, South Sulawesi, Indonesia. First Indonesia Seaweed Forum.

Dakay, B.U. 2010. *The Future of the Carrageenan Industry*. Paper presented at SEABFEX III, Surabaya, Indonesia. 14–17 July 2010.

Hurtado, A.Q. 2005. *The role of women and children in seaweed farming in the Philippines and environmental impacts of seaweed farming*. Final report submitted to IFC. 24 pp.

Hurtado, A.Q. & Agbayani, R.F. 2002. Deep sea farming of *Kappaphycus* using multiple raft long-line method. *Botanica Marina,* 45: 438–444.

Hurtado, A.Q., Agbayani, R.F., Sanares, R. & de Castro-Mallare, M.T. 2001. The seasonality and economic feasibility of cultivating *Kappaphycus alvarezii* in Panagatan Cays, Caluya, Antique, Philippines. *Aquaculture*, 199: 295–310.

Jain, S. 2006. *The seaweed industry: exploring an alternative to poverty*. Manila, Department of Trade and Industry. 124 pp.

National Statistics Office (NSO). 2010. *National Statistics Office* [online]. Manila. [Cited 9 January 2013]. www.census.gov.ph/

Neish, I.C., Hurtado, A.Q., Julianto, B. & Saragih, D. 2009. *Good aquaculture practices for Kappaphycus and Eucheuma. A compilation of nine training modules for seaweed farmers.* Seaplant.net Monograph no. HB2F 0909 V4 GAP. Makassar, Sulawesi Selatan, Indonesia.

Philippine National Standards/Bureau of Agricultural and Fisheries Products Standards (PNS/BAFPS). 2009. *Dried raw seaweed specifications*. 11 pp.

Seaweed Industry Association of the Philippines. 2009. *Seaweed Statistics*. Cebu City, Philippines.

Sievanen, L., Crawford, B., Pollnac, R. & Lowe, C. 2005. Weeding through assumptions of livelihood approaches in ICM: seaweed farming in the Philippines and Indonesia. *Ocean & Coastal Management*, 48: 297–313.

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

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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*.

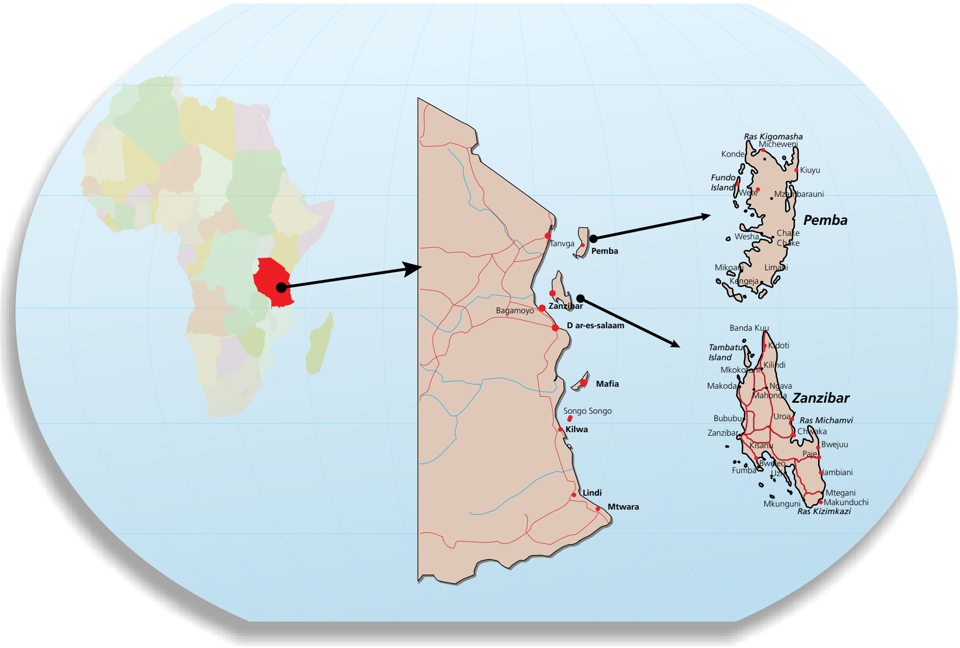
From the two seaweed species farmed in Tanzania, a gel called "carrageenan" is extracted and used in a number of industries, including food, pharmaceutical, cosmetic, and textile. Seaweed is thus valued on the quality of the carrageenan. The gel extracted from *E. denticulatum* is called *iota* carrageenan 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



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

2. CARRAGEENAN SEAWEED PRODUCTION AND VALUE CHAIN

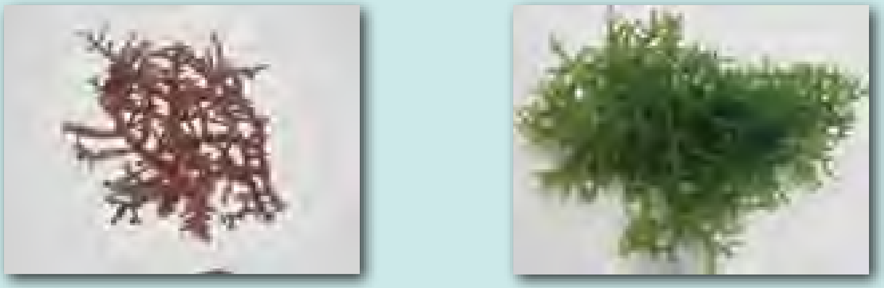
2.1 History

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).

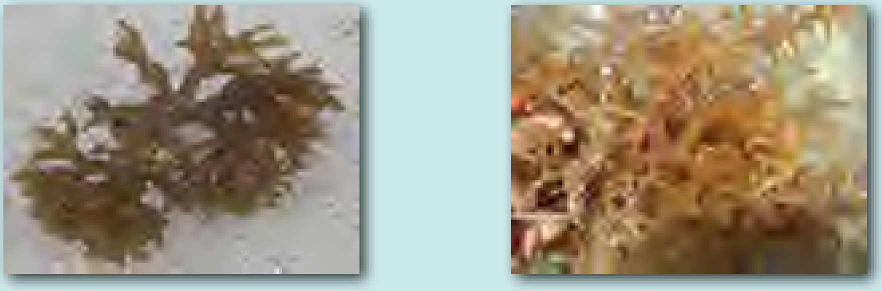
FIGURE 2

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

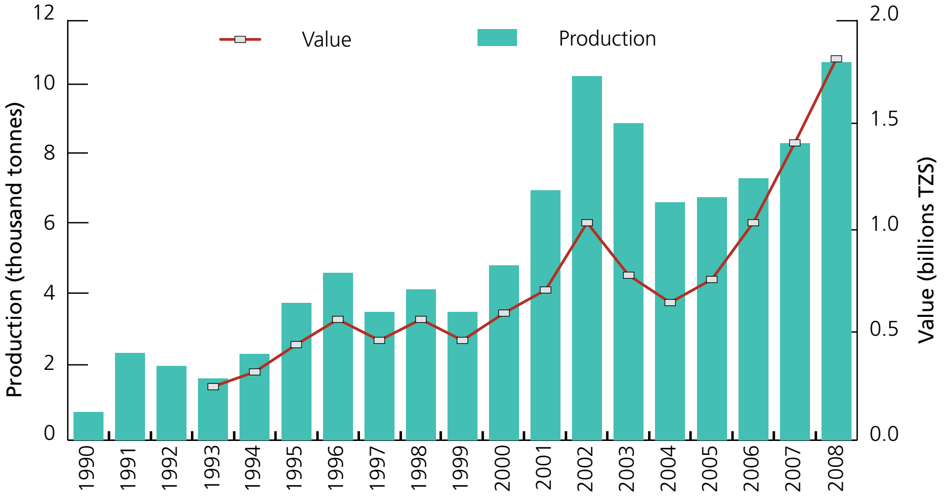
As mentioned above, the idea of farming seaweed in Tanzania was introduced in the early 1970s by Professor Keto Mshigeni of the University of Dar es Salaam (Mshigeni, 1973; 1976), who also conducted the first culture trials (Mshigeni, 1985). These experiments encouraged private entrepreneurs in the late 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).

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[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).

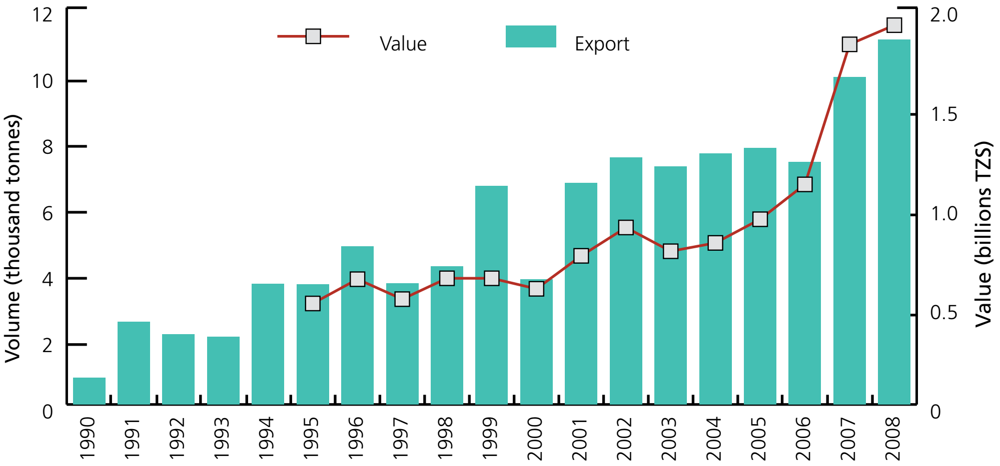
Production and trade

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).

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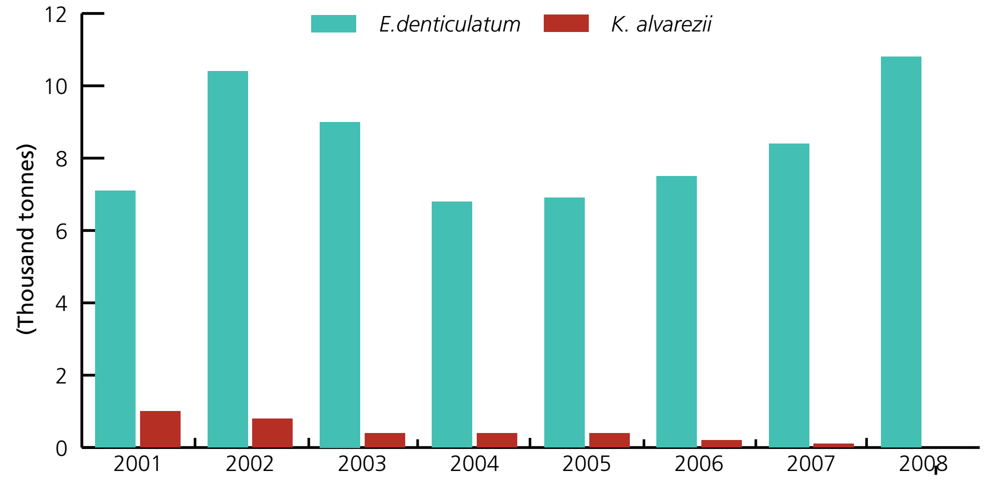
[3] An agarophyte is seaweed producing the hydrocolloid agar as part of the makeup of their cell wall. This agar can be harvested commercially for use in biological experiments, among other applications.

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

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[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).

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[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

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[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.

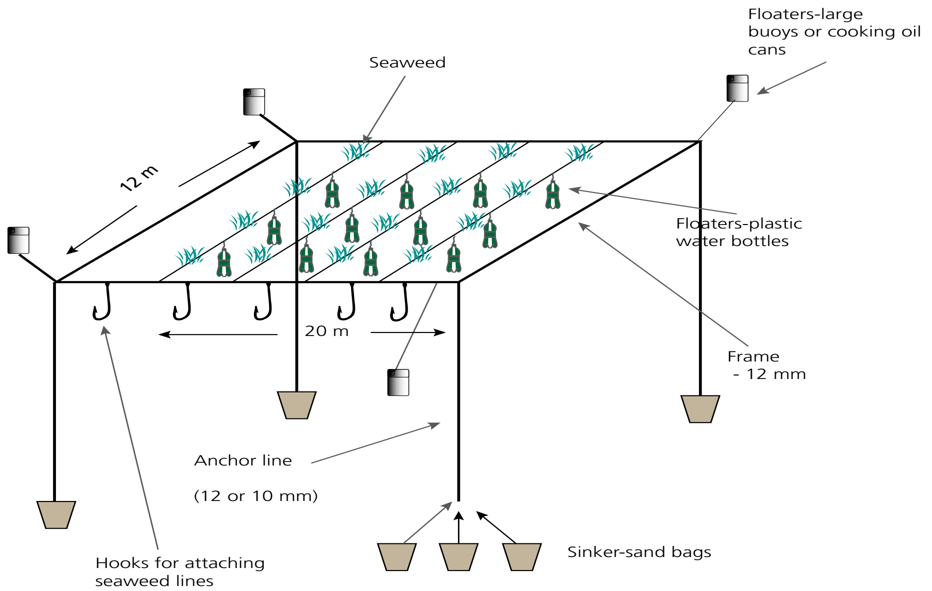
Trials have also been conducted on deep-water farming with bamboo rafts (Zuberi, 2000; Msuya and Kyewalyanga, 2006; Msuya and Salum, 2006). However, this technique has not been adopted primarily because of the limited availability of bamboos along the coast and the fact that bamboo rafts are not durable.

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)

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[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:

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[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.

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[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.

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[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

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[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

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[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

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[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

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[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.

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[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,

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[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

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[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.

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[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.

References

ACDI/VOCA. 2005. *Smallholder empowerment & economic growth through agribusiness & association development (SEEGAAD) – final project report*. Cooperative Agreement No. 623-A-00-03-00005-00. 42 pp.

Ask, E.I. 1999. *Cottonii and spinosum cultivation handbook*. Philadelphia, USA, FMC Food Ingredients Division. 32 pp.

Bryceson, I. 2002. Coastal aquaculture developments in Tanzania: sustainable and non-sustainable experience. *Western Indian Ocean J. Mar. Sci.,* 1(1): 1–10.

Brycesson, I. 2009. Mariculture in the WIO region – challenges and prospects, main challenges for coastal aquaculture development in WIO region: who are the winners and losers? Presented at the IFS/WIOMSA Workshop on Coastal Aquaculture Development in East Africa: challenges and prospects. Zanzibar, Tanzania.

Carlsson, A.S., van Beilen, J.B., Möller, R. & Clayton, D. 2007. Micro- and macro-algae: utility for industrial applications. *In* D. Bowles, ed., *Outputs from the EPOBIO Project*. United Kingdom, CPL Press.

Conand, C., Muthiga, N., Aumeeruddy, R., De La Torre Castro, M., Frouin, P., Mgaya, Y., Mirault E., Chiewo, J. & Rasolofonirina, R. 2006. A three-year project on sea cucumbers in the south-western Indian Ocean: National and regional analyses to improve management. *SPC Beche-de-mer information Bulletin,* 23: 11–15.

Eklöf, J.S., de la Torre Castro, M., Adelskoild, L., Jiddawi, N.S. & Kautsky, N. 2005. Differences in macrofaunal and seagrass assemblages in seagrass beds with and without seaweed farms. *Estuar. Coast. Shelf Sci.,* 63: 385–396.

Eklund, S. & Pettersson, P. 1992. *Mwani is money: the development of seaweed farming and its socio-economic effects in the village of Paje*. Report from a Minor Field Study, No.24, Department of Social Anthropology, Stockholm University. Stockholm.

Hayashi, L., Yokoya, N.S., Ostini, S., Pereira, R.T.L., Braga, E.S. & Oliveira, E.C. 2008. Nutrients removed by *Kappaphycus alvarezii* (Rhodophyta, Solieriaceae) in integrated cultivation with fishes in re-circulating water. *Aquaculture,* 277:185–191.

Hurtado, A.Q. 1992. Cage culture of *Kappaphycus alvarezii* var. *tambalang* (Gigartinales, Rhodophyceae). *J. Appl. Phycol*., 4: 311–313.

Hurtado, A.Q. & Agbayani, R.F. 2002. Deep-sea farming of *Kappaphycus* using multiple raft long-line method. *Botanica Marina,* 45: 438–444.

Hurtado, A.Q. & Critchley, A.T. 2006a. Epiphytes. *In* A.T. Critchley, M. Ohno & D.B. Largo, eds. *World seaweed resources: an authoritative reference system*. Amsterdam, ETI BioInformatics.

Hurtado, A.Q. & Critchley, A.T. 2006b. Seaweed industry of the Philippines and the problem of epiphytism in *Kappaphycus* farming. *In* P. Siew-Moi, A.T. Critchley & P.O. Ang, Jr, eds. *Advances on seaweed cultivation and utilization in Asia*. Kuala Lumpur, University of Malaya Maritime Research Centre.

Hurtado, A.Q., Critchley, A.T., Trespoey, A. & Bleicher-Lhonneur, G. 2006. Occurrence of *Polysiphonia* epiphytes in *Kappaphycus* farms at Calaguas Is., Camarines Norte, Philippines. *J. Appl. Phycol.*, 18: 301–306.

Jaasund, E. 1976. Intertidal seaweeds in Tanzania: a field guide. Tromsø, Norway, University of Tromsø. 160 pp.

Kivaisi, A.K. & Buriyo, A.S. 2005. *Assessment of native gar extracted from Gracilaria cornea and Gracilaria salicornia harvested along the Tanzanian coast for culturing microorganisms*. Presented at the Fourth Western Indian Ocean Marine Science Association (WIOMSA) Scientific Symposium. Grand Baie, Mauritius.

Largo, DB., Fukami, K. & Nishijima, T. 1995. Occasional pathogenic bacteria promoting ice-ice disease in the carrageenan-producing red algae *Kappaphycus alvarezii* and *Eucheuma denticulatum* (Solieriaceae, Gigartinales, Rhodophyta). *J. Appl. Phycol.*, 7: 545–554.

Lombardi, J.V., Marques, H.A., Barreto, O.J.S. 2001. Floating cages in open sea water: an alternative for promoting integrated aquaculture in Brazil. *World Aquaculture*, 32(3): 47,49–50.

Lombardi, J.V., Marques, H.L.A., Pereira, R.T.L., Barreto, O.J.S. & Paula, E.J. 2006. Cage polyculture of the Pacific white shrimp *Litopenaeus vannamei* and the Philippine seaweed *Kappaphycus alvarezii. Aquaculture,* 258: 412–415.

Lyimo, T.J., Mvungi, E.F., Lugomela, C. & Bjork, M. 2006. Seagrass biomass and productivity in seaweed and non-seaweed farming areas in the east coast of Zanzibar. *Western Indian Ocean J. Mar. Sci.*, 5:141–152.

Mamiro, G.B. & Manege, L. 2001. *Implementation of a mushroom farming and other ZERI visions in Tanzania: seaweed value addition.* A paper presented at the consultative workshop on the ZERI regional project (RAF-99-201). Windhoek.

Mmochi, A.J., Shaghude, Y.W. & Msuya, F.E. 2005. *Comparative study of seaweed farms in Tanga, Tanzania*. Submitted to SEEGAAD Project. 37 pp.

MNRT. 2005. *Seaweed development strategic plan*. Ministry of Natural Resources and Tourism, Tanzania. Dar es Salaam, University Printing Press. 47 pp.

Mshigeni, K.E. 1973. Exploitation of seaweeds in Tanzania: the Genus *Eucheuma* and other algae. *Tanzania Notes and Records*, 72: 19–36.

Mshigeni, K.E. 1976. Seaweed farming: a possibility for Tanzania's coastal Ujamaa villages. *Tanzania Notes and Records*, 79–80: 99–105.

Mshigeni, K.E. 1983a. Algae resources, exploitation and use in East Africa. *In* F.E. Round & D.J. Chapman, eds., *Progress in phycological research*, Vol. 2, pp. 387–419. Amsterdam, Elsevier Science.

Mshigeni, K.E. 1983b. *Mwani: ukulima wake baharini na manufaa yake kwetu*. Dar es Salaam, Tanzania Publishing House. 43 pp.

Mshigeni, K.E. 1985. *Pilot seaweed farming in Tanzania: progress report and future trends*. Dar es Salaam, University of Dar es Salaam. 22pp.

Mshigeni, K.E. 1992. Seaweed farming in Tanzania: a success story. *In* Mshigeni K.E., J. Bolton, A. Critchley and G. Kiangi, eds. *Proceedings of the first international workshop on sustainable seaweed resource development in sub-Saharan Africa*, pp. 221–240. Windhoek, Namibia.

Mshigeni, K.E. 1998. The seaweed resources of Tanzania. *In* A.T. Critchley & M. Ohno, eds. *Seaweed resources of the world*, pp. 389–397. Tokyo, Japanese International Cooperation Agency.

Msuya, F.E. 1995. *Feasibility study for starting seaweed farming in Lindi and Mtwara Regions, Tanzania*. Regional Integrated Project Support (RIPS) Programme (Phase I), Mtwara, Tanzania. Zanzibar, Tanzania, Institute of Marine Sciences. 49 pp.

Msuya, F.E. 1996. *Seaweed farming in Lindi and Mtwara regions.* Regional Integrated Project Support (RIPS) Programme (Phase II: Implementation and Expansion). IMS 1997/01. Zanzibar, Tanzania, Institute of Marine Sciences. 71 pp.

Msuya, F.E. 2000. Seaweed farming in Tanzania. *In* T.R. McClanahan, C.R.C. Sheppard & D.O. Obura, eds. *Coral reefs of the Indian Ocean: their ecology and conservation*, pp. 186–188. New York, Oxford University Press.

Msuya, F.E. 2005. Seaweed farming in Tanzania: farming processes and interactions between farmers and other stakeholders. *In* B.L.M. Mwamila & A.K. Temu, eds. *Proceedings of the National Stakeholders Workshop on Establishment of an Innovation Systems and Clusters Programme in Tanzania*, pp. 195–206. Bagamoyo, Tanzania, University of Dar es Salaam and Sida/SAREC.

Msuya, F.E. 2006a. The impact of seaweed farming on the social and economic structure of seaweed farming communities in Zanzibar, Tanzania. *In* A.T. Critchley, M. Ohno & D.B. Largo, eds. *World seaweed resources: an authoritative reference system*. Amsterdam, ETI BioInformatics.

Msuya F.E. 2006b. Seaweed farming as a potential cluster. *In* B.L.M. Mwamila & A.K. Temu, eds. *Proceedings of the Innovation Systems and Clusters Programme in Tanzania: Cluster Initiative Launching Workshop*, pp. 102–113. Dar es Salaam.

Msuya, F.E. 2007. Combating *Kappaphycus* die-offs in Tanzania. *Forum Phycologicum*, 66: 2–4.

Msuya, F.E. 2008. *Technology transfer for seaweed soap production: machines installation, training, and official launching*. Report submitted to Small and Medium Enterprises (SMEs) Competitiveness Facility. Kidoti, Zanzibar. 15 pp.

Msuya, F.E. 2009a. *Development of seaweed cultivation in Tanzania: the role of the University of Dar es Salaam and other institutions*. EC FP7 Project, SARNISSA. 25 pp.

Msuya, F.E. 2009b. *Progress on the farming of seaweed in rafts in Fundo, Wete, Pemba*. Report Submitted to Birr Sea Weed Company. Dar es Salaam. 9 pp.

Msuya, F.E. 2009c. *Innovation of the seaweed farming industry for community development: the case of the Zanzibar Islands, Tanzania*. Presented at the Annual Agricultural Review Workshop. Zanzibar, Tanzania.

Msuya, F.E. 2009d. *Seaweed farming innovation through the Zanzibar Seaweed Cluster Initiative*. Presented at the 6th Regional Conference on Innovation Systems and Innovative Clusters in Africa, and 1st PACF-EA Chapter Conference. Dar es Salaam.

Msuya, F.E. & Kyewalyanga, M.S. 2006. *Quality and quantity of the phycocolloid carrageenan in the seaweeds* Kappaphycus alvarezii *and Eucheuma denticulatum as affected by grow out period, seasonality, and nutrient concentration in Zanzibar, Tanzania*. Report submitted to Degussa Texturant Systems/Cargill Texturizing Solutions, France. 29 pp.

Msuya, F.E. & Porter, M. 2009. *Impacts of environmental changes on the farmed seaweed and seaweed farmers in Songosongo Island, Tanzania*. Report submitted under a Collaborative Project on Sustaining Coastal Fishing Communities, Memorial University of Newfoundland-University of Dar es Salaam. 26 pp.

Msuya, F.E. & Mmochi, A.J. 2008. *Deep water floating lines technique could solve the problem of seaweed die-off in Tanzania*. Presented at the 23rd Congress of the Phycological Society of Southern Africa. Rocky Bay, KwaZulu-Natal, South Africa.

Msuya, F.E. & Kyewalyanga, M.S. 2008. *Quality control and assurance of the seaweed soap*. Report submitted to Small and Medium Enterprises (SMEs) Competitiveness Facility. 19 pp.

Msuya, F.E. & Salum, D. 2006. *The effect of cultivation, duration, seasonality, and nutrient concentration on the growth rate and biomass yield of the seaweeds Kappaphycus alvarezii and Eucheuma denticulatum in Zanzibar, Tanzania.* Technical Report No. WIOMSA/MARG-1/2006-7. 23 pp. (also available at http://www.wiomariculture.org/pubs/MsuyaF-MARG%20I%20Final%20Technical%20Report-Modified.pdf).

Msuya, F.E. & Salum, D. 2007. *Effect of cultivation duration, seasonality, nutrients, air temperature and rainfall on carrageenan properties and substrata studies of the seaweeds Kappaphycus alvarezii and Eucheuma denticulatum in Zanzibar, Tanzania*. Technical Report WIOMSA-MARG I No. 2007–06. 36 pp. (also available at http://wiomsa.net/index.php?option=com_jdownloads&Itemid=53&task=view.download&catid=30&cid=273).

Msuya, F.E., Dickinson, T. & Whittick, A. 1994. *Community in transition: the impact of seaweed farming on the women of Paje, Zanzibar, Tanzania*. Video production, Institute of Marine Sciences, University of Dar es Salaam, Tanzania.

Msuya, F.E., Ngoile, M.A.K. & Shunula J.P. 1996. *The impact of seaweed farming on the macrophytes and macrobenthos of the East Coast of Unguja Island, Zanzibar, Tanzania*. IMS 1997/05. Dar es Salaam, University of Dar es Salaam, Tanzania. 68 pp.

Msuya, F. E., Mmochi, A. J. & Muhando, C. 2007b. *Ripoti ya mikutano ya kutenga maeneo ya matumizi ya bahari katika ghuba ya Mlingotini Wilaya ya Bagamoyo, Tarehe 17 – 27 Januari 2007.* Taasisi ya Sayansi za Bahari, Chuo Kikuu cha Dar Es Salaam, S.L.P. 668, Zanzibar, Tanzania, Mpango wa Sustainable Coastal Communities and Ecosystem (SUCCESS), Wafadhili. USAID. 19 pp.

Msuya, F.E., Shalli, M.S., Sullivan, K., Crawford, B., Tobey, J. & Mmochi, A.J. 2007a. *A comparative economic analysis of two seaweed farming methods in Tanzania.* The Sustainable Coastal Communities and Ecosystems Program. Coastal Resources Center, University of Rhode Island and the Western Indian Ocean Marine Science Association. 27 pp. (also available at http://www.wiomariculture.org/pubs/CompSeaweedEconReport.pdf).

Munoz, J. & Sahoo, D. 2007. Impact of large scale *Kappaphycus alvarezii* cultivation in coastal waters of India. *XIX^th^ International Seaweed Symposium: Program and Abstracts.* Kobe, Japan.

Paula, E.J., Pereira, R.T.L. & Ohno, M. 1999. Strain selection in *Kappaphycus alvarezii* var. *alvarezii* (Solieriaceae, Rhodophyta) using tetraspore progeny. *J. Appl. Phycol.*, 11: 111–121.

Rodrigueza, M.R.C. & Montano, M.N.E. 2007. Bioremediation potential of three carreegenophytes in tanks with seawater from fish farms. *J. Appl. Phycol.*, 19: 755–762.

Samoilys, M.A. & Kanyange, N.W. 2008. *Natural resource dependence, livelihoods and development: perceptions from Tanga, Tanzania.* Nairobi, IUCN ESARO. (also available at http://cmsdata.iucn.org/downloads/081118_tanga_report_low_res.pdf).

Schmitz, F. 1895. Marine Florideen vo Deutsch Ost-Afrika. *Bot. Jahrb.*, 2:137–177.

Scoones, I. 1998. *Sustainable rural livelihoods: a framework for analysis.* IDS Working Paper no. 72. Brighton, UK, Institute of Development Studies, University of Sussex.

Semesi, S. 2002. *Ecological and socio-economic impacts from Eucheuma seaweeds in Zanzibar, Tanzania.* M.Sc. Thesis. Å.Sc. ThesisNoragric, Agricultural University of Norway.

Shechambo, F., Ngazy, Z. & Msuya, F.E. 1996. *Socio-economic impacts of seaweed farming in the east coast of Zanzibar, Tanzania.* IMS 1997/06, Institute of Marine Sciences, University of Dar es Salaam. Dar es Salaam. 81 pp.

Sonder, W. 1879. Algae. *In* Baron Carl Claus von den Deckens, ed. *Reisen in Ost-Afrika in den Jahren 1859–1865*, Vol. 3 (3: Botanik), pp. 79-95. Leipzig, Germany, Akademische Druck- u. Verlagsanstalt.

Sulu, R., Kumar, L., Hay, C. & Pickering, T. 2006. *Kappaphycus* seaweed in the Pacific: review of introductions and field testing proposed quarantine protocols. *In* A.T. Critchley, M. Ohno & D.B. Largo, eds. *World seaweed resources: an authoritative reference system.* Amsterdam, ETI BioInformatics.

Vairappan, C.S. 2006. Seasonal occurrences of epiphytic algae on the commercially cultivated red alga *Kappaphycus alvarezii* (Solieriaceae, Gigartinales, Rhodophyta). *J. Appl. Phycol.*, 18: 611–617.

Vairappan, C.S., Chung, C.S., Hurtado, A.Q., Soya, F.E., Bleicher-Lhonneur, G. & Critchley, A. 2008. Distribution and symptoms of epiphyte infection in major carrageenophyte-producing farms. *J. Appl. Phycol.*, 20: 477–483.

Wells, S., Samoilys, M. & Makoloweka, S. 2007. Conclusions and lessons learnt. *In* S. Wells, S. Makoloweka & M. Samoilys, eds. *Putting Adaptive Management into Practice: Collaborative Coastal Management in Tanga, Northern Tanzania*, pp. 170–185. Nairobi, IUCN-EARO. 197 pp.

Zuberi, L. 2000. *Final Report on Seaweed Farming Raft Method of Cultivation.* Tanga, Tanzania, Tanga Coastal Zone Conservation and Development Programme.

Zuberi L., Urio, F., van Ingen, T. & Wells, S. 2007. Enhancing livelihoods. *In* S. Wells, S. Makoloweka & M. Samoilys, eds. *Putting Adaptive Management into Practice: Collaborative Coastal Management in Tanga, Northern Tanzania*, pp. 103–123. Nairobi, IUCN-EARO. 197 pp.

Social and economic dimensions of carrageenan seaweed farming in Solomon Islands

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ACKNOWLEDGEMENTS

The author wishes to acknowledge the funding, technical, logistic and other supports provided by various organisations to this study, including the Food and Agriculture Organization of the United Nations (FAO), the Secretariat of the Pacific Community (SPC), the Fisheries, Aquaculture and Marine Ecology Division of New Caledonia, and the Ministry of Fisheries and Marine Resources (MFMR) of Solomon Islands. The author also thanks the people in Wagina for their knowledge and experiences shared in the study.

1. INTRODUCTION

The major objective of this study was to provide a comprehensive evaluation of the socio-economic dimensions of seaweed farming in Solomon Islands. To this end, the Wagina seaweed farming community, one of the four major seaweed production areas in the archipelago, was selected for carrying out an in-depth field survey. The selection was made in close cooperation with the Aquaculture Division of the Ministry of Fisheries and Marine Resources (MFMR) of Solomon Islands.

Field survey data collected in Wagina Island, Choiseul Province, were complemented with key informant interviews, including staff from relevant governmental and non-governmental institutions, agents and exporters, regarding perceptions on the potential of seaweed production, problems affecting the sector and possible solutions. Secondary information was researched and relevant information summarized to provide a sound historic background on seaweed farming in Solomon Islands, in view of the governmental and non-governmental support provided for the establishment, dissemination and commercialization of seaweed farming activities and produce, marketing channels, production and farmgate price development.

2. CARRAGEENAN SEAWEED PRODUCTION AND VALUE CHAIN

2.1 History

Seaweed farming in Solomon Islands started with initial experimental trials in 1988. An overview of seaweed production sites established between 1988 and 2009 and potential sites in the future is provided in Figure 1. The main events in the development process can be briefly chronicled as follows:

- 1988: First trials were undertaken by the Overseas Development Agency (ODA) of the United Kingdom at Vona Vona Lagoon and Rarumana village in the Western Province in cooperation with the MFMR. The one-year project demonstrated good growth for the *Kappaphycus alvarezii* samples imported from Fiji (Tiroba and McHugh, 2006). However, most trials were affected by fish grazing.
- 2000: The Aquaculture Division of the MFMR was established and started collecting seed stocks remaining from the 1988 growth trials in Vona Vona Lagoon.
- 2001: The Aquaculture Division carried out growth trials in Rarumana.
- 2002: More than 600 kg of dried seaweed was produced in Rarumana. The Rural Fishing Enterprise Project (RFEP) funded by the European Union (Member Organization) became involved in seaweed farming. In cooperation with the Secretariat of the Pacific Community (SPC) and MFMR, the RFEP conducted a seaweed training workshop in November, targeting 30 fisheries officers. Successful growth trials under the RFEP at Rarumana were completed in 2003.
- 2003: The remaining funds (SBD1.5 million, EU STABEX[1] funds) from the RFEP project were allocated to provide further support in the framework of a one-year seaweed farm development project. The project provided farm materials, outboard motors, and a warehouse in Rarumana; and the first PFnet (broadband, e-mail) system was set up to ensure communication between producers and buyers.
- 2004: In July, a warehouse was built in Wagina where the second PFnet was set up. A feasibility study for further support from the European Union (Member Organization) was carried out.
- 2005: By early 2005, there were about 130 farmers in Rarumana and the Shortland Islands (Western Province) plus 300 farmers in Wagina, Choiseul Province; seaweed farming had also expanded to Malaita and Makira-Ulawa. About seven

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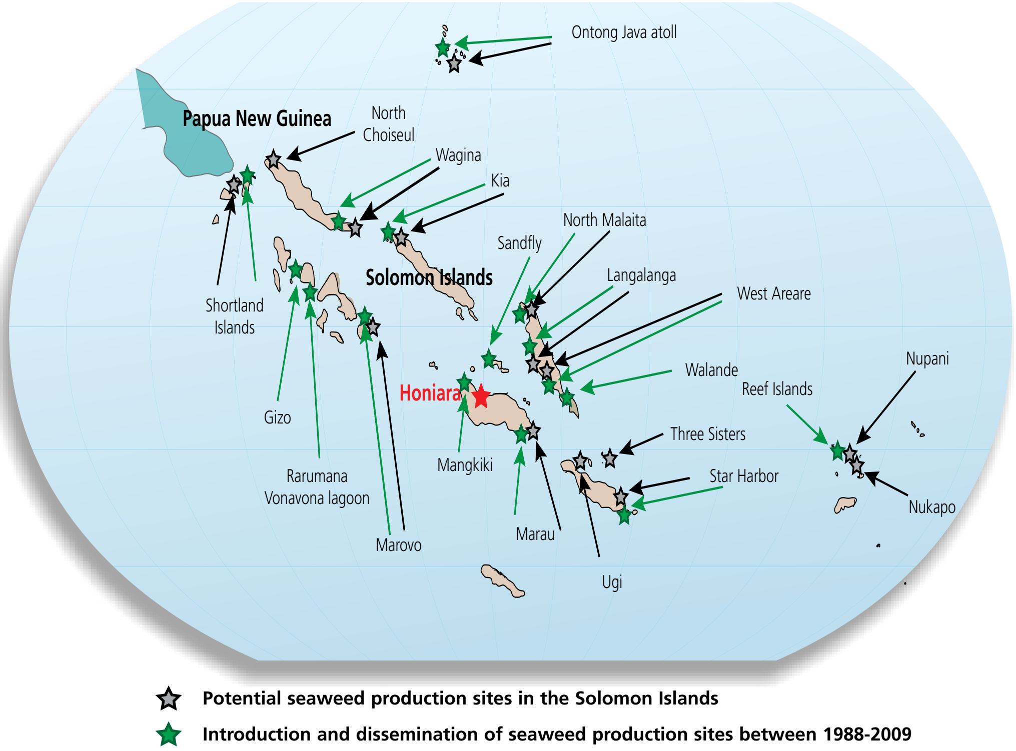
[1] The STABEX (from the French: Système de Stabilisation des Recettes d'Exportation) is the acronym for a European Commission compensatory finance scheme to stabilize export earnings of the African, Caribbean and Pacific (ACP) countries. It was introduced with the purpose of remedying the harmful effects of the instability of export revenue from agricultural products.

FIGURE 1

Overview of established and future possible seaweed production sites in Solomon Islands



export licences were approved; however, only one exporter (Solomon Seaweed) renewed its licence in 2006. Agents were paid a commission based on production. Export of seaweeds was tax-free.

- 2005: In July 2005, a three-year, SBD15 million seaweed commercialization project (CoSPSI) funded by the European Union (Member Organization) (STABEX funds) began, which was extended until January 2009, with a focus on sites in Ontong Java Atoll, Reef Islands, Malaita. The project also supported continued seaweed farming development at Wagina and Rarumana.
- 2005: With assistance from CoSPSI, the International Waters Project (IWP) (Global Environmental facility, SPREP) established within the framework of its community development approach a seaweed farming operation in the eastern Marovo Lagoon, which has remained one of the major producers.
- 2006: In May, the farmgate price for seaweed dropped from SBD2.00/kg to SBD1.50/kg[2] owing to increasing fuel prices, which in turn increased national and international freight costs.
- 2007: A severe earthquake and associated tsunami on 2 April resulted in the loss of some of the best seaweed farming areas in the Western Province (Rarumana), and an estimated total loss of 20–30 percent of the CoSPSI project's production.
- 2008: In July, the farmgate price for seaweed increased to SBD 3.10/kg.
- 2009: The remaining CoSPSI funds were used to support a seaweed farming adviser based at the MFMR for one year (April 2009 – March 2010).

2.2 Production and trade

Production

National production of dried seaweed in Solomon Islands fluctuated substantially

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[2] USD1 = SBD7.21 (June 2011).

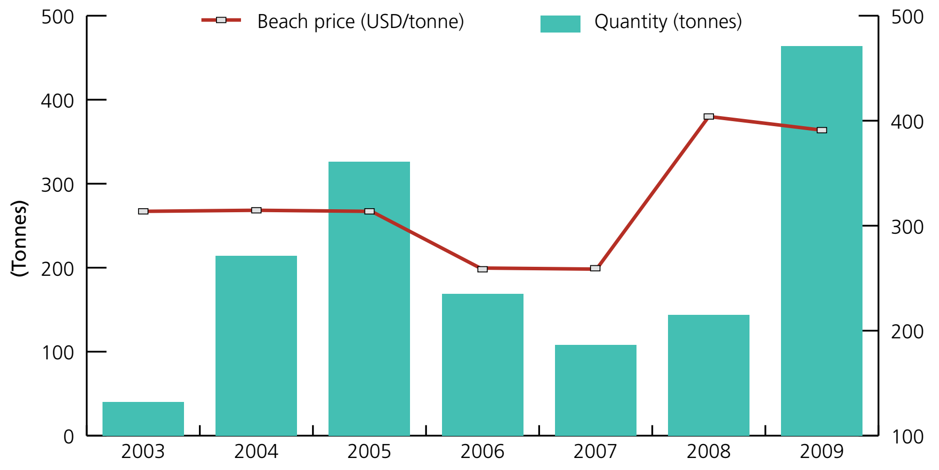
between 2003 and 2009 from a minimum of 40 tonnes in 2003 to a maximum of 460 tonnes in 2009 (Figure 2 and Table 1).

Problems encountered in the earlier days were related to fish grazing, which can be seasonal and may be avoided by moving stocks to areas where fish grazing is minimal. Farmers at Rarumana and Shortlands suffered severe losses because of an outbreak of the filamenteous epiphyte *Polysophonia*. This problem can be solved (particularly in the Rarumana area) by moving seaweed to locations with better water temperature and flow conditions, where the epiphyte disappears. However, at the time of writing, Rarumana is no longer a viable seaweed production site owing to the filling of the lagoon as a result of the 2008 tsunami. Moreover, some production has been lost due to outbreaks of "ice-ice" which causes seaweed to lose its pigment, turning white as a result. This condition results from the stress induced by low salinities and/or high water temperatures.

Trade

Seaweed cultivated in Solomon Islands is dried and exported as raw material for processing carrageenan. Initially, seaweed was regarded as a high-value commodity

FIGURE 2
Quantity and price of seaweed production in Solomon Islands, 2003–09



Note: Production in 2009 is based on estimates of local seaweed agents in Wagina.
Source: MFMR Aquaculture Development Plan (2009–2014).

TABLE 1
Production and beach prices of dry seaweed in Solomon Islands

Year	Quantity	Beach price		
		Local currency	US dollars	Exchange rate
	(tonnes)	(SBD/kg)	(USD/tonne)	(SBD/USD)
2002	4	2.0	296	6.75
2003	40	2.0	266	7.51
2004	214	2.0	267	7.48
2005	326	2.0	266	7.53
2006	169	1.5	197	7.61
2007	108	1.5	196	7.65
2008	144	3.1	404	7.67
2009	~460	3.1	391	7.92

Note: Production in 2009 is based on estimates of local seaweed agents in Wagina.
Source: MFMR Aquaculture Development Plan (2009–2014).

and, thus, the freight charges applied by the interisland cargo transporters were equalled to those of bêche-de-mer (i.e. sea cucumbers). However, freight costs were corrected after it was recognized that seaweed, a low-value, high-volume commodity is the exact opposite of bêche-de-mer, a high-value, low-volume product. In addition, the government recognized that seaweed is a commodity similar to copra and, hence, exempted it from export taxes.

Price

The beach (farmgate) price for seaweed was initially established under the diversification programme of the RFEP. A beach price of SBD2.00/kg was set based on market intelligence and using copra production as a benchmark to attract growers. Fluctuations in local seaweed prices result from the international market balance of demand and supply, fuel prices (which determine national and international freight costs), as well as export taxes.

According to Pickering (2005), seaweed farmers of the Solomon Islands received a beach price of USD0.26/kg (35 percent water content) in 2005, which was comparable with that received by producers in Fiji (USD0.27/kg, 30 percent water content) but slightly lower than the unsubsidized prices paid to farmers of Kiribati (USD0.32/kg, 35 percent water content). However, comparison of export prices of the three countries is difficult as the Fiji export price to FMC Biopolymer has been recorded as USD0.55 free on board (f.o.b.), while export prices for Solomon Islands (selling to Degussa) and Kiribati (selling to CP Kelco) are believed to range between USD0.68 and USD0.73 cost, insurance and freight (c.i.f.).

Accounting for only about 0.2 percent of world seaweed production, seaweed farmers in Solomon Islands are generally price-takers and easily affected by price fluctuations in the international markets. Such fluctuations in conjunction with increased fuel prices resulted in a decline in the seaweed price from SBD2.00/kg to SBD1.50/kg in the country in May 2006.[3]

Increases in fuel prices have a double effect on seaweed prices in Solomon Island, as they increase not only export freight costs but also inland shipping costs from the mostly remote rural areas to Honiara (the capital city of Solomon Islands). An SPC mission in December 2006 observed that the unregulated domestic shipping levied a "commodity-based" freight rate for seaweed that was higher than for other cargoes. The decline in price made some farmers disillusioned and seek alternative livelihoods such as fishing for lobster tails. Consequently, seaweed cultivation almost halved in 2006 (Table 1).

The fall in seaweed prices coincided with the opening of the sea cucumber fishery. Many seaweed farmers also fish sea cucumbers, a resource considered to be one of the most important sources of cash income for rural coastal communities, provided that stocks are not overexploited. The beach price of dried sea cucumber varies, depending on the species and quantity fished, and has been reported to range between SBD5.5/kg and SBD86.8/kg. The close association and competition between the sea cucumber fishery and farmed seaweed production in Solomon Islands is revealed by the peak in seaweed production achieved in 2005, which coincided with closures in the national sea cucumber fishery (2004–06). Conversely, the decline in seaweed production in 2007 was connected with the opening of the sea cucumber fishery – harvest from the fishery peaked at 279 tonnes (dry weight) in 2007 (Figure 3) at an average beach price of SBD37.4/kg of dried sea cucumber.

In 2008, the beach price of dried seaweed was raised to SBD3.10/kg. Seaweed production increased noticeably as a result (Table 1 and Figure 2). This increase in prices

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[3] The lowest price of SBD1.50/kg was never observed in Wagina, where agents maintained a minimum price of SBD2.00/kg.

FIGURE 3

Seaweed production vs sea cucumber exports in Solomon Islands

coincided with limited income opportunities in the heavily depleted sea cucumber fishery. Rising prices were made possible by the combined effects of increased demand in the international seaweed market and the adoption of a flat rate for inland freight costs, which replaced the higher commodity cargo freight rate.

2.3 Value chain

Seaweed production in Solomon Islands is still a primary farming activity with no involvement of transnational companies, wholesalers or regional traders. Through the Aquaculture Division of the MFMR and upon request, the Government of Solomon Islands provides seaweed commercialization licences to private seaweed trading companies. Each licence requires a minimum trading volume of 200 tonnes. Licences are provided based on the proper documentation of the company's facilities, export links and information on costs for export freight and overseas market prices.

Initial processing is mainly carried out by individual farmers. Agents based at production sites control only the quality (dryness) of the product delivered by farmers and ship the packed bags to Honiara. Inland marine freight and transport is organized between seaweed companies and interisland cargo operators. The cargo operators have accepted to apply to seaweed the same freight prices charged for copra, i.e. SBD0.50/kg. These operators also organize and cover the costs of the small-boat transfer of dried seaweed bags from warehouses to the cargo boat. However, at the time of writing, agents of seaweed purchasing companies organize and cover the latter costs.

Additional drying and quality control of dried seaweed landed in Honiara may be undertaken by trading companies prior to shipment overseas. To date, Solomon Seaweed is the only trading company that has invested in appropriate warehouse facilities where seaweed quality is checked, and further dried, if necessary, before good-quality seaweed materials are baled and exported in containers to Europe.

Proper drying at the farm is crucial because it can reduce shipping costs, avoid the need for re-drying and the weight loss thus incurred, and ensure a high gel content of seaweeds when they reach their destination. Solar tent dryers (transparent plastic sheets) were introduced in 2007/08 to improve drying and mitigate quality deterioration due to rainfall (freshwater contact). A price premium was once introduced by one buyer to encourage farmers to deliver clean, properly dried, grade-A seaweed. However, during the recent field survey, no such grading systems were reported, nor thought necessary.

Incentive schemes have also been developed to encourage large deliveries from seaweed farmers. For example, a farmer selling one tonne of dried seaweed in a month to Solomon Seaweed would be able to receive a bonus of SBD250 from the company. Hon Lin, another trading company operating since June 2009, offers an even greater bonus of SBD320 per tonne of dried seaweed sold to it. However, there are only 5–7 farmers in Wagina who could reach the one-tonne delivery benchmark.

It is believed that it would be feasible to install a local plant at Honiara to carry out primary processing to produce alkali-treated carrageenan chips if the national seaweed production were increased to 1 000–2 000 tonnes per year. This activity would result in additional employment and a reduction in international freight costs (Preston, Tiroba and Robertson, 2009).

3. CARRAGEENAN SEAWEED FARMING: ECONOMIC AND SOCIAL PERFORMANCE

A socio-economic survey was carried out at the end of 2009 to evaluate the socio-economic dimensions of seaweed farming in Solomon Islands. A focus was placed on one of the four seaweed farming regions: Wagina in Choiseul Province.

During the field survey, data were collected to carry out an estimation of net revenues per hour of labour for current cash-earning activities in Wagina, which include seaweed farming, finfisheries, lobster tail fishery and mat weaving. Net profit per hour of family labour is used to make comparisons across various activities for income generation. A general economic approach is difficult to implement fully because of the following factors:

- Labour is generally not viewed as a cost factor by rural people. In Honiara, unskilled labour is remunerated with about SBD30/day, i.e. an hourly wage of SBD 3.75/hour. In Wagina and other rural areas, such labour may not be paid in cash (or only partially, at the rate of SBD10–20/day); instead, labourers need to be provided with food items for which costs may or may not accrue, depending on whether food and beverage items are sourced from subsistence production or purchased in local shops.
- Mat weaving materials are free of charge, i.e. *Pandanus* leaves grow in the wild and are subject to harvest as requested.
- No farm rent or lease is paid for any seaweed growing area as sites are allocated on a community-governed system at no charge.
- To date, seaweed farms have been set up for farmers with either governmental or project support, which covered all costs that accrued. This included free provision of farming materials; however, this practice was discontinued in early 2009.
- Any secondary housing for seaweed farmers on small islands is not paid for but built using free material and unaccounted labour. The same observation applies for drying tables and any other sheds or shelters built.
- Transportation by boat is only considered a cost if a fibreglass boat and an outboard engine are purchased. Dug-out canoes are built by villagers at an unaccounted cost as materials are free and labour input is not recognized.
- Operational tools including dug-out canoes, knifes, hammers, axes or boiling pots (the latter in the case of mat weaving) are items that are present in almost every household serving various, non-income-generating uses.
- Fishing gear such as masks, snorkels, fins, torches and spear guns may be used to engage in both lobster and finfishing. However, net present value (NPV) and costs have been accounted for each activity individually in the scenarios considered here.

3.1 Economic performance

The financial analysis of three cases of seaweed farming in Solomon Islands is summarized in Table 2. The analysis is based on data provided by respondents from the

TABLE 2
Annual revenue, cost and profit of seaweed farming in Solomon Islands

Item no.	Item	Case I	Case II	Case III
(1)	**Total length of lines (km)**	**4.0**	**4.0**	**2.4**
(2)	**Dried seaweed produced (tonne)**	**17.4**	**21.7**	**9.2**
(3)	- Productivity (tonne/km of lines)	4.35	5.43	3.84
(4)	**Price of dried seaweed (USD/tonne)**	**391.4**	**391.4**	**391.4**
(5)	**Revenue (USD)**	**6 818**	**8 494**	**3 611**
(6)	- Productivity (USD/km of lines)	1 705	2 123	1 505
(7)	**Cost (USD)**	**1 052**	**6 014**	**922**
(8)	- Fixed cost (USD)[1]	531	1 096	531
(9)	- Variable cost (USD)	521	4 919	391
(10)	Operational cost (USD)	332	3 782	164
(11)	Transportation cost (USD)	189	1 136	227
(12)	**Net profit (USD)**	**5 766**	**2 480**	**2 689**
(13)	- Net profit per hour of family labour (USD/hour)	1.14	0.68	0.58
(14)	- Profit margin (%)	85	29	74
(15)	**Family labour used (hours)**	**5 064**	**3 666**	**4 628**
(16)	- Average wage of unskilled labour as shadow price of family labour (USD/hour)	0.47	0.47	0.47
(17)	- Imputed value of family labour (USD)	2 398	1 736	2 191
(18)	**Net profit excluding family labour (USD)**	**3 368**	**744**	**497**
(19)	- Profit margin (%)	49	9	14
(20)	- Break-even price (USD/tonne)	198	357	337

Notes: USD1 = SBD7.92 (2009). (3) = (2)/(1). (5) = (2) × (4). (6) = (5)/(1). (7) = (8) + (9). (9) = (10) + (11). (12) = (5) – (7). (13) = (12)/(15). (14) = (12)/(5)*100. (17) = (15) × (16). (18) = (12) – (17). (19) = (18)/(5)*100. (20) = [(7) + (17)]/(2). Numbers may not add up due to rounding.

field survey, and collection of information on the range of local prices for the various items. The exchange rate of USD1 = SBD7.92 in 2009 (Table 1) is used to convert the local currency to the US dollar.

Investment and capital cost

The total length of lines used in seaweed farming is 4.0 km in both Case I and Case II and 2.4 km in Case III. Because of the various factors explained above, costs and labour for setting up any of the existing farms are not included.

For Case I and Case III, one drying table and one paddle canoe are used in each case. It is assumed that the table and canoe are purchased in the Wagina community; the amortized annual capital cost (i.e. fixed cost) is USD531 (Table 2, item 8).

For Case II, one fibreglass boat (21 ft [6.4 m]), one outboard engine (15 hp), and one drying table are used. Assuming that these items are purchased, then the fixed cost is USD1 096 per year (Table 2, item 8).

Operational and variable cost

While no major changes concerning alternative production methods have been made since the start of seaweed production in 2002, technical improvements include the substitution of simple black plastic sheets (intended to protect seaweed from rain while drying) with transparent solar plastic sheets or tents that no longer require removal during the drying process regardless of the weather conditions. However, the use of solar plastic sheets is much more expensive; and they can be torn by strong wind. In addition, netting to cover drying tables has been improved by importing a better-quality product. Experimentation has also resulted in the selection of better-quality ropes that last longer.

For Case I and Case III, where relatively more family labour is used in daily operation, the annual operational expense is USD332 and USD164, respectively, which is mainly for ropes, solar plastic (Case I) or black plastic (Case III), netting, etc. For Case II, where daily operation is conducted entirely by hired labour, the annual operational expense is USD3 782 (Table 2, item 10).

The opportunity cost of family labour is unknown and has to be imputed. As mentioned above, the average hourly wage of unskilled labour in Honiara is about SBD 3.75/hour, amounting to USD0.47/hour at the exchange rate in 2009. This wage rate can used as a shadow price of family labour (Table 2, item 16) to calculate the imputed value of family labour (Table 2, item 17).

For Case I and Case III, where non-motorized paddle canoes are normally used, the expense on transportation is USD189 and USD227, respectively, which is mainly for purchasing fuel for motorized boats borrowed during the harvest season. For Case II, where a motorized boat is used for daily operation, the expense for transportation is USD1 136 (Table 2, item 11).

Revenue, cost and net profit

Dried seaweed production under Cases I, II and III is 17.4, 21.7 and 9.2 tonnes, respectively (Table 2, item 2). With the beach price being USD391/tonne, these production levels generate, respectively, USD6 818, 8 494 and 3 611 in sales revenues for the three cases (Table 2, item 5). The total cost (Table 2, item 7) is equal to the sum of the fixed cost (Table 2, item 8) and the variable cost (Table 2, item 9).

A net profit (Table 2, item 12) can be calculated by deducting the cost (Table 2, item 7) from the revenue (Table 2, item 5). It should be noted that this net profit includes the value of family labour and hence may not be directly comparable across the different cases that use different amount of family labour. However, this indicator provides a useful indication of the economic viability of seaweed farming operations.

A “net profit excluding family labour” (Table 2, item 18) can be calculated by deducting the imputed value of family labour (Table 2, item 17) from the net profit (Table 2, item 12). This indicator provides a “cleaner” measure of profitability, which is more comparable between different operations.

The results in Table 2 indicate that:

- Seaweed farming is economically viable and profitable under all three cases.
- There is evidence that the use of family labour increases the economic viability of seaweed farming in Solomon Islands. With the same scale of operation, Case I (which uses more family labour) has a higher profit margin than Case II (Table 2, item 14), although Case II has higher productivity (Table 2, item 3). The higher profit margin would allow Case I to be more resilient to negative shocks.
- In terms of the net profit without family labour (Table 2, item 18), the profit margin of Case I (49 percent) is still higher than that of Case II (9 percent). As indicated in Table 2 (item 13), the “net profit per hour of family labour” in Case I is USD1.14, which is much higher than the average wage rate of unskilled labour (item 16: USD0.47). Thus, the higher profitability of Case I reflects, to some extent, the “internalization” of better-paying jobs.
- The higher fixed cost due to the use of a motorized fibreglass boat is another factor negatively affecting the net profit in Case II. However, motorized transport is required in order to transport dried produce to the selling points. Given the average farm size in Wagina (and elsewhere in Solomon Islands), it can be assumed that individual investment in such motorized fibreglass boats is not viable. A community-owned motorized boat may be the best alternative.
- Case I has a larger scale of operations (4 km of lines) than Case III (only 2.4 km) and a higher profit margin than the latter in terms of both the net profit (Table 2, item 14) and net profit without family labour (Table 2, item 19). This reflects, to

some extent, the higher productivity (Table 2, item 3) of Case I (4.35 tonne/km of lines) compared with Case III (3.84 tonne/km). However, even if productivity in Case III were as high as that of Case I (i.e. 4.35 tonne/km), its profit margin, which would be 77 percent for the net profit (Table 2, item 14) and 24 percent for the net profit without family labour (Table 2, item 19) would still be lower than Case I. These results provide evidence supporting the existence of economies of scale in seaweed farming in Solomon Islands.[4]

In sum, the experiences in Wagina demonstrate that seaweed farming may become an important source of income for rural coastal people in Solomon Islands, in particular in remote areas, given that a certain farm size is reached (≥ 4 000 m of lines). Extension efforts should continue to promote the 4–6-week production cycle to ensure regular cash flow and income to farmers.

Seaweed farming vs other economic activities

Besides seaweed farming, other economic activities in Wagina (i.e. the area under survey) include finfisheries, lobster tail fishery and mat weaving. The profitability of these activities is summarized in Table 3. The results indicate that:

- The net profits per hour of family labour of the four activities are all higher than the average wage of unskilled labour in Honiara (USD0.47/hour).
- Seaweed farming is less profitable (per hour of family labour) than finfishery and lobster tail fishery but more profitable than mat weaving. Finfishery and lobster tail fishery are more lucrative activities than seaweed farming; the prices of their products are USD0.9/kg and USD5.0/kg, respectively, as compared with USD0.4/kg for dried seaweed. Mat weaving is not a regular economic activity in Wagina and contributes to household incomes occasionally.
- The fixed cost of seaweed farming is lower than finfishery and lobster tail fishery but higher than mat weaving. Fishing gear such as masks, snorkels, fins, torches and spear guns may need to be used for lobster fishing and finfishing. This equipment is usually specific for fishing, while the drying table and boats used in seaweed farming can also be used for other functions.
- The profit margin of mat weaving is the highest, reflecting its minimal need for capital investment (only a large boiling pan and cutting knifes are needed) and material inputs. The profit margin of seaweed farming tends to be higher or lower than finfishery and lobster tail fishery, depending on whether its daily operation is conducted by family labour or hired labour.

3.2 Social performance

A total of 58 households in the 3 communities of Wagina (Arariki, Tengangea/Kukutin and Nikumaroro) were surveyed. These households accounted for about 28 percent of the population in the region. About 70 percent of the households under survey engaged in seaweed farming.

Livelihoods

Increased incomes, improved living standards, and enhanced food security are the most important changes brought about by seaweed farming as perceived and reported by the survey respondents. Many costal inhabitants in Solomon Islands view seaweed farming as a risk avoidance mechanism that helps diversify sources of income for the community. The survey data indicate that seaweed farming households are much more

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[4] This survey investigated average (about 1 tonne/month) and small-scale farms (new starters may produce only 100 kg/month) as large-scale production (about 3 tonnes/month) is represented by only 5–7 farms in Wagina. Net revenues for average farms – handling about 4 000 m of production line – yield a much more favourable return relative to the smaller sized farms.

TABLE 3
Profitability of seaweed farming vs other economic activities in coastal communities of Solomon Islands

Activities			**Cost**			**Profitability**	
		Revenue	**Total**	**Fixed**	**Variable**	**Net profit**	**Profit margin**
		USD per hour of family labour					**%**
Finfishery	Maximum	6.44	1.56	0.49	1.06	4.89	76
	Minimum	2.85	1.56	0.49	1.06	1.30	45
Lobster tail fishery	Maximum	5.45	1.38	0.44	0.94	4.07	75
	Minimum	2.42	1.38	0.44	0.94	1.04	43
Mat weaving	Large mat	0.39	0.01	0.01	–	0.38	96
	Small mat	0.50	0.02	0.02	–	0.47	95
Seaweed farming	Case I	1.35	0.21	0.10	0.10	1.14	85
	Case II	2.32	1.64	0.30	1.34	0.68	29
	Case IIII	0.78	0.20	0.11	0.08	0.58	74

Notes: USD1 = SBD7.92 (2009). Revenue, cost and net profit measured by US dollar per hour of family labour used in the activities.

diversified than other households – half of all non-seaweed households have fewer than two income sources while 92.5 percent of seaweed households have at least two income sources.

The survey data also revealed that seaweed farming households in Wagina earn on average about SBD 26 258 (USD3 315) per year, which is 67 percent higher than other households. On average, seaweed farming accounts for 42.4 percent of total annual income in seaweed households.

Fisheries of finfish, lobster and sea cucumber are more lucrative activities than seaweed farming, but the fishing seasons are relatively short; as a consequence, seaweed farming provides greater livelihood opportunities for households in Wagina because of its higher annual revenue potential. In addition, the fact that fisheries are vulnerable to a number of natural and administrative factors makes them less dependable means of livelihood for most people in Wagina.

In summary, most seaweed farming households (65 percent) were convinced that seaweed aquaculture was a viable livelihood alternative that increased their incomes and helped them meet living costs, school fees and other financial obligations. Seaweed farming also provided better and regular cash flows to some households as compared with other options. It is also considered a relatively easy technology to learn, providing good prospects for the future well-being of households.

Women and children

The Wagina field survey revealed that seaweed aquaculture is normally a family enterprise that involves all household members. Although men account for 68 percent of the labour input, women actively participate in all stages of seaweed farming (Table 4). Women's contributions to farming activities (33 and 34 percent for harvesting and for replanting and maintenance, respectively) are greater than their contributions to post-harvest activities (32, 24 and 24 percent for drying, packaging and selling, respectively). This

TABLE 4
Contribution of female labour to seaweed aquaculture business

Activities in seaweed aquaculture	**Contribution of female labour**
	(%)
Harvesting	33
Replanting and maintenance	34
Drying	32
Packaging	24
Selling	24
All	32

is different from the stereotype role of women in aquaculture, i.e. specializing in post-harvest activities.

As farm sites are often too far away from seaweed farmers' homes to allow them to commute on a daily basis, family members may be either separated for extended periods or children may fail to attend school as they accompany their parents to the farming sites.

Families may decide that children should participate in the seaweed farming venture, meaning that they have to leave school at an early stage, forgoing access to secondary and perhaps tertiary education.

Community development

The survey shows that seaweed farming has contributed to increased cooperation and unity within the community. Many respondents see seaweed farming as a key activity for the future economic development of the community. Even respondents who were not engaged in seaweed farming noted that most changes brought upon the community by seaweed farming were positive. These changes include increased and more regular income and the equipment of households with diesel-fuelled generators or small photovoltaic lighting. Respondents also considered that the purchasing power to buy food in local stores had improved.

These changes may not always be beneficial. As people substituted seaweed farming for other activities such as fisheries and gardening, the supplies of garden produce and fresh seafood declined and were substituted by less nutritious but more expensive processed food (e.g. canned tuna and luncheon meat). Tobacco and betelnut were also highly consumed by men and women.

Responses with regard to the impact of seaweed farming on social structures and institutions varied among the survey participants. More than half (57 percent) of the people interviewed believed that there were no major impacts; and social networking and tight family structures are considered as traditional values that have persisted since seaweed has been grown in Wagina.

However, 38 percent of respondents think that seaweed farming has improved social networks in the sense that it has contributed to form stronger groups of families sharing the same interest. Improvement of social services (e.g. school and church) in the community was frequently quoted.

While most respondents believed that seaweed farming had triggered positive competition among farmers and families, some respondents (17 percent) reported an increase in jealousy and complained about people stealing ropes, seaweed and other materials. However, such negative impacts were not considered major issues.

Environmentally, the establishment of seaweed farms involves the felling of local mangroves to obtain the necessary pegs. Farmers also cut down a considerable number of native trees for poles for the construction of drying tables, which are not built very effectively and tend to have a short life span as a result.

4. GOVERNANCE AND INSTITUTIONS

Within the framework of the MFMR's 2009–2014 Solomon Islands Aquaculture Development Plan, seaweed (*Kappaphycus alvarezii*) was given the highest priority as an export commodity. In 2008, the Government allocated a budget of SBD300 000 for seaweed farming, which became effective in 2009, with the hope that a commercial seaweed sector could be established by 2010, reaching a sustainable annual production of 500–600 tonnes.

The Aquaculture Division within the MFMR was established in 2000. At present, the Aquaculture Division has five full-time staff members, all of whom are involved in seaweed dissemination and strengthening. Priority has been given to the consolidation of existing seaweed production areas rather than to the expansion to new locations. Besides providing supports to seaweed farmers, the Aquaculture Division is also responsible for issuing seaweed commercialization licences to private trading companies.

Cooperation with other ministries and governmental departments is laid down in the development strategy plan. In supporting the agrarian sector, the Ministry of Agriculture and the Ministry of Lands recognize aquaculture as an alternative land use. The Ministry of Lands is associated with seaweed farming in land tenure and land survey matters. The Department of Environment within the Ministry of Environment, Conservation and Meteorology is committed to providing the environmental assessments that may accrue from seaweed farming activities and expansion of the sector.

Through its aquaculture programme, the SPC continues to not only provide support to the seaweed industry of the Solomon Islands in its role as the intergovernmental focal point for the aquaculture sector, but also providing specific technical advice and advocacy to the seaweed industry.

No laws and regulations concerning seaweed farming and commercialization are in place, other than the fact that no export taxes are being charged.

The CoSPSI project has contributed to seaweed farming in the country. The results of the Wagina survey indicated that most assistance in setting up the farms, training, and maintenance, harvesting and drying activities was provided by this project.

5. CHALLENGES AND THE WAY FORWARD

Past experiences of seaweed farming in Solomon Islands have revealed a considerable degree of production risk. Natural risk factors including earthquakes, geologic instabilities, active volcanism and tsunamis may lead to dramatic production losses. Climatic conditions such as seawater temperature rises resulting in high mortality rates, prolonged rainy periods as well as strong currents and heavy seas contributing to seed losses and reduced harvests will not be eliminated in the future.

Some locations are chronically affected by grazing of herbivorous fish; losses can be too high to justify seaweed production. Such problems may seriously reduce potential production levels. In addition, logging and other coastal development activities are likely to continue – if not increase – and cause further sedimentation in coastal areas, which may also reduce production.

Increases in fuel prices crucially affect the viability of the sector. Increases in production costs, inland and export freight prices may make farm operations economically less attractive and perhaps no longer viable. Fluctuating world market prices for seaweed may have the same effect.

Furthermore, alternative income opportunities may appear more attractive to local farmers and may trigger loss of interest in producing seaweed. This is particularly true for copra production. Although current copra prices are not very high, future price increases may elicit interest from farmers. In addition, political instability and insufficient governmental and external-aid-funded support for the sector are further risk factors for the industry's development potential.

However, there is great potential for the development of seaweed farming in Solomon Islands. The country has a number of unutilized areas suitable for seaweed farming and a large proportion of rural coastal communities that are highly dependent on diminishing marine and other natural resources. According to the Aquaculture Division of the MFMR, if 60 percent of households in the promising sites participated in seaweed farming, dried seaweed production in Solomon Islands would reach 12 528 tonnes/year; the production would be 16 704 tonnes/year if the participation rate were 80 percent.[5]

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[5] Whether the estimations are realistic are open to debate. The final report of the CoSPSI project specifies a potential of 2 000 tonnes/year, assuming farmers are provided with further technical and financial assistance (Preston, Tiroba and Robertson, 2009).

It would require concentrated efforts, time, and substantial funding and support to realize the potential of seaweed farming in Solomon Islands. Local land tenure and governance systems allow members of coastal rural communities to utilize suitable sites for producing seaweed; skills are relatively easy to attain; and basic farming materials are freely available. However, given the lifestyle and the low financial capabilities of rural coastal people, covering investment, maintenance and operational costs to ensure a continuous seaweed farming operation represents a major bottleneck for maintenance and further expansion of current operations.

Governmental or externally funded projects could assist farmers in acquiring and adopting financial management skills. Financing schemes made available to local agents in order to retain a feasible amount of cash for each harvest sale may be a way to help farmers meet operation and maintenance costs. Technical and financial training of farmers should include information on economies of scale, cash flows needed to cover operation costs, and achievable net returns.

The establishment of community-owned motorized boat transport, or alternatively transport provided by local agents, could reduce the investment requirement for farmers to buy a motorized boat and assist them to ensure the transfer of their harvests to the selling points. However, in order to be sustainable and avoid unnecessary distortion, such transportation services should not be free of charge but should be placed under the market mechanism.

To encourage continuous production, the government may need to establish a minimum price guarantee to subsidize local farmgate prices when world market prices drop below a certain threshold. The costs to re-establish seaweed farms after a major drop-out may involve much higher costs than the occasional subsidies and will ensure continuation of national agent and exporter networks.

The government may also assist in increasing reliability of interisland cargo freight services by negotiating with the existing operators a guaranteed freight volume for seaweed harvested. Thus, frustrations shared between farmers and local agents for not being able to purchase harvest or to export regularly may be reduced or eradicated. Given the projected future growth in national seaweed production, the establishment of specialized interisland seaweed cargo freight may be assessed, at least on certain routes.

In cooperation with private seaweed trading companies, the government should evaluate the purchase of high-quality/low-price materials internationally and their regular provision at all farming sites. Local agents purchasing seaweed harvested should be used to build up a national distribution network, as is already being done.

From an environmental viewpoint, impact assessments need to be undertaken with regard to the disposal of plastic sheets, ropes and wood material from sheds, drying tables and other buildings erected on farm sites. The current drying tables in Wagina are not effectively built, requiring a considerable amount of indigenous trees for their construction. The development and dissemination of effectively built drying tables will help reduce the felling of local native trees. However, for large-scale farms, the introduction of permanent drying tables made of aluminium or plastic materials that are more resistant to weather conditions, thus having a much longer life span than locally built tables, is an option worth exploring.

The same argument applies to local mangrove resources that are used to produce pegs for erecting ropes and lines in shallow seawater. The impact of their disposal into near-shore areas, particularly given the future increase in farm areas, also needs to be assessed.

References

Ministry of Fisheries and Marine Resources (MFMR). 2009. *Solomon Islands aquaculture development plan, 2009–2014*. Noumea, New Caledonia, Ministry of Fisheries and Marine Resources – Solomon Islands and Secretariat of the Pacific Community. 54 pp. (also available at www.spc.int/aquaculture/ index.php?option=com_docman&task=doc_details&gid=36&Itemid=3).

Pickering, T. 2005. *Advances in seaweed* aquaculture *among Pacific Islands countries*. Presentation to the Secretariat of the Pacific Community (SPC) Sub-regional Seaweed Meeting. Nadi, Fiji.

Preston, G.L., Tiroba, G. & Robertson, M. 2009. *Commercialisation* of *seaweed production in the Solomon Islands*. Project ST 98/009. Completion Report. Solomon Island Department of Fisheries and Marine Resources and European Commission.

Tiroba, G. & McHugh, D.J. 2006. Solomon Islands – country report. *In* D.J. McHugh. *The seaweed industry in the Pacific islands*, pp. 47–53. Canberra, Australian Government, Australian Centre for International Agricultural Research. (also available at http://aciar.gov.au/publication/WP61).

Social and economic dimensions of carrageenan seaweed farming in India

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ACKNOWLEDGEMENTS

The authors express their sincere thanks to Dr S. Ayyappan for his constant encouragement and support during the course of this work. The authors also acknowledge the support of Dr A.G. Ponniah and Dr G. Syda Rao. The authors also express their gratitude to Mr Abhiram Seth, Dr M. Sakthivel, Dr G. Gopakumar, Dr K. Palanisamy, Dr N. Kaliaperumal, Dr P. Kaladharan, and Mr Vinod Nehimiah for their personal cooperation and technical inputs.

1. INTRODUCTION

India possesses 434 species of red seaweeds, 194 species of brown seaweeds and 216 species of green seaweeds. Traditionally, seaweeds have been collected from natural stocks. However, these resources have been depleted by overharvesting and hence the need for their cultivation has arisen over time. Today, seaweed cultivation techniques have been standardized, improved and made economically viable. In addition, the industry has developed a preference for greater stability through a sustained supply in terms of quantity and quality of farmed, raw materials. Nevertheless, collection of seaweed production statistics is not systematic in India; official time series of seaweed production are not readily available at the time of writing.

Despite the various native seaweed species in India, it was not until the beginning of the twenty-first century that the country made concrete progress towards organized seaweed farming. The delay in progress was caused by a number of factors including locational disadvantages, inconsistent performance of species for commercial exploitation, absence of a complete package of farming practices, and insufficient industry and policy support.

Although the commercial potential of *Kappaphycus alvarezii* had been previously recognized and its culture technology had been perfected by the Central Salt and Marine Chemicals Research Institute (CSMCRI), culture at a commercial scale only began when PepsiCo India Holdings Ltd (PepsiCo) made its entry into the venture with a pilot-scale investment in the early 2000s. The entry of PepsiCo turned out to be decisive, as it acted as a catalyst to rejuvenate the industry–institutional linkages. The concept of self-help groups (SHGs) spearheaded by the National Bank for Agricultural and Rural Development (NABARD) also led to rapid development in the Mandapam area of Ramanathapuram, which soon became the hub of seaweed farming in the country.

Self-help groups in the fishing villages of Vedalai, Thonithurai, Ariyankkundu and R. Vadakadu operate more than 1 000 rafts at the time of writing. Many of the SHGs have been able to obtain a yield of more than 50 kg per raft per cycle (dry weight). Based on the findings from this study, seaweed farming offered 161 and 144 days per farmer per year of annual employment in the Rameshwaram and Mandapam areas, respectively. With current development projections targeting 5 000 families in the near future, the seaweed sector could generate about 765 000 person-days of employment in Ramanathapuram District. It has been estimated that India can produce one million tonnes of dried seaweed and provide employment to 200 000 families with annual earnings of about INR100 000 per family.[1] The annual turnover of *Kappaphycus* seaweed farming alone is estimated to be INR2.0 billion.

Spearheaded by private investments, the institutional and financial support of the Government of India through development agencies and research institutes has been fundamental for the development of the sector. The distinct possibility of expansion of operations based on successful commercial trials in potential sites will give a significant boost to the sector. Seaweed farming has all the potential to rise from a low-income livelihood activity into a reasonably profitable commercial enterprise in coastal India.

2. CARRAGEENAN SEAWEED PRODUCTION AND VALUE CHAIN

2.1 History

The first organized attempt to culture seaweed at an industrial scale in India was initiated by PepsiCo in 2000. After experiments, substantial activities began in 2002

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[1] Exchange rate as of April 2010: USD1.00 = INR44.422.

with the leasing of an area of 10 ha on the Palk Bay side towards Mandapam;[2] about 100 kg of planting material (*K. alvarezii*) received from the CSMCRI were seeded. Early challenges included heavy grazing by fish and the need for modifications in the culture technology to enable adoption by local growers. Monoline cultivation gave way to raft culture with net bottoms to prevent grazing by fish.

After having demonstrated the economic feasibility of the proposed venture, the company decided to modify its business model in 2003. Instead of hiring daily wageworkers, PepsiCo encouraged workers to engage in contract farming by making available the culture infrastructure on a staggered payment basis. Although contract farming offered a greater potential for increased income, the proposed contractual arrangement did not gain immediate acceptance among fishing villagers.

In August 2008, PepsiCo sold its eight-year-old seaweed cultivation business in India to a group of entrepreneurs led by a former PepsiCo executive. PepsiCo transferred the assets of the seaweed venture at book value to a newly formed company, Aquagri. Through Aquagri, PepsiCo continues to honour its buyback commitment made to the SHGs.

Aquagri has placed its focus on the agricultural by-produce, ensuring marketing through strategic associations with agro-based businesses. At the time of writing, the company was planning to extend operations on the Gujarat coast and set up the first seaweed processing plant in Tamil Nadu. Aquagri has also provided buyback guarantees for the new cultivation projects launched by the CSMCRI in the states of Gujarat and Andhra Pradesh; in addition, Aquagri has indicated its intent to set up manufacturing facilities at these centres once activities scale up.

Ramanathapuram District in Tamil Nadu (Figure 1) was identified as the target location for studying the structure, conduct and performance of seaweed farming in India in view of its historical background, locational advantages, industry interactions, socio-economic institutional framework and opportunities for expansion and growth. For these reasons, Ramanathapuram District has long been recognized as the centre of seaweed farming in India. Table 1 provides a timeline of the major events marking the development of seaweed farming in Tamil Nadu since 2000.

2.2 Production

Seaweed farming production in India increased from 21 tonnes in 2001 to more than 714 tonnes (dry weight) in 2009 (Table 2).

Kappaphycus seaweeds grow profusely in areas with sandy or rocky bottoms, salinity in the range of 28–33 ppt, temperature about 30 °C ± 3 °C, depth about 1.5 m, moderate light intensity and wave action. A seed plant of 150 g grows to more than 600 g in 45 days in calm waters such as those found in the Palk Bay area. Seaweeds only require sunlight and transparent seawater with mild wave action for replenishing bottom nutrients. However, *Kappaphycus* can grow even faster in the open sea where wave action is fairly high (AFI, 2008).

Seaweed farming can be affected by many problems. Grazing fish such as siganids (rabbitfish) and puffers can damage the crops. Siganids are the most destructive, especially if the plants have not grown much. Entire crops can be devoured and even dense beds can be severely damaged. There is no simple solution except to move the farming location to another site where predators are less prevalent. Turtles pose a special problem – besides grazing, they also crawl through the farms, causing

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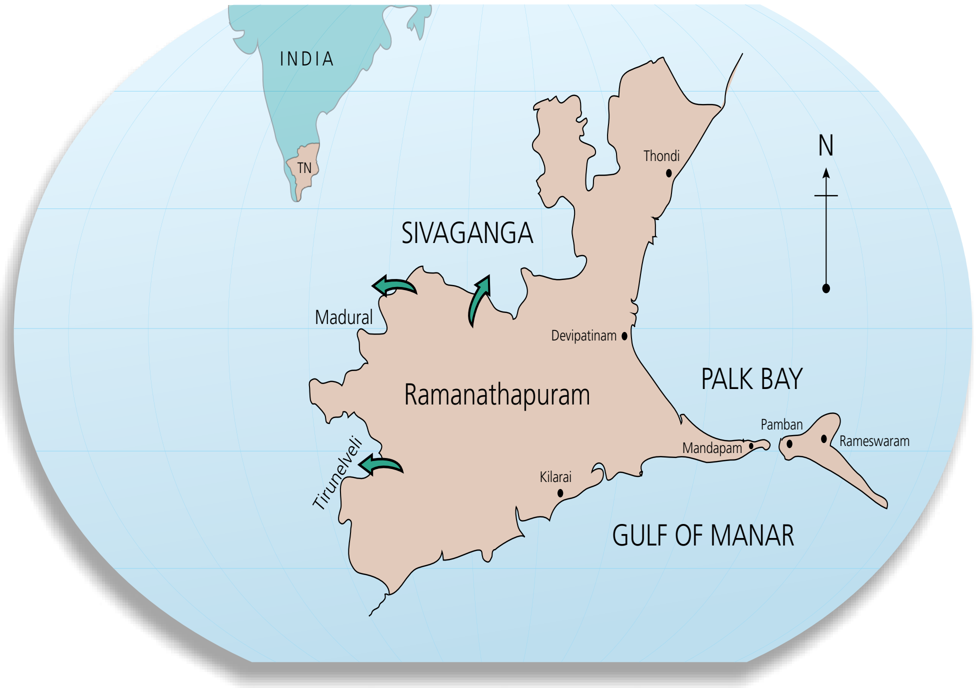
[2] PepsiCo had initially requested permission to operate along a 35-km stretch along the Gulf of Mannar and Palk Bay, equivalent to an area of about 350 ha. The company had a preference for the Gulf of Mannar because of its calmer seas, conducive to faster growth rates (average daily growth rate [ADGR] of 6–8 percent). However, because the selected area fell within the Gulf of Mannar Marine National Park, cultivation was restricted to the Palk Bay side, where growth rates are lower (ADGR of 2.5–3.5 percent).

FIGURE 1

Map of Ramanathapuram District, Tamil Nadu, India



devastating physical damage. Long-spined sea urchins are also a pest and can cause injury to farmers who try to remove them.

The most common symptom of poor health is "ice-ice", a disease so named because of the white segments that appear on the plants, causing them to break at that point. There is disagreement about its causes. Some people argue that the segments are indicative of a bacterial or viral infection while others attribute the disease to physical stress caused by changes in the farming environment.

Storms lead to strong water movements that can cause plants to break apart and even cause physical damage to the rafts and lines. Locations that are subject to cyclical cyclones should be avoided; if this is not possible, precautions should be taken during the period of storms (McHugh, 2003). The period from October to December in Tamil Nadu is one of seasonal rains and cyclones.

In spite of these challenges, it has been estimated that seaweed can be farmed in about 200 000 ha or 0.001 percent of the exclusive economic zone (EEZ) of India (Krishnamurthy, 2005). The rocky beaches, mudflats, estuaries and lagoons on the Indian coasts offer ideal habitats for seaweed farming.

2.3 Value chain

Harvested seaweeds are sun-dried on the beach and then bundled into bales. Although the institutions and companies involved in the development of seaweed farming have constructed drying platforms, most drying is still conducted by farmers on the sandy beaches. Apparently, this problem has not yet been corrected owing to Aquagri's willingness to source the dried weed irrespective of its impurities.

The marketing channels for seaweed are illustrated in Figure 2. Basic prices are arranged to the satisfaction of farmers taking into account the effort invested. In 2009, Aquagri was offering INR16/kg of dried weed. Although it has been argued that Aquagri currently holds a monopsony advantage, competing companies have

TABLE 1

A timeline of the development of seaweed farming in Tamil Nadu

2000	Agreement with the Central Salt and Marine Chemicals Research Institute (CSMCRI) on *Kappaphycus* cultivation and genesis of the undertaking.
2001	The project seaweed cultivation was commenced in February 2001. The net-bag technique was the method formulated by the CSMCRI, but was not found suitable for commercial scale. The Tamil Nadu Government granted PepsiCo access to 1 km of waterfront (10 ha) for pilot-scale cultivation at Palk Bay. Farming began in Munaikkadu (Mandapam area) by adapting the monoline method.
2002	Coastal Regulation Zone (CRZ) officials visited the PepsiCo site to monitor the 10-ha farming area and certified the project. Monoline cultivation was in place until April 2002. Owing to severe grazing, the entire seeded area (10 ha) was lost in May. Thereafter, trials were conducted to establish a commercially viable method. The sum of INR200 000 was paid to the Tamil Nadu Maritime Board (TNMB) for the leasing of the 1-km waterfront area. A full-fledged quality control laboratory to check the quality of dry weeds was also established.
2003	Based on the results of more than 120 trials, the bamboo raft technique emerged as the most suitable, commercially viable method. The daily-wage model was withdrawn and the contract faming method was successfully implemented in March 2003.
2004	About 3 500 rafts were harvested, delivering 126 tonnes. Another 5 000 rafts were seeded for further expansion. Trial cultivation was also carried out in Prakasam District (Andhra Pradesh).
2005	PepsiCo expanded farming to Tuticorin District (southern tip of Tamil Nadu). For the first time, three self-help groups (SHGs) received subsidies from the District Rural Development Agency (DRDA) to engage in seaweed cultivation. The Department of Biotechnology (DBT) sanctioned INR9 million to rehabilitate tsunami-affected areas, which led to the floating of 5 500 rafts. The company entered into an agreement with the State Bank of India (SBI) for establishing a buyback guarantee; both infrastructure and cultivators were placed under insurance coverage.
2006	Expansion of farming to Tanjore District. A total of 8 100 rafts were harvested, delivering 244 tonnes of dry weed. The sap extracted from *Kappaphycus* was found to be an excellent biofertilizer.
2007	Expansion of farming to Pudukkottai. The DBT activated a project in Tanjore but, owing to poor growth/ whitening, it was moved to Mandapam. Monoline method was restarted again in Mandapam as it was found to provide better returns. Trial cultivation was carried out in Krishna District (Andhra Pradesh); however, salinity drop in back waters and rough waves in open seas led to poor plant growth.
2008	Aquagri took over the PepsiCo project. Commercialization of AquaSAP started.
2009	Construction of a semi-refined carrageenan (SRC) unit at SIPCOT was initiated.

TABLE 2

Area production and exports of *Kappaphycus* in Tamil Nadu, India, 2001–09

Year	Cultivation method	Growth rate (%)	Business model	Procurement cost, INR/kg (dry weight)*	Number of ML/BR	Production dry weight (tonnes)	Exports (FCL of dry seaweed)
2001	ML	1.5–6.0	Company owned	Daily wage system	Test plots	21	1
2002	ML	2.2–2.4	Company owned	Daily wage system	ML: 5 275	82	4
2003	BR: 75% ML: 25%	2.0–2.5	Company owned and contract farming	Daily wage system & 4.50	ML: 3 567 BR: 1 962	147	7
2004	BR	2.6	Contract farming	4.50 & 7.50	BR: 3 469	126	6
2005	BR	3.25	Company owned	7.50 & 8.50	BR: 3 450	135	6
2006	BR	2.5–3.0	Company owned	8.50 & 10.00	BR: 8 100	244	12
2007	BR: 95% ML: 5%	2.5–3.0	Contract farming and private cultivators	10.00 & 12.00	BR: 10 464	315	15
2008	BR: 90% ML: 10%	2.5–3.0	Company owned	12.00 & 14.00	BR: 16 000+	588	28
2009	BR: 90% ML: 10%	2.5–3.0	Company owned	14.00/kg (dry) 1.75/kg (fresh)	BR: 18 000+	714**	34**
Total						2 372	113

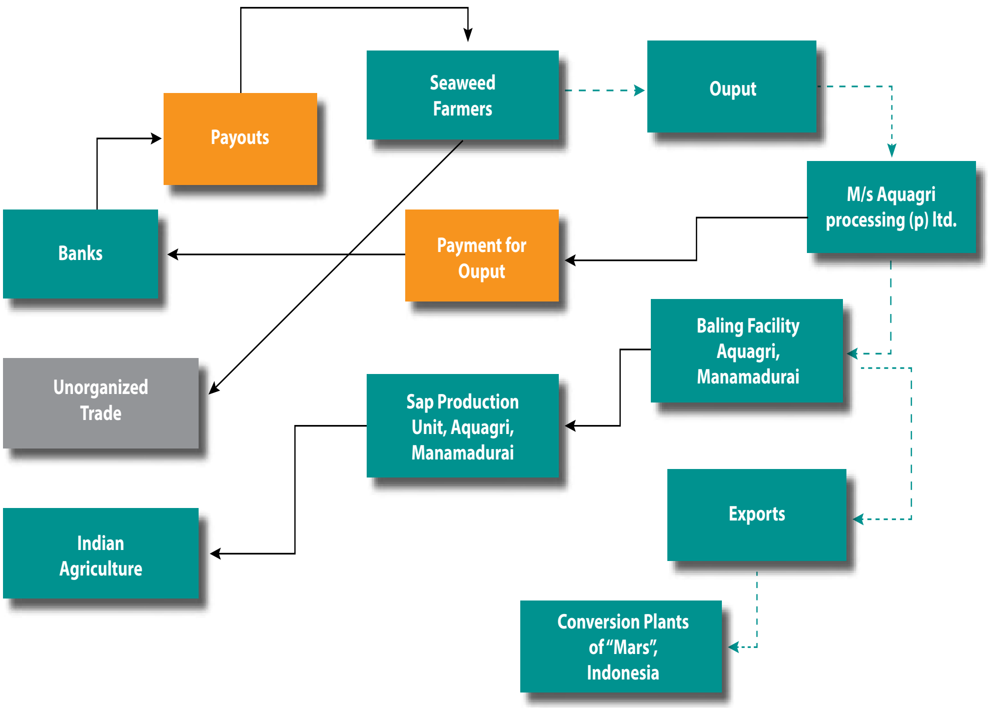
* The column includes two values to indicate that prices offered to self-help group (SHG) members were revised in the same year.

** Data incomplete for 2009.

Note: BR = bamboo rafts; ML = monoline; FCL = full container load (1 container = 21 tonnes).

FIGURE 2

Marketing channels of seaweed farmers in Ramanathapuram District, Tamil Nadu



routinely induced the farmers to break the contracts by offering a marginally higher price. However, Aquagri has developed its own price-incentive schemes for loyal and high-volume producers. In addition, non-price arrangements such as assisting farmers to meet their family and social obligations have contributed to build bonds of mutual trust and loyalty.

SAP[3] is a major product extracted from the dried weed in India. The partnership established between PepsiCo and the CSMCRI to explore more water- and energy-efficient processing technologies led to the development of a fresh-weed processing system that yielded SAP, an organic fertilizer rich in micronutrients, aminoacids and growth hormones. Since then, SAP has been applied to a range of crops (brinjal, onion, corn, black gram, paddy, sugar cane) and has consistently increased yields by 12–40 percent. According to the CSMCRI, *Kappaphycus* SAP also contains considerable quantities of nitrogen, phosphorus, potassium, organic matter, sodium calcium, magnesium, manganese, iron, copper, zinc, cobalt, molybdenum, sulphate and chloride. Incidentally, applying SAP at the germination stage of seaweed cultivation has also shown impressive results in terms of increase in growth of roots and shoots.

At the time of writing, efforts were under way to build a plant in Manamadurai for the extraction of carrageenan; with the plant scheduled to be commissioned in January 2010. Dried seaweed is exported by PepsiCo to carrageenan conversion plants in Indonesia. International price fluctuations, which have disrupted the development of seaweed farming in other locations in the world, have had relatively little impact in India owing to the large demand from the domestic market.

Aquagri has recently completed the construction of two facilities for processing seaweeds in Tamil Nadu (Mandapam and Manamadurai). These facilities are capable

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[3] In this context, SAP is not a generic term but indicates the liquid biofertilizer developed by Aquagri and branded as AQUASAP.

of handling 150 tonnes/day of fresh seaweed; most of the input material is being converted to SAP; the residual content after extraction of SAP is used for the extraction of carrageenan. These are state-of-the-art facilities using solar power and biofuels as energy sources. Aquagri has sourced the technology for extracting SAP from wet seaweeds and acquired exclusive marketing rights for three years from the CSMCRI.

Other firms such as SNAP are also developing *Sargassum*-based value-added products, including organic manure, foliar sprays, and liquid and gel fertilizers. SNAP is certified by the Agricultural and Processed Food Products Export Development Authority (APEDA) under the National Program for Organic Produce Certification. Other government departments have also certified SNAP products.

Competitive pricing arrangements were extended to farmers by PepsiCo. Price incentives were also offered to growers who produced more than the targeted quantity, so as to prevent breaching of contracts. With the opening of the new SAP plant, Aquagri would increase its purchases of wet *Kappaphycus*, enabling growers to devote a greater portion of their time to farming rather than drying. Wet seaweed was being purchased from the SHG members at the rate of INR1.50/kg at the time of writing.

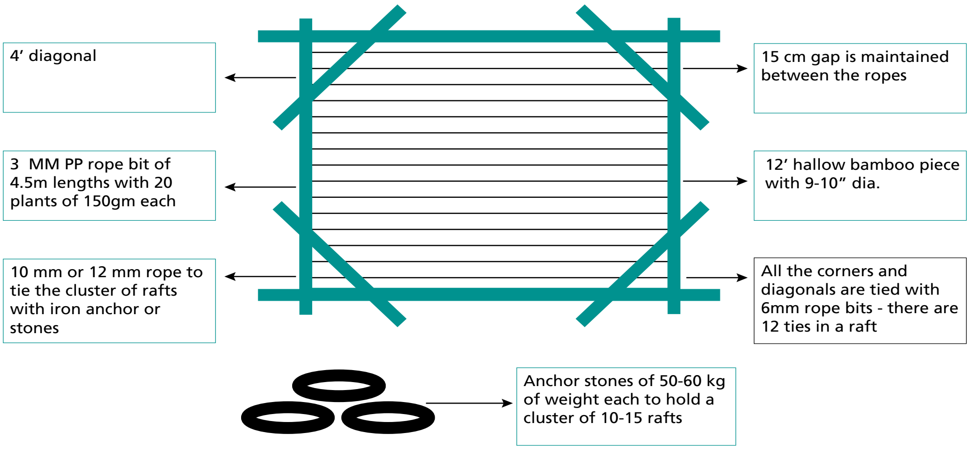
3. CARRAGEENAN SEAWEED FARMING: ECONOMIC AND SOCIAL PERFORMANCE

3.1 Techniques

Two different culture techniques are practised in Mandapam: raft culture (also called floating) and monoline culture (also called off-bottom). The raft method is suitable in areas where water currents are weak, e.g. Palk Bay. A floating frame made of bamboo (normally of dimensions 3 m × 3 m) is used to suspend the seaweed about 50 cm below the surface. Three-millimetre polypropylene ropes are stretched in parallel between the two sides of the raft, at intervals of 10–15 cm. The seedlings are tied to the ropes and the raft is anchored to the bottom. Anchor ropes may be needed to hold the raft below the surface at the beginning, but as the plants grow and add weight to the raft, extra support (such as polystyrene foam boxes tied to the corners of the raft[4]) may be required to prevent it from sinking too low in the water. Specific details of this technique are provided in Figure 3.

FIGURE 3

Top view of a 3 m × 3 m bamboo raft with 4 ft (1.22 m) diagonals



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[4] In Palk Bay, both thermocol pieces and empty plastic bottles are used for flotation. Plastic bottles are now being phased out as an environmental safety measure.

With a 15 cm interval between 2 lines, 20 lines can be attached to a 3 m × 3 m raft, which would provide a total of 60 m of lines for planting seaweed.

A cluster of 10 rafts in the normal season (4–6 rafts in the monsoon season) can be anchored with a 15kg, 5-toothed iron anchor. Alternatively, holed stones can be linked with chains and then tied to the cluster. The major advantage of floating rafts is that they can be easily moved to another location if necessary, and removed from the water during bad weather. Rafts can also be used as drying racks by providing appropriate support when placed onshore.

In typical monoline culture, a seaweed farmer is given 45 ropes of 60 m. These are tied in two sections to avoid sags in the line caused by the weight. Thus, the lines are arranged in two 45 m × 30 m plots, with each line straddling the two plots. A total of 300 seaweed cuttings are inserted in each rope, leaving a spacing of 20 cm. The initial weight of seedlings is 200 g and, thus, a total of 60 kg of seed material is required per 60 m rope. Normally, the seaweed plants are simply tied up to the nylon ropes. However, in the summer months of May–June (the fish breeding season), the plants are covered with net bags to avoid grazing by fishes, which increases production costs. The seeds are always covered with net bags in Tuticorin and Kanyakumari.

3.2 Economic performance

Productivity and profitability: raft vs monoline

According to the information provided by Tamil Nadu Department of Fisheries (TNDoF, 2009), a subsidized raft aquaculture operation (*Kappaphycus*) by an SHG farmer trainee goes as follows:

- It costs about INR738 to construct and seed a 3 m × 3 m raft. Most of the investment (INR568) is needed for building the farming system; INR 130 is needed for seeding; and INR 40 is needed for miscellaneous tools (Table 3).
- Assuming that on average a farmer trainee manages 45 rafts,[5] then the operation would require an initial investment of INR 33 230. Half of the investment is subsidized by the TNDoF; the other half is financed with a commercial bank loan.
- Operation normally runs for only 270 days per year because seaweed culture is usually not practised during the northeast monsoon (about 95 days). Therefore, there are 6 operation cycles per year (45 days per cycle). Then, the amortized capital cost is INR123 per cycle (Table 3).
- With 60 kg of initial seeds planted on lines of a total of 60 m in length, a 3 m × 3 m raft would be able to generate about 280 kg of fresh seaweed in a 45-day cycle; out of which, 60 kg would be used as seed materials for the ensuing cycle; the rest processed into 20 kg of dried seaweed (10:1 ratio; 2 kg removed as impurities).
- At the price of INR16/kg, the 20 kg of dried seaweed would yield INR320 of revenue per raft per cycle.
- As part of the harvest is used as seed materials, the initial seed materials should not be counted as an expense.
- The operation is usually conducted by family labour and requires little cash expenses. However, there is on average a financial expense of INR8.2 per raft per cycle, including expenses of INR6.8 in interest and INR1.4 for insurance.

A typical 60-m monoline operation in Ramanathapuram District goes as follows:

- It costs about INR38 to set up a 60-m monoline system, which is much cheaper than a 3 m × 3 m raft system. The cost of the nylon ropes accounts for 33 percent of total investment; however, labour charges for installation account for the highest share (38.5 percent).

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[5] If a farmer can seed and harvest one raft per day, then on average a farmer would be able to manage 45 rafts for a 45-day production cycle. However, many farmers are able to handle as many as three rafts a day, greatly enhancing their economic returns.

TABLE 3
Investment requirement for one raft (3 m × 3 m) in Tamil Nadu

Items	Investment (INR)	Amortized capital cost for 6 cycles/year operation (INR/cycle)
Farming system (3 m × 3 m raft; 60-m lines for growing)	**568**	**94.7**
- 1 bamboo raft (64-ft)	211	35.2
- 5 cornered anchors	63	10.5
- Floats	25	4.2
- 3-mm nylon rope (1.25 mm thickness/4.5 m length/20 lengths)	52	8.7
- 20 ropes for seeding	21	3.5
- 6-mm thickness nylon rope (for raft construction, 36 m)	75	12.5
- 3.5 m × 3.5 m nets for reducing grazing	89	14.8
- 2-mm thickness ropes for tying the nets to raft bottoms (28 m)	10	1.7
- Nylon rope for tying rafts together (5.4 m)	12	1.9
- 10-mm anchor ropes (17 m)	10	1.7
Initial seed	**130**	**21.7**
- Seed materials (*Kappaphycus*, 60 kg)	105	17.5
- Expense for transporting seed materials	25	4.2
Tools	**40**	**6.7**
- Mats, ladders, baskets, knives, etc.	40	6.7
Total	**738**	**123.1**

- Similar to the raft system, the 60 kg of initial seed materials is worth INR105, which is not counted as an expense because the materials will be replenished by part of the harvest.
- Harvest is normally conducted after 45 days in Ramanathapuram District.[6] A 60-m rope may yield 400 kg of fresh seaweed;[7] 100 kg of which is separated as planting material for the subsequent cycle; the rest become 28 kg of dried seaweed (10:1 ratio; 2 kg impurities removed).
- At the price of INR16/kg, the 28 kg of dried seaweed production generate INR448 of sales revenue per cycle per rope.
- If the wage for family labour is not included, the operating cost per rope is INR120, including INR50 for harvesting.

The operation and financial situations of the two systems highlighted above are summarized and compared in Table 4. The results indicate that:

- The monoline operation appears to have higher yield than the raft operation. For the same length of rope (60 m) and same amount of seed materials (60 kg), the production of monoline operation (400 kg of fresh seaweed) is higher than the raft operation (280 kg). Consequently, the sales revenue of the former is 40 percent higher than the latter.
- The cost of the monoline operation (INR158) is a little higher than the raft operation (INR106), which mainly reflects the operation and harvest cost under the monoline operation. As mentioned above, the amortized cost of the monoline farming system is much lower than that of the raft.
- The net profit per cycle for the monoline operation is INR290 (USD6.0), higher than the INR206 (USD4.3) for the raft system. This result implies that, on average,

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[6] Because growth rates are higher, the production cycle is shortened to only 30 days in the southern districts of Tuticorin and Kanyakumari.

[7] The expected yield ranges from 350 to 400 kg of fresh seaweed.

TABLE 4
Financial analysis of raft culture vs monoline culture in India

Item no.	Item	A 3 m × 3 m raft (60 m lines for growing)[1]	Monoline (60 m lines for growing)
(1)	**Production**		
(2)	- Initial seed materials (kg)	60	60
(3)	- Fresh seaweed per 45-day cycle (kg)	280	400
(4)	- Fresh seaweed reserved as seeds (kg)	60	100
(5)	- Dried seaweed product (kg)	20	28
(6)	**Price of dried seaweed (INR/kg)**	**16**	**16**
(7)	- Price of dried seaweed (USD/tonne)	331	331
(8)	**Revenue (INR/cycle)**	**320**	**448**
(9)	**Cost (INR/cycle)**	**114**	**158**
(10)	- Operational expense (including depreciation)	106	158
(11)	Farming system	95	38
(12)	Initial seeding	4.2	–
(13)	Tools	6.7	–
(14)	Operation	–	70
(15)	Cost of harvesting	–	50
(16)	- Financial expenses	8.2	–
(17)	Interest	6.8	–
(18)	Insurance	1.4	–
(19)	**Net profit (INR/cycle)**	**206**	**290**
(20)	**Net profit (USD/cycle)**	**4.3**	**6.0**

[1] Data for the raft system adapted from Seaweed Culture, Golden Jubilee Village Self Employment Opportunities, Government of Tamil Nadu (2008-09).

Notes: USD1 = INR48.405 (2009). (8) = (5) × (6). (9) = (10) + (16). (12) Including only the cost of seed transportation. (19) = (8) – (9). Numbers may not add up due to rounding.

the raft farmer could earn about USD4.3 per day, amounting to USD1 150 per year for 270 days of production.

Although monoline culture appears to be more profitable than raft culture, the operational difficulties may be greater (there is a higher threat of grazing by fish; ropes could break, leading to crop loss; and plot maintenance is labour-intensive).

The above analysis is based on the assumption of 400 kg/cycle for monoline culture. If the yield is only 350 kg/cycle, then the net profit will be only INR210, similar to the raft culture.

The non-monetary advantages of raft culture make it a preferred system choice in Ramanathapuram District. Therefore, this study concentrates on the socio-economics of the raft culture system.

Profitability and viability of raft culture

Consider the 3-year operation of a 1-ha seaweed farm with 900 rafts with the following specifications:

- Each raft contains 60 m lines for growing. With 900 rafts, the farm has 54 km of lines for growing.
- After three years of operation, a new set of investments needs to be made.
- One production cycle lasts 45 days. There are 4 production cycles in the first year and 6 cycles in the second and third years.
- In a production cycle, each raft is planted with 60 kg of seed material and produces 20 kg of dried seaweed after part of the harvest is set aside as seed materials for the next cycle.

The initial investment requirements for the seaweed farm are summarized in Table 5.

The annual revenue, cost and net profit of the farm are summarized in Table 6. The results indicate that:

- The farm is profitable with USD9 460/ha (USD175/km of line) for the first year (4 cycles) and USD16 228/ha (USD301/km of line) for the second and third years (6 cycles per year).
- The profit margins are 40 percent for the first year (4 cycles) and 45 percent for the second and third years (6 cycles per year).
- The break-even prices (USD199/tonne for the first year and USD180/tonne for the second and third years) are much lower than the actual price (USD331/tonne).

The cash flow situation of the three-year operation is summarized in Table 7. The results indicate that:

- The farm's net cash inflow is USD190 for the first year and USD19 293 for each of the second and third years.
- The positive cash inflow in the first year implies that the farm can recover its investment within the first year. Specifically, the pay-back period for the operation is about 0.98 year.
- The internal rate of return (IRR) of the 3-year operation is 110 percent.

TABLE 5
Initial investment for a 1-ha seaweed farm with 900 rafts (54 km of growing lines)

Item no.	Item	Unit	Annual amount
(1)	**Initial investment**	**USD/ha**	**12 336**
(2)	- Seedlings (54 tonnes)	USD/ha	1 952
(3)	- Farming system (900 rafts)	USD/ha	10 383
(4)	**Initial investment per kilometre of lines**	**USD/km**	**228**

Notes: USD1 = INR48.405 (2009). (1) = (2) + (3). (4) = (1)/54. Numbers may not add up due to rounding.

TABLE 6
Annual revenue, cost and net profit of a 1-ha seaweed farm with 900 rafts

Item no.	Item	Unit	1st year (4 cycles per year)	2nd and 3rd years (6 cycles per year)
(1)	**Annual dried seaweed production (per cycle: 20 kg/raft)**	**tonnes/ha**	**72**	**108**
(2)	**Price of dried seaweed**	**USD/tonne**	**331**	**331**
(3)	**Annual revenue**	**USD/ha**	**23 799**	**35 699**
(4)	**Annual costs**	**USD/ha**	**14 339**	**19 471**
(5)	*Fixed cost*	*USD/ha*	*4 076*	*4 076*
(6)	- Depreciation	USD/ha	3 066	3 066
(7)	- Interest on investment (7%)	USD/ha	864	864
(8)	- Insurance (1.2%)	USD/ha	147	147
(9)	*Operating cost*	*USD/ha*	*10 263*	*15 395*
(10)	- Braider twining charges	USD/ha	2 231	3 347
(11)	- Transportation	USD/ha	1 934	2 901
(12)	- Raft maintenance	USD/ha	5 875	8 813
(13)	- Miscellaneous	USD/ha	223	335
(14)	**Annual net profit**	**USD/ha**	**9 460**	**16 228**
(15)	Annual net profit per kilometre of line	USD/km	175	301
(16)	**Profit margin**	**%**	**40**	**45**
(17)	**Break-even price**	**USD/tonne**	**199**	**180**

Notes: USD1 = INR48.405 (2009). (3) = (1) × (2). (4) = (5) + (9). (5) = (6) + (7) + (8). (9) = (10) + (11) + (12) + (13). (14) = (3) – (4). (15) = (14)/54. (16) = (14)/(3)*100. (17) = (4)/(1). Numbers may not add up due to rounding.

TABLE 7
Financial feasibility of a 1-ha farm over 3 years

Item no.	Items	Unit	Year 1	Year 2	Year 3
(1)	Cash outflow	USD	23 609	16 405	16 405
(2)	- Investment	USD	12 336	–	–
(3)	- Interest & insurance	USD	1 010	1 010	1 010
(4)	- Operation	USD	10 263	15 395	15 395
(5)	Cash inflow (operation)	USD	23 799	35 699	35 699
(6)	Net cash inflow	USD	190	19 293	19 293
(7)	Pay-back period	Year		0.98	
(8)	Internal rate of return	%		110	

Notes: USD1 = INR48.405. (1) = (2) + (3) + (4). (6) = (5) – (1) Numbers may not add up due to rounding.

Summary

In sum, the above analyses provide strong evidence of the economic and financial profitability and viability of seaweed farming in Tamil Nadu. The estimated high rate of return on investment is consistent with the findings of Padilla and Lampe (1989), who calculated an IRR of 78 percent for seaweed farming in the Philippines; Shang (1976), who estimated an IRR of 56 percent for Gracilaria cultivation; and Firdausy and Tisdell (1991), who reported an IRR of 123 percent in Bali. Seaweed farming has thus emerged as one of the most profitable livelihood options for coastal fishing communities in various locations of the Asian continent.

3.3 Social performance

The socio-economic status of seaweed farmers was assessed through personal interviews using a pre-tested schedule. Details on socio-economic parameters associated with seaweed farming were collected from 437 sample respondents,[8] 226 from Mandapam and 211 from Rameshwaram.[9] The two regions represent the mainland and island ecosystems, respectively (Figure 1).

The SHGs surveyed were predominantly formed by women, although a few SHGs consisted exclusively of men while some SHGs were mixed. Agencies that actively support the SHGs include the DBT, Ramanathapuram Rural Development Agency (RDDA) and TNDoF. The Aquaculture Foundation of India (AFI) has provided seedlings and other materials to farmers in the region.

At the time of writing, a number of SHGs in Vedalai, Thonithurai, Ariyankkundu and R. Vadakadu were handling more than 1 000 rafts each. These SHGs have been exposed to *Kappaphycus* culture longer than other groups; because of this experience, they are able to obtain annual yields exceeding 50 kg per raft (dry weight). The performance of the most recent SHGs is expected to improve over time. Overall, farmers report that they have been able to obtain good returns from the activity. Seaweed farming is expanding to other districts within Tamil Nadu such as Pudukottai and Thanjavur.

Family characteristics

The characteristics of seaweed farming households under survey are summarized in Table 8. The results indicate that the average family size of the surveyed seaweed

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[8] The population of organized SHG seaweed farmers at the time of the survey was estimated at 1 000. The sample was drawn based on purposive sampling proportionate to size.

[9] Farmers in the Mandapam region included in the sample were specifically located in Vedalai, Umilyalpuram, Munaikadu, T. Nagar, Meenavar colony and Thonithurai. The locations covered in Rameshwaram were Pamban, Akkalmadam, Nallupanai, Ariyankudu, A. Vadakadu, Parvatham, Sambai, Mangadu and Olaikuda.

TABLE 8
Family characteristics of surveyed seaweed farmers

Indicators	Mandapam (N = 226)	Rameshwaram (N = 211)
Average family size (no.)	4.5	5.5
Share of nuclear family (%)	97	77
Share of joint family (%)	3	23
Share of family with male household head (%)	64	66
Share of family with female household head (%)	36	34

farming households was 4.5 in Mandapam and 5.5 in Rameshwaram. This is consistent with the national average of 4.5 for fisher families reported by the Marine Fishery Census (CMFRI, 2005).

Most of the sample respondents' families belong to the nuclear family type.[10] However, Rameshwaram has a relatively greater number of joint families[11] involved in seaweed farming. The social development programmes promoted by the Government of Tamil Nadu have led to a general improvement in the socio-economic conditions of the overall population. These programmes have also altered the structure of families, with joint families giving way to nuclear families. This phenomenon is also occurring in coastal villages.

As in most other states of India, household heads in Tamil Nadu are usually the most senior male in the family. Recently, widows have also represented as household heads if they are income-earners. However, the survey results indicate that a substantial proportion of seaweed farming households under survey (36 and 34 percent for Mandapam and Rameshwaram, respectively) were led by female household heads. The concept of the SHG was founded on the basic premise that women are more responsible and have a better disposition to work towards achieving social and economic independence. In the case of seaweed farming, rather than assuming a leadership role, males in fishing households have followed their women. The initial success of women in seaweed farming motivated men to enter the activity as well.

Age and education

The age and education characteristics of surveyed farmers are summarized in Table 9. The results indicate that about 60 percent of the surveyed farmers in both regions were middle-aged individuals (31–50 years old). This age bracket corresponds to a productive group of individuals that is usually receptive to new ideas and is capable of implementing them, even if doing so involves some risk.

TABLE 9
Age and education of surveyed seaweed farmers

Age & education	Share of surveyed households (%)	
	Mandapam (N = 226)	Rameshwaram (N = 211)
Age		
≤ 31	31	25
31–50	61	59
> 50	8	16
Education		
Illiterate	1	7
Elementary	43	8
Lower primary	21	18
Upper primary	22	43
Secondary	11	18
Higher secondary	2	6

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[10] A nuclear family is a family group consisting of only a father and mother and their children, who share living quarters.

[11] A Hindu joint family or Hindu undivided family or a joint family is an extended family arrangement prevalent among Hindus and consisting of many generations living under the same roof. All the male members are blood relatives and all the women are either mothers, wives, unmarried daughters or widowed relatives.

The estimated 52.8 percent of average literacy rate in the district was lower than the national average (65 percent), reflecting relatively poor educational facilities in the area. However, the surveyed seaweed farmers appeared to have higher literacy rate than the national average. Indeed, about 13 and 24 percent of respondents in Mandapam and Rameshwaram, respectively, have reached a secondary level of schooling or higher.

On average, the surveyed farmers in Rameshwaram appeared to have a higher education level than those in Mandapam.

Employment

Fishing and seaweed farming are the two most important occupations in the two areas under survey. The occupation and professional experience of surveyed farmers are summarized in Table 10. The results indicate that almost half of the respondents in Mandapam practised fishing as their primary occupation, while only 13 percent chose fishing as the primary occupation in Rameshwaram. Seaweed farming has become the primary livelihood activity of fishers in Rameshwaram, which has helped reduce pressure on the fish stocks of the area. The emergence of seaweed farming has also helped reduce political tension with neighbouring Sri Lanka over access to common fishing grounds.

Most of the respondents (92 and 72 percent in Mandapam and Rameshwaram, respectively) have 11–25 years of experience in fishing. Most of these individuals belonged to the middle-aged group and could successfully adapt to innovations in seaweed farming techniques.

As the concept of seaweed farming was introduced only after 2001, most of the respondents had only up to 5 years of experience in seaweed farming. Although most farmers had fewer years of experience in seaweed farming than in fishing, many of them have chosen the latter as their primary occupation (Table 10). This indicates the level of commitment of stakeholders, as fishers perceive seaweed farming to be a less risky and more sustainable activity compared with traditional fishing practices.

The employment patterns of surveyed seaweed farming households are summarized in Table 11. The results indicate that:

- On average, one member per family is involved in active fishing in both areas.
- On average, one member per family is involved in post-harvest activities (i.e. peeling, drying, freezing, processing, value addition) in the Mandapam area, while two members are involved in the Rameshwaram area.
- For seaweed farming, on average, two members per family are involved in the activity in both Mandapam and Rameshwaram.

TABLE 10
Occupation and professional experience of surveyed seaweed farmers

Occupation & professional experience	Share of surveyed households (%)	
	Mandapam (N = 226)	Rameshwaram (N = 211)
Occupation		
- Respondents taking fishing as primary occupation	48	13
- Respondents taking seaweed farming as primary occupation	52	87
Fishing experience		
≤ 10 years	6	23
11–25 years	92	72
> 25 years	2	5
Seaweed farming experience		
≤ 5 years	87	84
6–7 years	9	13
> 7 years	4	3

TABLE 11
Employment patterns of surveyed seaweed farming households

Name of the occupation	Mandapam (N = 226)		Rameshwaram (N = 211)	
	Average no. of members per family	No. of days employed per person per year	Average no. of members per family	No. of days employed per person per year
Active fishing	1	179	1	181
Post-harvest activities	1	96	2	100
Seaweed culture/harvest	2	144	2	161

- The average annual working days per person in fishing and post-harvest activities is marginally higher in Rameshwaram (181 and 100 days) than in Mandapam (179 and 96 days). A similar trend was also observed for seaweed farming (161 days in Rameshwaram as opposed to 144 days in Mandapam).

As indicated in Table 11, on average, a seaweed farming household in Mandapam and Rameshwaram has two family members engaged in seaweed farming; the average annual total of working days is 144 days per person in Mandapam and 161 days per person in Rameshwaram. It is estimated that there were about 517 and 483 seaweed farming households in Mandapam and Rameshwaram, respectively. Therefore, seaweed farming would be able to provide 148 896 and 155 526 person-days of employment per year in the two areas, respectively. The various development programmes in the region are currently planning for a total of 5 000 families to become involved in seaweed farming, which would translate into 765 000 days of employment in the district (assuming 153 days of employment per person per year). More generally, it has been argued that seaweed farming could provide employment to 200 000 families in the country, with annual earnings of about INR100 000 per family (AFI, 2008).

Wealth and indebtedness

Housing is an important indicator of the socio-economic status of an individual, particularly in small villages. All respondents in both areas were living in their own houses. With regard to the housing type, the proportion of kutcha[12] houses was high in Mandapam (75 percent). The proportion of kutcha and pucca houses was about the same (49 percent) in Rameshwaram (Table 12). Only four respondents in Rameshwaram (two percent of the surveyed households in the regions) were found to reside in reinforced cement concrete houses.

Livestock husbandry is an important source of supplementary income for the fisher households. Maintaining livestock is often seen as a symbol of prestige among rural households. About 55 percent of respondents in Mandapam and 59 percent in Rameshwaram maintain livestock to supplement their income and domestic needs (Table 12). The most common livestock type is poultry.

Table 13 presents the average amounts of loans taken out, repaid and outstanding for Mandapam and Rameshwaram. Households take out loans for different purposes, including domestic activities and social obligations. Although the institutional loan procedures are slightly more cumbersome, respondents tend to prefer institutional loans to those provided by commercial moneylenders because the repayment process

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[12] A pucca house is one that has walls made of any of the following materials: burnt bricks, stones (packed with lime or cement), cement concrete, timber, ekra, etc. In addition, the roof is made of tiles, galvanized corrugated iron sheets, asbestos cement sheets, reinforced brick concrete, reinforced cement concrete, timber, etc. In a kutcha house, the walls and/or roof are made of materials other than those mentioned above, such as un-burnt bricks, bamboo, mud, grass, reeds, thatch, loosely packed stones.

TABLE 12
Wealth status of surveyed seaweed farming households

Housing and livestock ownership	Share of surveyed household (%)	
	Mandapam (N = 226)	Rameshwaram (N = 211)
Type of house		
- Kutcha	75	49
- Pucca	25	49
- Reinforced cement concrete	0	2
Livestock owners		
- Cattle owners	18	4
- Buffalo owners	7	0
- Poultry owners	30	55

TABLE 13
Level of indebtedness in the surveyed regions

	Average loan taken out per household (INR)	Average loan repaid per household (INR)	Outstanding loan per household (INR)
Mandapam			
Institutional	4 350	3 050	1 300
Moneylenders	1 505	1 292	213
Rameshwaram			
Institutional	8 071	7 607	464
Moneylenders	5 089	4 763	324

is regarded as more transparent; this trend has accentuated since the advent of seaweed farming in the region.

Income and livelihood

The income status of surveyed seaweed farmers is summarized in Table 14. The results highlight the clear potential of seaweed farming for improving the socio-economic status of communities in both regions.

Seaweed farming appeared to provide higher income than fishing. In both regions, most respondents' income from fishing was within the range of INR10 001–20 000, while most respondents' income from seaweed farming was more than INR20 000.

In Rameshwaram, the income from seaweed farming was more than INR30 000 for almost half of the respondents, more than INR40 000 for more than 32 percent of the respondents, and more than INR50 000 for 10 percent of the respondents.

As indicated in Table 15, food items accounted for more than 60 percent of the consumption expenditure of an average household in Mandapam and Rameshwaram; medical expenses and clothing were the other two relatively large expenditure items. Such consumption patterns reflect the characteristic of households with relatively low incomes.

Seaweed farming has enabled households to raise their economic status significantly, with members of SHG families contributing substantially to total household income. In the last five years, the surveyed households have been able to acquire electronic appliances such as TVs, DVD players and mobile phones in addition to household appliances such as mixers and grinders. A total of 135 respondents (60 percent) and 141 persons (67 percent) have purchased mobile phones in Mandapam and Rameshwaran, respectively, in the last five years.

The surveyed seaweed farmers were asked how income from seaweed farming affected their livelihood; the answers are summarized in Table 16. The results indicate that:

TABLE 14
Income status of surveyed seaweed farmers (N = 437)

Income levels (INR per year)	Share of surveyed households (%)			
	Mandapam (N = 226)		Rameshwaram (N = 211)	
	Fishing	Seaweed farming	Fishing	Seaweed farming
Less than 10 000	28	9	13	2
10 001–20 000	69	33	57	25
20 001–30 000	3	57	19	24
30 001–40 000	0	1	8	17
40 001–50 000	0	0	2	22
50 001–80 000	0	0	1	8
80 001–100 000	0	0	0	1
More than 100 000	0	0	0	1

TABLE 15
Consumption expenditure patterns in Mandapam and Rameshwaram

Item	Mandapam		Rameshwaram	
	Expenditure (INR/year)	Percentage of total expenses (%)	Expenditure (INR/year)	Percentage of total expenses (%)
Food	18 525	65.19	19 819	62.79
- Fish	8 030	28.26	9 448	30.00
- Meat	2 568	9.04	2 205	6.97
- Oils	2 358	8.30	2 704	8.55
- Other food	5 569	19.60	5 462	17.27
Clothing expenses	2 027	7.13	3 407	10.77
Children education	1 210	4.26	1 749	5.53
Medical expenses	4 284	15.08	3 668	11.60
Electricity	836	2.94	851	2.69
Fuel charges	1 193	4.20	807	2.55
Recreation	0	0.00	583	1.85
Social function	342	1.20	701	2.22
Others	0	0.00	0	0.00
Total	**28 417**	**100.00**	**31 625**	**100.00**

TABLE 16
Impacts of seaweed farming on household expenditure

Expenditure supported by income from seaweed farming	Share of surveyed household (%)	
	Mandapam (N = 226)	Rameshwaram (N = 211)
Consumption expenditure		
- purchase quality clothing	99	89
- engage in social and religious travelling outside the district/state	37	25
- celebrate a marriage in the family	4	46
- transfer to a better educational institution	0	9
Capital expenditures		
- purchase cattle/poultry	74	84
- purchase consumer durables (e.g. modern electronic appliances)	69	66
- purchase or renovate current home	68	48
- purchase agricultural land	0	4

- Income from seaweed farming has helped most respondents improve their clothing and enabled many of them to engage more frequently in social functions such as social and religious travelling. Seaweed money has helped almost half of the respondents in Rameshwaram celebrate a marriage in the family.
- Income from seaweed farming has also helped most respondents purchase household assets such as livestock and consumer durables. Most respondents have used seaweed farming income for home purchase or renovation. About 4 percent of respondents in Rameshwaram have been able to purchase agricultural land with their seaweed income.

Summary

The results of the survey reveal that seaweed farming has emerged as a new, sustainable livelihood option for the fishing communities in the surveyed district. Encouragement of seaweed aquaculture with appropriate policy, financial, technical and institutional support can also serve to relieve pressure on overexploited fish stocks. Dramatic structural changes in the socio-economic status of many fishers have taken place the last ten years – a number of seaweed farmers actually started as hired labour for other farmers; however, many of them used this initial experience to become members of an SHG. After a few production cycles, SHG members can aspire to operate their own set of rafts and become a farmer capable of hiring labour to look after their own plots.

Seaweed farming has major strengths but also some weaknesses. Although Tamil Nadu is the second-most literate state in India (second only to Kerala), the expected social transformation resulting from higher levels of education (e.g. reduction in drinking and gambling) has yet to be reinforced, although the advent of seaweed farming seems to have made a positive contribution in this regard. A problematic feature of organized seaweed farming in India is that farmers are tempted to renege on their contracts if they are offered higher prices by competing agents, possibly leading to a chain reaction among neighbouring farmers. The established procurers have taken steps to address this situation by offering higher prices to farmers who attain high levels of production and ensure proper stock management.

4. GOVERNANCE AND INSTITUTIONS

4.1 Government agencies

Government agencies have actively supported seaweed cultivation through financial assistance and training. One of the agencies is the National Fisheries Development Board (NFDB). The NFDB is a government agency chartered in 2006 with the specific aim of supporting the development of the fisheries sector in India. Considering the vast potential of seaweed cultivation and processing in India, the NFDB has developed supporting schemes for the promotion of these activities. This support includes: (i) training and demonstration programmes; and (ii) the establishment of seaweed processing units. The NFDB also considers the provision of financial assistance for the construction of seaweed processing plants.

At the state level, the TNDoF supports seaweed farming as an alternative livelihood strategy for small-scale fishers (R. Dinakaran, personal communication, 2009). From 2007 to 2009, the TNDoF trained 1 300 fishers (13 batches of 100 members each) in the farming of *Kappaphycus*. This included 200 members of 40 SHGs who received a government subsidy under the Joint Liability Group scheme of the TNDoF.

4.2 Financial institutions

The State Bank of India (SBI) began to promote seaweed cultivation projects in collaboration with the Aquaculture Foundation of India (AFI) in 2006. It is estimated that each member of participating SHGs earned more than INR5 000 a month after repaying the monthly loan instalment to the SBI. This model represented a new approach for funding livelihood restoration projects following the destruction caused by the tsunami in December 2004. Almost 80 percent of those involved in these SHGs were women.

To ensure smooth implementation, farming contracts were arranged between the SBI and PepsiCo, enabling the bank to provide credit support to the SHGs interested in seaweed cultivation while PepsiCo agreed to procure the harvested seaweed.

The experience with SHGs has proved a major success in entrepreneurship development and loan recovery. By 2006, the SBI had granted a total of about INR 22.6 billion to more than 540 000 groups, 64 662 of which were located in Tamil Nadu. This approach was also implemented in the livelihood restoration project in Mandapam and extended to Tuticorin and Kanyakumari in the southern tip of Tamil Nadu. The SBI had plans to extend the project to other states and other coastal districts in Tamil Nadu. By March 2007, the SBI was planning to release more than INR1.0 billion in credit to support the livelihoods of more than 10 000 families.

Encouraged by the success of these SHGs, the District Rural Development Agency (DRDA) began providing subsidies to selected SHGs under the Swarnjayanti Gram Swarozgar Yojana programme, which covered 50 percent of the project cost, provided the subsidy did not exceed INR10 000 per person or INR125 000 per SHG, whichever was less. Under this scheme, the Bank of Baroda financed 40 SHGs (covering 200 members) in 2008–09. Sporadic financing has also been provided in Thanjavur, Tuticorin and Kanyakumari districts of Tamil Nadu by the Indian Overseas Bank and the SBI.

Another financial institution that has provided assistance to seaweed farming is the National Bank for Agriculture and Rural Development (NABARD). It is a refinancing development bank with a mandate for facilitating credit flow for promotion and development of agriculture and small-scale industries in rural areas of India. The funds available to commercial banks, including the SBI, for lending to the agriculture sector are normally routed through NABARD. Under this scheme, financing of SHGs is collateral-free. Because many SHGs in the Mandapam area already had savings accounts with their local banks, the channelling of collateral-free microcredit was facilitated. The involvement of the banks has also assisted the SHGs with mobilization, capacity building, training and extension of technology. Marketing arrangements were assured through contract-farming mechanisms wherein PepsiCo agreed to procure the harvested seaweed at a predetermined minimum price and remit the cash through the bank accounts.

An "Aquaclinic Centre" (Meenvalamaiyyam) in Mandapam has been promoted by NABARD and the M.S. Swaminathan Research Foundation, an Indian NGO that implements training programmes on various livelihood opportunities in fisheries (including seaweed culture), in association with the TNDoF. Seaweed culture has been singled out by the Government of India as one of the rural technologies deserving of promotion (Kunnumkal and Sant, 2002).

4.3 Self-help Groups (SHGs)

An SHG is an association of rural poor who have volunteered to organize themselves into a working group. The members of an SHG agree to save regularly and pool their savings into a common fund (known as the group corpus) and utilize the common fund through a common management arrangement.

At the time of writing, there were more than 110 SHGs involved in seaweed farming in Ramanathapuram District. Each group usually comprised five persons. In 2002–03, the daily-wage corporate model was the prevailing production arrangement in the region, which came to be replaced by the more successful SHG/Kudumbam (family) model of cultivation (KMC) model.

The KMC is a farming system initially introduced by PepsiCo and then widely adopted for *Kappaphycus* culture in Tamil Nadu. All seaweed farming in Ramanathapuram District is under the KMC. Cultivation is organized by members of an SHG who normally belong to the same family but may include other members from the same community. Collectively, the group prepares the rafts, seeds the lines, provides maintenance and harvests on the due date. Basic infrastructure is facilitated by the company, the harvest is purchased on a buyback basis and payments are affected by the company through the bank accounts of the SHG. A major advantage of the SHG/KMC model is that fishers are given an opportunity to become entrepreneurs in an activity with growth potential.

4.4 Research institutes and NGOs

A number of research institutes and NGOs have made substantial contributions to the seaweed farming movement in India. Some examples are:

- The Seaweed Research and Utilization Association (Mandapam), which was established in 1970, has been engaged in seaweed-related research activities such as organizing an annual symposium on algae-related topics, and it publishes a journal, *Seaweed Research and Utilization*.
- The Krishnamurthy Institute of Algology, which was established by a group of Indian researchers who felt the need for an institution devoted to research and development on algal studies, conducts studies on morphology, taxonomy, life history and basic algae chemistry. It also conducts periodical seminars and symposia on algal-related subjects and has been publishing a journal, *Indian Hydrobiology*.
- The Aquaculture Foundation of India (AFI), an NGO based in Chennai, Tamil Nadu, plays an active role in the promotion of seaweed farming in the southern districts of Tamil Nadu. The AFI identifies the most suitable SHGs for further involvement with government agencies and financial institutes. With support from Aquagri and the government departments, the AFI also imparts training and provides support to SHG participants for obtaining government subsidies and financing from financial institutes. It also works in collaboration with colleges and universities to increase the scale of seaweed farming.

5. CHALLENGES AND THE WAY FORWARD

The adoption of the SHG model introduced by PepsiCo in 2003 has allowed Indian farmers to circumvent many socio-economic problems that hinder development of the seaweed sector in other developing countries. A participatory approach to culture and management via contract farming has facilitated rapid expansion of seaweed farming in India. Seaweed farming, an activity that began as a livelihood option, has now led to an institutionalized socio-economic transformation of the farming villages. The insights gained from seaweed farming development in India can be summarized as follows.

- The adequate implementation of the SHG model of production largely explains the success of seaweed farming in Tamil Nadu.
- The commercial cultivation of *Kappaphycus* culture is perhaps the first enterprise of its type initiated by a corporate entity in Indian agriculture.
- One of the factors explaining the success of the SHG model is the consistent support provided by the banking sector led by NABARD and other commercial banks such as the SBI, Indian Overseas Bank, and Bank of Baroda.
- The clear policy and financial support provided by the Government of India through development agencies and research establishments has given a substantial fillip to the sector.
- The potential for expansion of operations in Andhra Pradesh and Gujarat will help consolidate the seaweed farming sector in India.

- The sector has been affected by poaching; however, the extent of the practice has been limited by the organizational structure of the SHGs.
- Industrial and urban runoff is reportedly having an adverse impact on the water quality of the grow-out sites. Improper garbage disposal in the region needs to be halted.
- Occurrence of seaweed diseases such as ice-ice and epiphytism – prevalent during the summer months – needs to be studied. Preventive and/or ameliorative measures need to be implemented.
- Corporate commitment has been essential to translating the concept of seaweed farming into tangible benefits to the farming community.
- The establishment of offshore seed jetties will enable farmers to increase yields by reducing the need to divert part of their output as cuttings for the next crop.
- Better coordination between the Tamil Nadu Department of Fisheries and the Department of Environment and Forests will allow stakeholders to conduct activities with a greater degree of confidence and trust.
- The seaweed sector in coastal India has all the potential to rise from the low-income conditions normally associated with basic livelihood activities to higher levels of employment, income and consumption.

Looking forward, there is an urgent need for establishing routine procedures for the collection, compilation and publication of data on standing stocks and landings from natural seaweed beds in India, by district and state. Entry into the *Kappaphycus* farming sector in India is restricted by knowledge. Corporations need to be educated on the immense scope in terms of returns to investment associated with seaweed farming, considering the low levels of initial investment and the fast turnover that can be expected given efficient human resource management. As envisaged in NAAS (2003), a mechanism (i.e. nodal cell) for rapid clearance of new projects and discussion of issues related to seaweed culture should be established to facilitate development seaweed farming in India. The nodal cell could also serve as an authoritative forum for the discussion of government orders and interdepartmental conflicts regarding seaweed farming development in India. Finally, any ambiguities arising from the tax regime on seaweed products in terms of excise and customs duties need to be clarified.

References

Aquaculture Foundation of India (AFI). 2008. *Final report of the DBT project: seaweed farming to rehabilitate tsunami affected coastal communities in Tamil Nadu*. New Delhi, Department of Bio-technology, Ministry of Science and Technology, Government of India. 41 pp.

Central Marine Fisheries Research Institute (CMFRI). 2005. *Marine Fisheries Census 2005*. Cochin, India.

Firdausy, C. & Tisdell, C. 1991. Economic returns from seaweed (*Eucheuma cottonii*) farming in Bali, Indonesia. *Asian Fisheries Science*, 4: 61-73.

Krishnamurthy, V., ed. 2005. *Seaweeds: wonder plants of the sea*. Chennai, India, Aquaculture Foundation of India.

Kunnumkal, M.C. & Sant, B.R., eds. 2002. *Directory of rural technologies: part IV*. Rajendranagar, Hyderabad, India, National Institute of Rural Development. 398 pp.

McHugh, D.J. 2003. *A guide to the seaweed industry*. FAO Fisheries Technical Paper No. 441. Rome, FAO. 105 pp. (also available at ftp://ftp.fao.org/docrep/fao/006/y4765e/y4765e00.pdf).

National Academy of Agricultural Sciences (NAAS). 2003. *Seaweed cultivation and utilization*. Policy Paper 22. New Delhi. 5 pp. (also available at www.naasindia.org/Policy%20Papers/pp22.pdf).

Padilla, J.E. & Lampe, H.C. 1989. The economics of seaweed farming in the Philippines. *Naga, The ICLARM Quarterly*, 12(3): 3-5.

Shang, Y.C. 1976. Economic aspects of *Gracilaria* culture in Taiwan. *Aquaculture,* 8: 1-7.

Tamil Nadu Department of Fisheries (TNDoF). 2009. *Swarna Grammeena Rozgar Yojana: seaweed cultivation*. Chennai, India, Department of Fisheries, Government of Tamil Nadu. 19 pp.

Social and economic dimensions of carrageenan seaweed farming in Mexico

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Robledo, D., Gasca-Leyva, E. & Fraga, J. 2013. Social and economic dimensions of carrageenan seaweed farming in Mexico. *In* D. Valderrama, J. Cai, N. Hishamunda & N. Ridler, eds. *Social and economic dimensions of carrageenan seaweed farming*, pp. 185– 204. Fisheries and Aquaculture Technical Paper No. 580. Rome, FAO. 204 pp.

1. INTRODUCTION

This paper focuses on the socio-economic analysis of the Dzilam de Bravo experience in seaweed farming, which is, at the time of writing, the only known case in Mexico in which coastal communities have been involved in this activity. Regarding the history of seaweed aquaculture in Mexico, only scientific and technical information deriving from academia is reported, as no related commercial activity has been established so far. While seaweeds have been continuously exploited in Mexico since the 1960s, this activity has been entirely based on the harvest of natural populations. Information on the marine algae industry in Mexico was obtained primarily through consultation of the grey literature and interviews with academics, consultants and government officials.

The economic feasibility of seaweed farming was evaluated using assumptions and data from the pilot cultivation carried out in Dzilam, taking into account selling prices in the international market. One of the major conclusions of the study is that any integration of seaweed growing and industrialization in Mexico would require interest from industry and local investors, as well as government authorities, in order to boost development of the activity.

Based on the experience in Dzilam de Bravo, various social and institutional factors on seaweed farming in Mexico were discussed, which indicate great potential of seaweed farming to become an integrated part of livelihood strategies for community development.

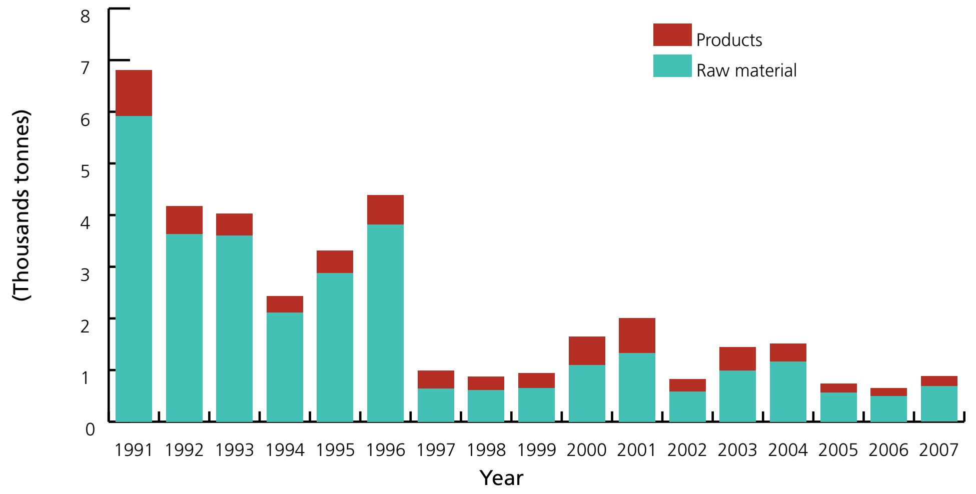
2. CARRAGEENAN SEAWEED PRODUCTION AND VALUE CHAIN

The commercial exploitation of phycocolloid-producing algae has occurred continuously for about 50 years in Mexico. However, this activity had not expanded significantly until very recently. In the Pacific Ocean, off the coasts of Baja California, commercial harvesting of natural populations of seaweed includes one species of Phaeophyta, *Macrocystis pyrifera*, and three species of Rhodophyta: *Gelidium robustum*, *Chondracanthus canaliculatus* and, more recently, *Gracilariopsis lemaneiformis* (Robledo, 2006). A high percentage of the seaweed biomass is exported, although efforts have focused in recent years on the use of seaweed meal or its transformation for other markets. Therefore, seaweed exports decreased from 50 000 tonnes in 1992–93 to about 17 400 tonnes in 2002–03. Currently, only 300–400 tonnes of dry seaweed are exported. This has resulted partly from a reduction in the demand for *M. pyrifera* as a source for alginate, and partly from the use of the harvested biomass in the production of fertilizers and seaweed meal in Mexico. At a global level, the *M. pyrifera* harvest has fallen from 35 000 to 5 000 tonnes in the last ten years. Similarly, a reduction in the processing of raw material from an average of 3 600 tonnes in the period 1991–96 to an average of 750 tonnes in the period 1997–2007 has been noted in Mexico (Figure 1).

Mexico exported 439 tonnes of seaweed in 2009 while imports of seaweed derivatives, primarily phycocolloids, have been increasing. Mexico currently lacks an industry for the extraction of phycocolloids, except for agar. This situation is reflected in the trade statistics for carrageenan, imports of which rose three and a half times between 1990 and 2009 (Figure 2). Agar imports were stable during the same period, probably owing to the annual production of 40–75 tonnes of agar by Agarmex, a company based in the Baja California peninsula that produces bacteriological and food-grade agar from an annual harvest of 800 tonnes of *Gelidium robustum*. With regard to carrageenan, while *Chondracanthus canaliculatus* is seasonally exploited in Baja California for export as a raw material to the United States of America and France, production volumes are low compared with other carrageenophytes in Latin America. Although tropical species report insufficient volumes for commercial extraction, *Eucheuma isiforme* has been sporadically exploited in the Yucatan peninsula. Based on these trends and the estimated domestic demand for carrageenan, Zertuche-González (1996) concluded that

FIGURE 1

Industrialization of seaweed in Mexico, 1991–2007



Source: INAPESCA (2010)

a carrageenan plant with a production capacity of about 400 tonnes could be set up in Mexico. The demand for carrageenan in Mexico rose steadily in the 1990s and 2000s; by 2009, imports had reached USD33.7 million. This trade deficit has created new opportunities for expanding the cultivation of carrageenophyte species in the country.

FAO has promoted phycocolloid production projects through the installation of two pilot plants in Baja California, one for carrageenan production and the other for alginate production. The latter currently extracts agar and conducts important applied research (along with the carrageenan plant). More recently, the Mexican Secretary of Agriculture, Livestock, Rural Development, Fisheries and Food has supported the installation of a pilot plant in Yucatan for the extraction of tropical-seaweed phycocolloids. This enterprise has enabled more accurate knowledge about the farming potential of seaweed in the region.

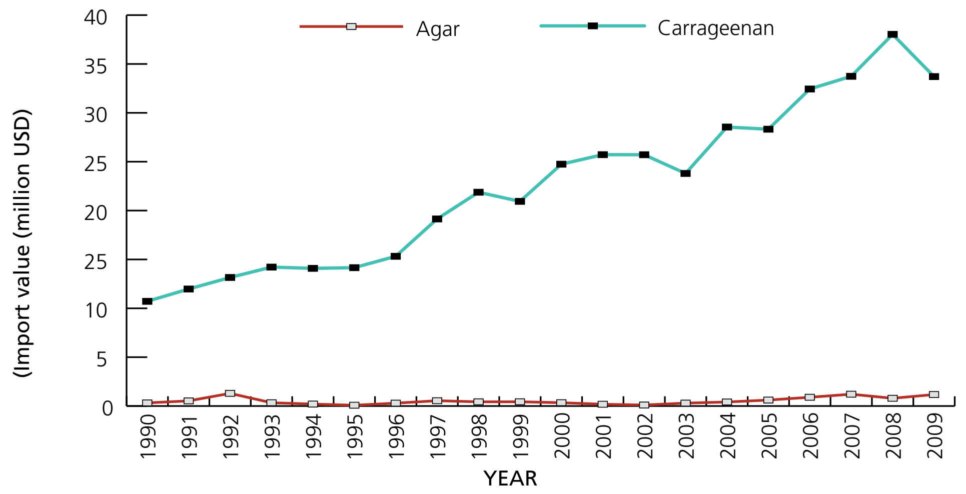
The significant growth of phycocolloid consumption in Mexico, especially carrageenan, opens up an opportunity for investment projects in the country, which will nevertheless require a thorough analysis of the economic and social aspects associated with the farming of the species and the formulation of proposals for fulfilment of this potential in the medium term.

Gracilaria farming has particularly thrived in Chile; some species of this seaweed have been studied in Mexico with a view towards commercial exploitation. Zertuche-González (1993) describes efforts and initiatives to grow this genus in Latin America, and reports that a project was carried out in 1988 to assess the feasibility of intertidal cultivation of *Gracilaria pacifica* (now renamed as *Gracilaria vermiculophylla*) in Mexico. The research was sponsored by FAO (AQUILA project) with support from the Secretary of Fisheries General Directorate of Aquaculture (Zertuche-González and García-Esquivel, 1989). Based on the results obtained, a private company conducted a commercial-scale pilot to estimate production costs of a 1-ha farm. The cost per dry tonne amounted to USD800, which meant very low profitability given the international market price at the time (USD1 000 per dry tonne). Given these results and the cheaper supplies of this genus in Asian countries, all projects aimed at developing its cultivation as a source of agar in Mexico were discouraged. Exploitation of natural beds in Baja California, which had been taking place since the 1990s, was terminated for the same reason.

The most interesting options that have emerged in the scientific and technical literature concern the cultivation of indigenous and/or introduced species, including

FIGURE 2

Mexican imports of phycocolloids, 1990–2009



Source: SIAVI (2010).

both agarophytes and carrageenophytes. However, commercial-scale cultivation would require a minimum annual production of 200 dry tonnes, which would necessitate the participation of commercial investors. Mexico has proposed options such as the farming of edible species (Godínez-Ortega *et al.*, 2008), the use of seaweeds for biofiltration (Robledo and Freile-Pelegrín, 2011) and the use of seaweeds as fodder for other herbivorous marine species that are currently farmed (e.g. shrimp and abalone). The consumption of seaweed is an age-old tradition in certain coastal communities in Mexico. Seaweeds containing either agar or carrageenan are boiled in water to prepare a drink that is normally served cold, or they are used for direct human consumption (Robledo and Freile-Pelegrín, 1998).

According to McHugh (2002), the promotion of the seaweed sector in developing countries requires organized support over a period of 3–5 years, with the possibility of involving the commercial sector or private-sector companies, while not ruling out the experience obtained through local projects implemented by the academic sector. To increase the chances of success, McHugh suggests adoption of the following measures:

- Joint funding of initiatives involving international producers and importers. International producers would usually request to be granted a degree of protection for their investments to shield them from competition, which may be achieved if the beneficiary country guarantees exclusive rights for initial production for a limited period.
- Initial capital grants for innovative companies in developing countries. These grants could take the form of low-interest loans or donations, which may be withdrawn if the company fulfils specific criteria such as reaching a specified level of exports after a development period of from three to five years.
- Support via funding and management and technical assistance to non-governmental organizations (NGOs) such as local cooperatives and women's groups.

McHugh (2002) points out that Argentina, Brazil, Mexico and Venezuela (Bolivarian Republic of) offer the brightest prospects for the development of seaweed industries, although market surveys and technical assistance are required. Although McHugh states that developing countries should avoid seaweed farming for the purpose of extracting hydrocolloids, the experiences with the processing of semi-refined carrageenan in Brazil indicate the opposite. Therefore, regardless of the chemical process used for extraction, the potential production of carrageenan in Mexico should not be discounted.

Mexico is the only Latin American country that has temperate, subtropical and tropical seas. No other country in the region has such diversity in its marine environment. A number of studies have assessed the use of native species as raw material for obtaining agar and carrageenan (Zertuche-González, 1988; Pérez-Enríquez, 1996a; 1996b; Freile-Pelegrín and Robledo, 1997, 2006; Robledo, 1998; Orduña Rojas and Robledo, 2002). Nevertheless, the major indigenous species do not appear in the list of those that the United States Food and Drug Administration (USFDA) authorizes as raw material for the extraction of this colloid, thereby limiting the marketing of any production to a few species. This has led to studies of introduced coldwater species such as *Chondrus crispus* (Zertuche-González *et al*., 2001) and warm-water species such as *Kappaphycus alvarezii* (Muñoz, Freile-Pelegrín and Robledo, 2004), both of which are approved by the USFDA, and whose pilot studies have yielded promising results. In this context, the commercial farming of the latter species in the tropical region of the Gulf of Mexico is deemed to have the greatest potential in the country.

2.1 Start-up in Mexico

In Mexico, *K. alvarezii* was introduced in 1999 in order to evaluate its potential for commercial-scale cultivation along the coasts of the Gulf of Mexico, especially in the Yucatan peninsula. Farming of the species began in the context of experimental studies coordinated by the Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional (CINVESTAV),[1] which, with federal and state government support, established community links aimed at setting up a demonstration plot with the assistance of 33 fishers from the community of Dzilam de Bravo. In 2002 and 2003, this community was deemed an ideal location for conducting a socio-economic study in the context of community management of coastal resources and management of protected natural areas, including the farming of this seaweed as an alternative to artisanal fishing (Fraga, Arias and Angulo, 2006; Robledo and Townsend, 2006).

Research studies on seaweed farming in Mexico have primarily stemmed from academic interest, entailing assessment of algal resources and biotechnical experimentation aimed at their exploitation and/or cultivation. While these studies have provided valuable information, they have not directly led to the exploitation and industrialization of seaweed. For example, commercial seaweed farming in the state of Yucatan has been developing for slightly more than ten years, including a social assessment process with an artisanal fishing community in Dzilam de Bravo on the state's central seaboard. These activities were preceded by preliminary studies conducted by CINVESTAV, which assessed various techniques for farming the red seaweeds *Gracilaria cornea* and *Eucheuma isiforme*, producers of agar and carrageenan, respectively. Intrigued by these experiences, and owing to the presence of researchers in the area, the local fishers became interested in the economic potential of seaweeds. The first contact was established in 1995 via a local resident, a ranger at the Las Bocas de Dzilam Nature Reserve, who began assisting the prospective studies of natural seaweed populations as a boat operator. In 1998, the initial contact person indicated that the president of the Dzilam de Bravo fishing cooperative was interested in developing non-conventional business activities. In the same year, together with some members of this cooperative, CINVESTAV began the experimental farming of the red seaweed *Gracilaria cornea* in an area called Mina de Oro, 4 km west of the port of Dzilam de Bravo. The location was chosen in accordance with certain ecological and oceanographic criteria relating to the abundance of red seaweed.

Subsequently, information was generated via a project financed by the National Commission for the Knowledge and Use of Biodiversity (known as CONABIO, its acronym in Spanish) aimed at preparing a handbook entitled "Technical Handbook:

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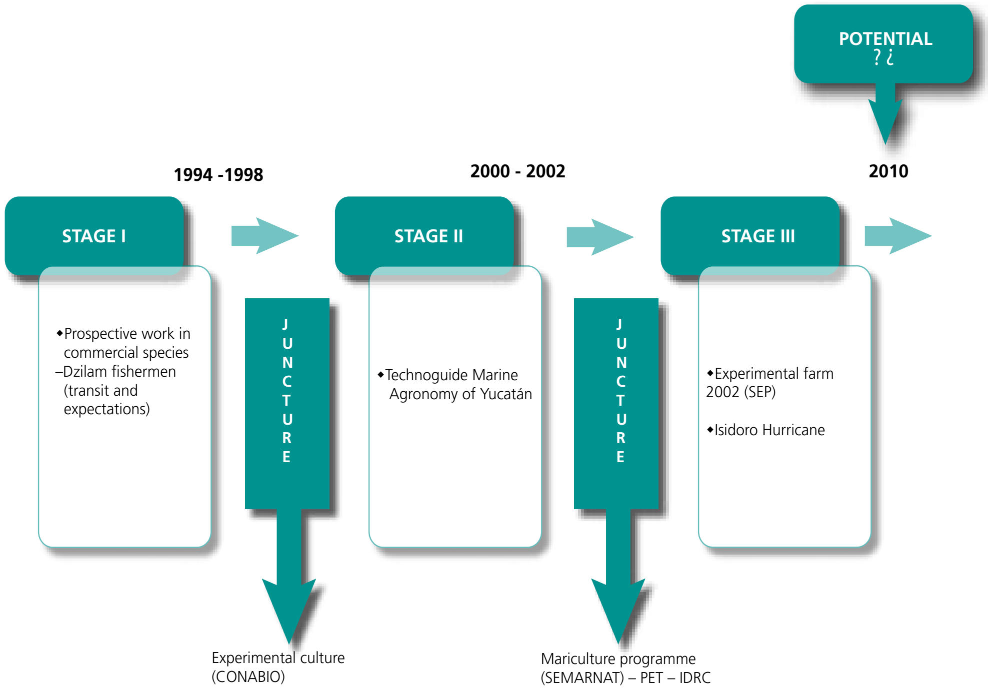
[1] Centre for Research and Advanced Studies of the National Polytechnic Institute.

FIGURE 3

The developmental process of seaweed farming in Yucatan, Mexico



Marine Agriculture in Yucatan – Cultivation of *Gracilaria cornea*", which was published in 1999 with financial assistance from the Ministry of the Environment, Natural Resources and Fisheries (SEMARNAP). This publication enabled the Yucatan office of SEMARNAP to convey its interest in seaweed farming techniques by proposing two Temporary Employment Programmes (PET) in 2000 in two coastal communities in Yucatan (Sisal and Dzilam de Bravo) with the goal of testing seaweed farming as a complementary or alternative activity to fishing. These programmes built on the results of the above-mentioned research projects. The fishing community in Dzilam de Bravo was more receptive than the one in Sisal; as a consequence, an experimental farm was set up in Dzilam to farm *Gracilaria* between November 2000 and January 2001. The harvested seaweed was sold to a European agar processing company (Iberagar) to obtain agarose. These events led CINVESTAV researchers to work jointly with the fishing community. Going beyond the promotion of seaweed farming, this cooperation entailed socio-economic engagement and the creation of links with the scientific work in order to enable improved living conditions in the communities where the research was being carried out. These closer links generated an interest in socio-economic research into this activity as an alternative to artisanal fishing in this community. In December 1999, a consultant from the International Development Research Center (IDRC) of Canada visited the seaweed production unit and supported a proposal for in-depth investigation of seaweed farming as an alternative activity to fishing, including an assessment of the social dimensions and the gender perspective. Financed by the Public Education Secretary (SEP), 33 fishers set up an experimental pilot farm of 3 000 m^2 on the coast of Dzilam de Bravo in March 2002, based on the species *K. alvarezii*, thereby diversifying the supply of raw material to obtain carrageenan for industrialization in France and Denmark. However, Hurricane Isidore lashed the coasts of the Yucatan peninsula in September 2002 and destroyed the farm, hampering the continuity of the project.

2.2 Value chain

The Latin American seaweed industry plays an important role at a global level as about 17 percent of all seaweeds and 37 percent of red seaweeds destined to phycocolloid production come from this region. The leading producer by far is Chile, which accounts for 13 percent of world seaweed supplies, being the largest producer of agarophytes (about 21 percent) and *Gracilaria* (50 percent). Argentina, Brazil and Mexico also contribute significant amounts of seaweed for the production of carrageenophytes and brown seaweed for the production of alginates (McHugh, 1996).

With regard to carrageenophytes, world production amounts to 160 000 tonnes of seaweed (dry weight), from which 28 000 tonnes of carrageenan are obtained, valued at USD270 million. The processing plants are located in Europe (United Kingdom of Great Britain and Northern Ireland, Denmark, France and Spain), Asia (China, Japan, the Philippines and the Republic of Korea), the United States of America and Chile. There are at least 24 recognized producers of carrageenan, as well as about 10 other minor producers. However, three companies account for 65 percent of total production. New applications are constantly being spawned, driving an industry annual rate of growth of 15 percent in the last 15 years.

In the specific case of *Kappaphycus alvarezii* farming in Mexico, three companies expressed an interest in purchasing the biomass grown by fishers on a pilot scale, and at least two of them evaluated the cultivated material (CP Kelco and Cargill TS). Agarmex, a Mexican subsidiary of the Spanish transnational Hispanagar, expressed interest in supporting farming initiatives in Yucatan and purchasing the harvest in order to promote development of the activity in the region. However, carrageenan production at the company's Mexican plant was not considered a priority. FMC (based in the United States of America) has mixed attitudes towards sourcing this seaweed from the Atlantic basin because of the poor track record of introduced *K. alvarezii* achieving commercial production levels and the fact that production in the native range (Indo-Pacific) meets FMC's current needs. In addition, as an introduced species, it might create corporate image problems.

Finding investors that are willing to participate in the seaweed industry in Mexico is problematic. More detailed studies on more productive farming techniques are needed. Demonstration projects need to have a clear commercial orientation, investors must be willing to take advantage of the research results, while groups of fishers need to have a desire to develop alternative activities to fishing, overcoming their economic dependence for the provisioning of supplies and the marketing of fishery products.

3. CARRAGEENAN SEAWEED FARMING: ECONOMIC AND SOCIAL PERFORMANCE

The technical and scientific literature contains very few studies regarding the management and economics of tropical macroalgae. A study by Lee and Ang (1991) notes that annual yields of about 45 kg/m^2 may be obtained from natural populations. Productivity comparisons made between different farming methods such as bottom monoline and floating or raft monoline reveal that, while greater biomass is obtained with the latter, the former is more profitable (Samonte, Hurtado-Ponce and Caturao, 1993). Other studies comparing hanging long-line, fixed-off-bottom and a combination of both methods, have demonstrated that the latter generates the highest net revenues and returns on investment for a 60-day growing period (Hurtado *et al*., 2001).

In addition to the species farmed and its growth in terms of environmental variables, any economic analysis of seaweed farm management should take into account social aspects that affect the operation of farms. In this study, an economic analysis was carried out to determine the viability of the off-bottom and floating-raft farming methods, taking into account two seeding sizes (50 and 100 g). The effect of the selling price of dry seaweed on the viability of the production project based on the experience from a previous pilot farm was also examined.

3.1 Farming and post-harvest systems

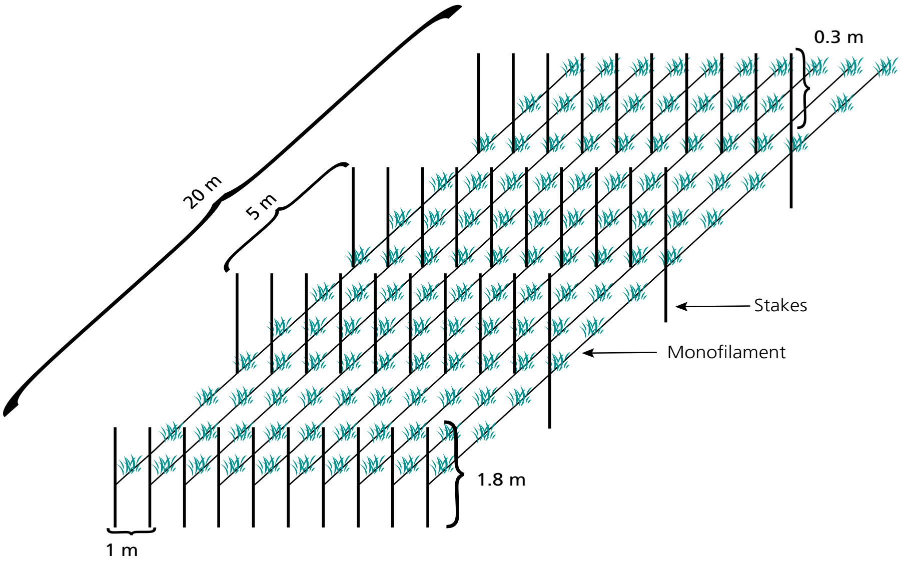
The selected area was Dzilam de Bravo, located at Km 71 on the Progreso-Dzilam de Bravo highway in the state of Yucatan, Mexico. This open-sea site is an area of moderate currents and winds, with little influence from freshwater streams and minimum and maximum depths of 1 m and 2.5 m at low and high tide, respectively. The seabed is solid and sufficiently stable for the installation of stakes. Both the substrate and oceanographic conditions are favourable for cultivating *K. alvarezii* (Muñoz, Freile-Pelegrín and Robledo, 2004).

Off-bottom system

A fixed-off-bottom system was used in Yucatan on the experimental trials and results were extrapolated to an area of 1 ha for the economic analysis (Muñoz, Freile-Pelegrín and Robledo, 2004). The modules consisted of ten 20-m lines placed at 1-m intervals. Stakes made of local hard wood, with a length of 1.8 m, were used to demarcate and hold the ropes. The thalli, with an average initial weight of 50–100 g, were placed 25 cm apart, in order to obtain a density of 80 plants per line. The seeds were fastened to the ropes with plastic raffia ("tie-tie") using the Philippine tying method to ensure their free movement and growth (Figure 4). The entire production area was enclosed by a two-inch (5 cm) mesh netting to reduce the incidence of epiphytism and grazing. The lines are set up during low tides in order to keep them submerged 25–30 cm below the surface.

FIGURE 4

Cultivation of seaweeds using the fixed-off-bottom method

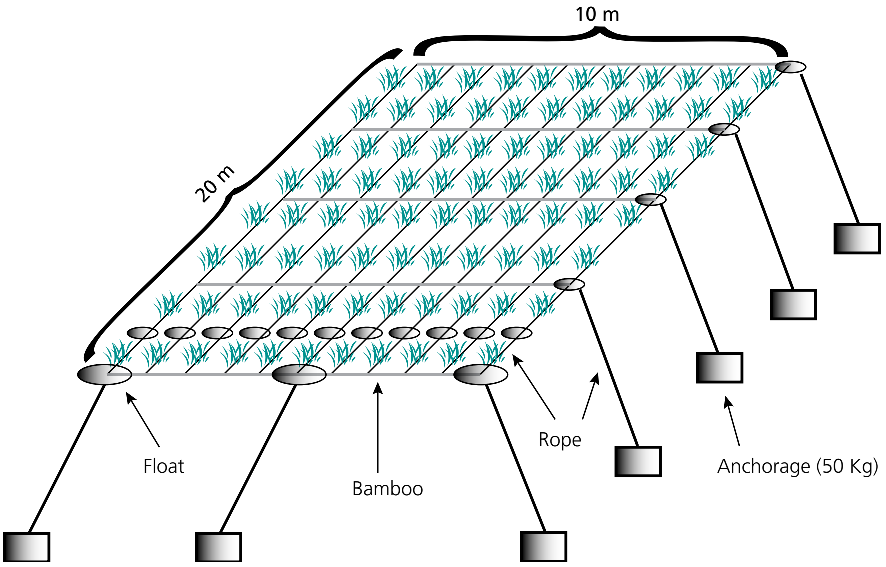


Floating system

The floating type system described by FAO (2005) was also considered for the analysis of a 1-ha farm. The system consists of 10 × 20 m modules, built with bamboo poles (jimbas, which are commonly used in artisanal octopus fishing in the region) that are placed in parallel at intervals of about 5 m and tied together with polypropylene ropes forming a rectangle. The polypropylene ropes are used as cultivation lines, 1 m apart from each other, for a total of 10 lines per module. Two seed sizes (50 and 100 g) were also considered for this system, placed 25 cm apart from each other and with a density of 80 fragments per line. The module was anchored to the sea bed with 50-kg weights, tied with polypropylene ropes at an angle of 45 ° to the water column. The depth of the module is regulated via floatation buoys tied to wooden posts at the edges of the frame. Depending on the biomass growth, additional floatation buoys are added if required (Figure 5). This keeps the cultivation module at a depth of 25–30 cm below the water surface. The boat (without engines) used for seeding, maintenance and harvesting is 4 m long.

FIGURE 5

Cultivation of seaweeds using the floating system



Harvesting and post-harvest treatments

A culture cycle of 60 days was assumed, after which plants generally reach 1 kg of growth or more (fresh weight), although common commercial practice entails only 30 days of cultivation. Stainless knives or penknives are used for harvesting, carefully placing the plants in plastic crates inside the boat. Seaweed is spread to dry across 1 × 5 m^2 wooden benches, on 2-mm-mesh PVC netting, in order to prevent sand and soil contamination. Drying to reduce humidity by 70 percent takes one or two days, and up to three days if sunlight is absent. After drying, the seaweed is packed in jute and/or plastic sacks for transportation in containers to ships that will take the product to processing plants in other countries.

3.2 Economic performance

Capital costs

Estimating according to the market prices prevailing in Yucatan, the total investment cost for the 1-ha off-bottom-system seaweed farm in Mexico is about USD10 459, while 1-ha floating-type system is more costly, about USD13 889 (Table 1).

The farming system, which is composed of stakes, rope, weights, floats, rafts, etc., is the main investment cost, accounting for 73 percent of the total investment for the off-bottom system and 80 percent for the floating system. It costs USD11 106 to build a 1-ha floating system, which is more expensive than the 1-ha off-bottom system (USD7 676). Other capital costs include investments in vehicles (mainly boats), equipment (knifes, plastic crates, scales, etc.) and drying facilities (Table 1).

TABLE 1
Investment requirements for 1-ha seaweed farm in Mexico

Items	Investment cost (USD)[1]	Amortized annual capital cost[2] (USD/year)
Off-bottom system		
Farming system	7 676	1 535
- Stakes	3 985	797
- Monofilament	501	100
- Protective netting	3 191	638
Vehicle, equipment and facilities	2 783	557
- Boat	1 077	215
- Equipment for use on land[3]	1 706	341
Total investment	10 459	2 092
Floating system		
Farming system	11 106	2 221
- Polypropylene rope	1 088	218
- Flotation buoys	3 392	678
- Weights	3 047	609
- Protective netting	3 191	638
- Bamboo (jimbas)	388	78
Vehicle, equipment and facilities	2 783	557
- Boat	1 077	215
- Equipment for use on land[3]	1 706	341
Total investment	13 889	2 778

[1] Converted from Mexican peso; USD1 = MXN13.
[2] Depreciation calculated based on five-year straight-line method.
[3] Including materials used for maintenance, harvesting and drying such as knives, plastic crates, scales and drying facilities.
Note: Numbers may not add up due to rounding.

Variable costs

The optimum temperature for growing *K. alvarezii* ranges from 25 to 30 °C (Ohno, Largo and Ikumoto, 1994). Seaweed farming in the area usually takes place between 15 March to 15 November with four two-month cycles, whereas the winter season is unsuitable for the activity.[2] Table 2 summarizes the technical and economic assumptions on the operation costs of seaweed farming in Mexico.

Both 50-g or 100-g seed can be used; their growth rates are assumed to be 5.6 percent (Muñoz, 2003) and 5.4 percent (Batista 2009) per day, respectively.[3] The unit costs of 50-g and 100-g seeds are MXN1 (USD0.075) and MXN2 (USD0.154) per piece,[4] respectively.

When 50-g seed is used, the labour cost is about MXN25 100 (USD1 931) per cycle, 78 percent of which is used to hire full-time employees to conduct routine maintenance and care, 19 percent for harvesting and drying, and 3 percent for seeding. For 100-g seed, the labour cost is about MXN29 900 (USD2 300) per cycle,

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[2] In winter (December–February), the water temperature in Yucatan falls to 21 °C, the turbidity of the water reduces light penetration, and the currents bring debris to the coastal area. Storms are another factor hindering seaweed farming in this season.

[3] The growth rate of 100-g seed reported for Panama (Batista, 2009) was used as a proxy as the farming environment in Panama is similar to that in Yucatan.

[4] The cost of 50-g and 100-g seeds was calculated on the basis of current costs at the CINVESTAV phycology laboratory.

65 percent for maintenance and care, 32 percent for harvest and drying, and 3 percent for seeding.

The rental cost for an onshore property to accommodate general services (e.g. drying and storage of equipment and materials) during the operation is about MXN42 000 (USD3 231) per year. The marketing cost for packing and shipping the products is about MXN1 787 (USD137) per tonne.

Revenue, cost and profit

Assuming 4 production cycles per year and 22 400 units of seeds per each cycle, then the initial seed biomass would be 4 480 kg per year for 50-g seeds and 8 960 kg for 100-g seeds, which would result in 27 tonnes and 54 tonnes of dried seaweed production per year, respectively.

Assuming a price of USD1 000/tonne (MXN13 000/tonne) of dry seaweed, the revenue, cost and profit situations of different farming systems are analysed and summarized in Table 3.[5] The results indicate that:

- Both the off-bottom system and floating system would generate profits. For the same seed mass, the profit margin of the off-bottom system is higher than that of the floating system. For the same farming system, the profit margin of using 100-g seeds is higher than that of using 50-g seeds.
- The off-bottom system appears to have a higher profit than the floating system. This is because of its relatively low initial capital investment,[6] while other costs are assumed to be the same for the two systems.
- Use of 100-g seeds appears to be more profitable under both systems. This is because growing 100-g seeds would generate almost twice as much biomass as growing 50-g seeds; and the higher revenues would more than compensate for the higher costs in terms of materials, labour and marketing. Indeed, although the biomass produced with 100-g seed is only two-times that of 50-g seeds; the profit is almost 6 times under the off-bottom system and 7 times under the floating system because of economies of scale in labour and capital costs.
- Under the off-bottom system, the internal rates of return (IRRs) are 40 and 189 percent for 50-g and 100-g seeds, respectively. Under the floating system, the IRRs are 25 and 141 percent for 50-g and 100-g seeds, respectively.
- With 50-g seeds, it takes 2.0 years to recover the initial investment in the off-bottom system and 2.7 years for the floating system. With 100-g seeds, the payback periods are 0.5 and 0.7 years for the off-bottom and floating systems, respectively.

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[5] The analysis was carried out using experimental results from the cultivation trials conducted by the CINVESTAV/Merida Unit on the Yucatan coast (Muñoz, 2003; Muñoz, Freile-Pelegrín and Robledo, 2004). The results were extrapolated to commercial scale (FAO, 2005). The analysis of costs and benefits was carried out in accordance with the economic theory of natural resources (Shang, 1990; Romero, 1994) while cost and investment assumptions were based on prices prevailing in the domestic market (Mexico).

The profitability indicators net present value (NPV) and internal rate of return (IRR) were used according to the formula:

$$NPV = \sum_{i=1}^{n} \frac{Cash\ flows_i}{\left(1 + discount\ rate\right)^i} - Initial\ investment$$

where n is the project's life in years. The discount rate was assumed to be 6 percent according to the interest rates paid by the Federal Treasury Certificates (CETES) at 28 days, plus approximately 1.5 points. CETES are negotiable instruments issued and settled by the Government of Mexico on maturity.

[6] The investment costs of the off-bottom cultivation system are 25 percent lower than that of floating rafts, primarily because of the weights and floats required by the latter system (Table 1).

TABLE 2
Technical and economic assumptions on seaweed farming in Mexico

Parameter	Value	Unit of measurement
Technical parameters		
Growth of 50-g seed	5.6 [1]	%/day
Growth of 100-g seed	5.4 [2]	%/day
Crop cycle	60	Days/cycle
Annual cycles	4	Cycles/annum
Initial seeds	22 400	Units/cycle
Loss or mortality	10	%/cycle
Cost		
Material cost		
- 50-g seed	1	MXN/unit
- 100-g seed	2	MXN/unit
Labour cost		
- Seeding	800	MXN/cycle
- Harvesting and drying – 50-g seed	4 800	MXN/cycle
- Harvesting and drying – 100-g seed	9 600	MXN/cycle
- Maintenance and care	19 500	MXN/cycle
Rental of onshore property	42 000	MXN/annum
Price parameters		
Price of dry seaweed	13	MXN/dry kg
Annual discount rate	6	%

Note: MXN13 = USD1.
[1] Muñoz (2003).
[2] Batista (2009).

The profitability analysis in Table 3 is under the assumption of seaweed price at MXN13 000 (USD1 000). However, in reality, prices for cottonii seaweed vary greatly over time, depending on supply and demand conditions, and are highly influenced by the target market (American, European, Asian, etc.) and socio-economic aspects of the countries where it is grown and processed. The price of *K. alvarezii* currently ranges from MXN7 800 to 18 200/dry tonne (USD600–1 400) in European and Asian markets (I. Neish, personal communication).

Break-even prices of *K. alvarezii* are calculated based on the production and costs specified in Table 3, which indicate that seaweed farming would be unprofitable at the lower bound price (USD600) for both systems. However, if 100-g seeds are used, seaweed farming would be profitable under both systems at prices above USD700. The break-even prices for 50-g off-bottom and floating systems are USD886 and USD911, respectively (Table 3).

3.3 Social performance

As mentioned above, experimental seaweed farming has been tried in Dzilam de Bravo, a large fishing community along the Yucatan coast.[7] However, the experimental pilot farm (composed of 33 fishers) was destroyed by Hurricane Isidore six months after its establishment in 2002.

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[7] In outlining the process of experimental seaweed farming, two important phases (occurring in 1988 and 2000–2002) may be identified. Both phases were led by CINVESTAV's Merida Unit, especially the research team of the Department of Applied Phycology and Marine Phycochemistry (Robledo, 1998; 2006).

TABLE 3
Revenue, cost and profit of seaweed farming in Mexico

Revenue, cost and profit (USD/year)	**Off-bottom system (1 ha)**		**Floating system (1 ha)**	
	50 g seed	**100 g seed**	**50 g seed**	**100 g seed**
Initial seed biomass (kg/year)	4 480	8 960	4 480	8 960
Dry seaweed at harvest (tonne/year)	27	54	27	54
Sales revenue (1)	**26 998**	**53 779**	**26 998**	**53 779**
Total cost (2)	**23 921**	**35 972**	**24 607**	**36 658**
- Marketing costs (3)	3 712	7 394	3 712	7 394
- Production cost (4)	20 210	28 579	20 895	29 264
- Material cost (5)	7 164	14 056	7 164	14 056
• Cost of seeds	6 892	13 785	6 892	13 785
• Cost of raffia and strings	271	271	271	271
- Labour cost (6)	7 723	9 200	7 723	9 200
• Seeding	246	246	246	246
• Maintenance and care	6 000	6 000	6 000	6 000
• Harvesting/drying	1 477	2 954	1 477	2 954
- Capital and rental cost (7)	5 323	5 323	6 008	6 008
• Depreciation	2 092	2 092	2 778	2 778
• Property rental	3 231	3 231	3 231	3 231
Cost structure				
Marketing in total cost (%)	16	21	15	20
Production in total cost (%)	84	79	85	80
Material in production cost (%)	35	49	34	48
- Seed in production cost (%)	34	48	33	47
Labour in production cost (%)	38	32	37	31
- Maintenance in production cost (%)	30	21	29	21
Capital & rental in production cost (%)	26	19	29	21
Net profit (8)	**3 077**	**17 806**	**2 391**	**17 120**
Profit margin (%) (9)	11	33	9	32
NPV (5 years; 6% discount rate) (USD)	11 318	73 359	7 884	69 929
IRR (5 years) (%)	40	189	25	141
Payback period (years)	2.0	0.5	2.7	0.7
Break-even price (USD/tonne)	886	669	911	682

Notes: MXN13 = USD1. Price of dry seaweed = USD1 000/tonne. (2) = (3) + (4). (4) = (5) + (6) + (7). (8) = (1) - (2) (9) = (8)/(1)*100. NPV = net present value. IRR = internal rate of return. Numbers may not add up due to rounding.

Lack of substantial development of seaweed farming in Mexico makes it difficult to make a quantitative evaluation of its social performance. Based on the limited experience in Dzilam de Bravo, some insights on the social dimensions of seaweed farming in Mexico are discussed below and summarized in Table 4.

Given fishers' declining revenues and the vulnerability associated with seasonality and weather events along the Yucatan coast and Dzilam de Bravo in particular, a core group of pioneering fishers and farmers is genuinely interested in resuming seaweed farming despite being fully aware of the obstacles to be faced, primarily with regard to organizational and marketplace issues. In addition to the core group, other individuals in the community are also interested in taking up seaweed farming. The pioneer group is also willing to transfer technology expertise to other communities, primarily in San Felipe, a port located 70 km away.

TABLE 4

SWOT analysis for seaweed farming in Dzilam de Bravo, Yucatán, Mexico

Strengths	Weaknesses
• Willingness to put knowledge acquired in farming into practice. • Proud to hear that Dzilam people are the pioneers of seaweed farming in the entire Yucatan peninsula. • Organizational feasibility. • Comprehensive cooperative including 30 people (fishing, handicrafts, tourism, aquaculture) soon to be legally registered. • Positive attitude towards risk. • Previous training in experimental farming. • Access to habitats. • Engagement in economic activities not dependent on the overexploited fishing resource. • Willingness to transfer know-how and experience in seaweed farming technology to other ports. • Social network (inclusion of families and friends) promoted by the new cooperative, which will enable stronger alliances and solidarity. • A new alliance (association) between fishers and tourism providers has emerged.	• Risks associated with climate change (more frequent red tides, hurricanes, murky waters, etc.). • The notion of immediate profit in connection with any complementary or alternative activity to fishing. • The impossibility of "preventing" the effects of "nortes" storms on seaweed farms. • Lack of training in marketing. • Unavailability of information regarding the potential of seaweed farming at a world level. • Move seaweed farming beyond temporary employment programmes (manage it as a business activity rather than a pilot project). • Weariness caused by the excessive number of experimental projects.
Opportunities	**Threats (limitations)**
• The new group wishes to become a comprehensive cooperative. • Federal and state governments have sufficient resources to fund agricultural projects or activities. • Harvest seaweed plots before the "nortes" storm season. • Rely on legal forms of land management (UMAs?) • Job creation. • Access to a biotechnological adviser. • Seaweed farming as an activity complementary to tourism. • May be alternated with fishing. • More organized division of labour. • Community members have the expertise to revive seaweed farming. • The new comprehensive cooperative group is more inclusive because it covers a range of activities, unlike the fishing cooperative.	• The envy of fishers who do not take part in the farming activities. • The arrival of PEMEX, which would displace fishing. • The temporality of the projects (short-term). • Lack of ownership of the farmed land. • Lack of access to technologies that enable conservation and preservation of the harvested product (e.g. protection of crops during the "nortes" storm season). • Fishing is declining.

Seaweed farming has elicited interest from the outset, despite having been introduced as an experimental project. It was taken up as a novelty and put forward by external groups as a viable alternative means of employment. The benefits of accessing new markets through different commercial channels (food, beauty products, pharmaceuticals, etc.) were also emphasized (Novaczek *et al*., 2001). The seaweed farming proposal emerged from the linkage between academia, the government (via the PET programme) and a group from the local fishing cooperative interested in undertaking employment that offered an alternative to the seasonality and the crisis-wracked artisanal fishing sector.

Fishers recognize that there are possibilities "as long as money is still available to fund the plots" (fisher interviewed in February 2010). Working at the family level may prove to be advantageous as alternative arrangements have led to disputes. Leadership is vital in this respect, which should be in the hands of men rather than women (women concurred on this point). The fishers interviewed are aware that the pilot project was more dynamic and successful in biotechnological rather than social and entrepreneurial terms. Therefore, a conclusion is that the pilot project was introduced prematurely without a solid social platform to enable better integration.

The manifest disengagement of the productive sectors and the ways in which government and civil society institutions operate reflect a paternalistic culture for project implementation (L. Durand, personal communication). Regardless of these problems, seaweed farming emerges as a strategic activity for coastal populations whose livelihood strategies have increasingly run into difficulties owing to precarious employment, low prices for fishery products, coastal land speculation, local regulatory measures and marine and fishing legislation in the Gulf of Mexico and the Caribbean Sea.

No activity enables members of the community to generate sufficient income to meet their basic needs completely. The community then resorts to a wide range of alternatives, of which the most important are federal and state government subsidies (temporary employment programmes). An interviewee made this comment: “As there is not much work to do here, the governor brought along a reef project.[8] This was facilitated by a fisher’s son from the port who studies at CINVESTAV, and previously studied in France. But because at CINVESTAV they are not free to do certain things – they wanted to hem him in – he went to the Autonomous University of Yucatan, and together with another scientist set up the reef project. There are also state government projects with SEDUMA which promoted seaweed collection and beach cleaning – a group of women do that. And for one month (15 February to 15 March) fishers receive provisions and 300 pesos a week to compensate for the grouper close season” (fisher and former seaweed farmer, February 2010). According to those interviewed in February 2010, tourism has little positive impact because “...there are no beaches. Tourists only come and have a look at the scenery. So it would be a good idea for women to manufacture and sell seaweed-based products to the tourists. Nevertheless, there are not many of them yet, and the most attractive inlets in Dzilam are a long way from town (an hour in a 24-foot boat).”

Regarding funding, the communities are aware of the scarcity of financial resources. The funding mechanisms provided by government authorities to the community of Dzilam de Bravo in support of the development of its productive activities “are for a very short period and for not much money. Besides, they are allocated only to four or five families and the remaining 3 000 inhabitants are excluded” (fisher and former seaweed farmer, 2010).

Alternatives should also be sought in order to incorporate important sectors of the population within productive activities such as older people and especially women who, while still looking after their families, are interested in self-employment opportunities to supplement household income. It is essential not to lose sight of the fact that these participatory planning processes need to develop gradually.

There is mistrust and a lack of credibility regarding external institutions that promise change through poverty-reduction programmes. Lack of confidence and trust among people was noted.[9]

4. THE WAY FORWARD

The methods currently used to grow *K. alvarezii* and other similar marine algae that contain carrageenan were developed 30 years ago in the south of the Philippines. While they require modest capital investment, they are labour-intensive and have a low level of profitability. Therefore, their use is only attractive in relatively poor areas that lack alternative economic opportunities. In many areas of Latin America, including Mexico, more productive farming techniques are needed. No significant progress has been made in this regard at the time of writing, although implementation of new systems using plastic net tubes to reduce seeding and harvesting times has produced excellent results in Brazil (R. Reis, personal communication) compared with the system

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[8] This reef project proposed the deployment of artificial reef balls along the coast of Dzilam to improve habitat for fisheries recruitment.

[9] A recent assessment undertaken by the Mexican Council for Sustainable Rural Development found that the greatest problem in Dzilam is the lack of organization in the community, which hampers the access to more profitable markets. The assessment pointed out that new leadership that truly represents the interests of the community is required.

using polypropylene ropes. The new system could be implemented especially during Yucatan's poor weather season, from December to March.

Unlike other Latin American countries such as Brazil, to date there have been no official initiatives to promote seaweed farming in Mexico.[10] While initial investment and operating costs are higher for seaweed farming as compared with wild harvests, farming guarantees more stable and better-quality production in the long term.

Companies that buy seaweed constantly complain about unstable production levels and seaweed quality. As with any agricultural activity, selection of strains is perhaps one of the aspects of greatest importance to the industry. Commercially relevant characteristics such as rapid growth, high yield and resistance to adverse conditions need to be investigated continuously. In accordance with the opinion of regional experts, biotechnological development could lead to a significant improvement in aspects such as resistance to epiphytism, increased quality of gels, and availability of improved seed (Baweja *et al*., 2009; Hayashi *et al*., 2010).

Techniques have been successfully tested in the region on different variants suited to various types of environment. However, practical experience on an adequate scale to establish the costs and activities of the operation is also of paramount importance. A promotion programme should ideally include demonstration commercial pilot farms (at least 1 ha) where technical training may be given *in situ*. Moreover, these farms should conduct programmes to develop new techniques that improve technical and engineering aspects (e.g. the testing of new materials or seeding and harvesting machinery) as well as the biological performance of the culture systems (e.g. the testing of new genetically improved strains).

In terms of sociodemographic processes, coastal populations in Mexico remain highly dynamic. Emigration and immigration are part of the labour mobility process in artisanal fishing, which continues to be a livelihood strategy platform for thousands of people in Mexico. In the case of Dzilam de Bravo, diversification of activities is urgently needed because of the highly seasonal nature of the labour market and the frequency of meteorological phenomena such as hurricanes and red tides (harmful algal blooms).[11]

Although the community receives substantial federal and state government subsidies and benefits from Global Environment Facility (GEF) programmes such as the Mesoamerican Biological Corridor, it is crucial to inject more financial resources in Dzilam de Bravo in order to set up farm plots for red seaweed.

However, this injection of funds should be subject to two fundamental conditions. The first is to conduct multidisciplinary studies from an institutional perspective in order to enable discussion among social science specialists, primarily social economists, economic anthropologists and cultural ecologists. The multidisciplinary studies should also establish links between research teams and fishers and fisher farmers from within and beyond the community in order to acquire an in-depth knowledge of the livelihood strategies of coastal populations.[12] Participatory methodologies can be used to increase trust between fishers and researchers in order to pursue common goals,

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[10] In the Latin America and Caribbean region, successful experiments have been carried out in Saint Lucia and Brazil aimed at producing seaweed for human consumption and carrageenan production, respectively.

[11] A focus group In Dzilam de Bravo that might take up seaweed farming consists of lobster divers who have endured episodes of decompression and are still suffering from the after-effects of this illness (mainly joint pains). Of the 60 lobster divers in Dzilam, all except one have suffered from decompression sickness more than four or five times during their working lives (reported by a local fisher, March 2010).

[12] The model suggested by Novaczek et al. (2001) may be used to facilitate the process.

such as the building of local capacities.[13] Funding should also be provided to facilitate dissemination of information. This democratization of information can start in the community of Dzilam de Bravo and embark on the culture of seaweed at a commercial scale in cooperation with groups from other places with similar farming interests.[14]

The second condition is to operate a plot beyond the experimental phase, i.e. test its commercial feasibility with a view to granting access to two identified and potentially successful community groups: fisher farmers with previous experience on working the land (former maize farmers) and traditional fishers (such as the pioneer seaweed farming group during the pilot phase), including young people who are settled in the port and wish to be entrepreneurs and innovators in business activities. In Dzilam de Bravo, there is the opportunity to reintroduce demonstration plots, which, combined with tourism, may generate income for a portion of the local population. As an employment strategy during the low fishing season, community members have also the opportunity to become trainers for other fishing ports. This could reduce tension among fishers from different groups. It is also possible to create a prototype small-family or extended-family company that serves as a business model for other farmers. This could enhance the interest and trust of other local groups. A commercial association between the prototype group and private fishery agents can also be considered, inasmuch as it generates new employment and tourism opportunities.

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[13] For example, multidisciplinary studies can provide useful background information to help NGOs or other institutions to conduct training courses and workshops that are more connected to the goals pursued by institutions.

[14] Apart from the port of San Felipe, at least one other community, the community of Islas Arenas in Campeche, is highly likely to undertake successful projects.

References

Batista, G.E. 2009. *Cultivo ecosostenible de Kappaphycus alvarezii en Panamá*. University of Las Palmas de Gran Canaria, Spain. (PhD thesis).

Baweja, P., Sahoo, D., García-Jiménez, P. & Robaina, R.R. 2009. Seaweed tissue culture as applied to biotechnology: problems, achievements and prospects. *Phycological Research*, 57(1): 45–58.

FAO. 2005–2010. Cultured aquatic species information programme. *Eucheuma* spp. Cultured Aquatic Species Information Programme. Text by G.C. Trono Jr. *In:* FAO Fisheries and Aquaculture Department [online]. Rome. Updated 13 January 2005. [Cited 12 February 2010]. www.fao.org/fishery/culturedspecies/Eucheuma_spp/en.

Fraga, J., Arias, Y. & Angulo, J. 2006. Communities and stakeholders in marine protected areas of Mexico, Dominican Republic and Cuba. *In* Y. Breton, D. Brown, B. Davy, M. Haughton & L. Ovares, eds. *Coastal resource management in the wider Caribbean: resilience, adaptation, and community diversity*, pp. 105–136. Kingston, Ian Randle/ IDRC. 265 pp.

Freile-Pelegrín, Y. & Robledo, D. 1997. Effects of season on the agar content and chemical characteristics of *Gracilaria cornea* from Yucatan, Mexico. *Botanica Marina*, 40: 285–290.

Freile-Pelegrín, Y. & Robledo, D. 2006. Carrageenan of *Eucheuma isiforme* (Solieriaceae, Rhodophyta) from Yucatan, Mexico. II. Seasonal variations in carrageenan and biochemical characteristics. *Botanica Marina,* 49: 72–78.

Godínez-Ortega, J.L., Snoeijs, P., Robledo, D., Freile-Pelegrín, Y. & Pedersen, M. 2008. Growth and pigment composition in the sublittoral red alga *Halymenia floresii* under different light qualities. *Journal of Applied Phycology*, 20(3): 253–260.

Hayashi, L., Hurtado, A.Q., Msuya, F.E., Bleicher-Lhonneur, G. & Critchley, A.T. 2010. A review of *Kappaphycus* farming: prospects and constraints. *In* A. Israel, R. Einav & J. Seckback, eds. *Seaweeds and their role in globally changing environments*, pp. 251–284. London, Springer. 480 pp.

Hurtado, A.Q., Agbayani, R.F., Sanares, R. & de Castro-Mallare, M.T.R. 2001. The seasonality and economic feasibility of cultivating *Kappaphycus alvarezii* in Panagatan Cays, Caluya, Antique, Philippines. *Aquaculture*, 199: 295–310.

INAPESCA 2010. Carta Nacional Pesquera, *Instituto Nacional de Pesca*, Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación, pp. 33-34. Diario Oficial de la Federación, México. 95 pp.

Lee, S.C. & Ang, Jr, P. 1991. A simple model for seaweed growth and optimal harvesting strategy. *Ecological Modelling*, 55: 67–74.

McHugh, D.J. 1996. *Seaweed production and markets*. FAO/GLOBEFISH Research Programme Vol. 48. Rome, FAO. 73 pp.

McHugh, D.J. 2002. *Prospects for seaweed production in developing countries*. FAO Fisheries Technical Circular. No. 968. Rome, FAO. 28 pp.

Muñoz, J. 2003. *Maricultivo del alga roja productora de carragenina Kappaphycus alvarezii (Doty) Doty ex Silva en Dzilam de Bravo, Yucatán*. Autonomous University of Baja California Sur, Mexico. (BSc thesis) (also available at http://biblio.uabcs.mx/tesis/te1405.pdf).

Muñoz, J., Freile-Pelegrín, Y. & Robledo, D. 2004. Mariculture of *Kappaphycus alvarezii* (Rhodophyta, Solieriaceae) color strains in tropical waters of Yucatan, Mexico. *Aquaculture*, 239: 161–177.

Novaczek, I., Harkes, I.H.T., Sopacua, J. & Tatuhey, M.D.D. 2001. An institutional analysis of sasi laut in Maluku, Indonesia. The World Fish Center Working Papers No. 14142. Kuala Lumpur.

Ohno, M., Largo, D.B. & Ikumoto, T. 1994. Growth rate, carrageenan yield and gel properties of culture kappa-carrageenan producing red alga *Kappaphycus alvarezii* (Doty) Doty in the subtropical waters of Shikoku, Japan. *Journal of Applied Phycology*, 6: 1–5.

Orduña-Rojas, J. & Robledo, D. 2002. Studies on the tropical agarophyte *Gracilaria cornea* J. Agardh (Rhodophyta, Gracilariales) from Yucatan, Mexico. II. Biomass assessment and reproductive phenology. *Botanica Marina*, 45: 459–464.

Pérez-Enríquez, R. 1996a. Summer biomass density and weight assessment of the red seaweed *Eucheuma isiforme* (Rhodophyta, Gigartinales) at Dzilam, Yucatan State, Mexico. *Botanica Marina*, 39: 251–253.

Pérez-Enríquez, R. 1996b. Growth of *Eucheuma isiforme* (C. Agardh) J. Agardh on experimental rafts off the coast of Yucatan State, Mexico. *Journal of Applied Phycology*, 8: 27–28.

Robledo, D. 1998. Seaweed resources of Mexico. *In* A.T. Critchley & M. Ohno, eds. *Seaweed resources of the world*, pp. 331–342. Tokyo, Japanese International Cooperation Agency.

Robledo, D. 2006. Seaweed resources of Mexico. *In* A.T. Critchley, M. Ohno & D.B. Largo, eds. *World seaweed resources: an authoritative reference system*. Amsterdam, Netherlands, ETI BioInformatics.

Robledo, D. & Freile-Pelegrín, Y. 1998. Macroflora marina de interés económico de las costas de Yucatán. *In* H. Benítez, E. Vega, A. Peña & S. Ávila, eds. *Aspectos económicos sobre la biodiversidad de México*, pp. 167–179. Mexico, CONABIO – SEMARNAP. 203 pp.

Robledo D. & Freile-Pelegrín, Y. 2011. Managing the interactions between plants and animals in marine multi-trophic aquaculture: integrated shrimp and valuable low food chain organisms with seaweeds. *In* J. Seckbach & Z. Dubinsky, eds. *All flesh is grass: plant-animal interrelationships*, pp. 367–384. London, Springer. 531 pp.

Robledo, D. & Townsend, W. 2006. Seaweeds and mangroves: improving environmental practices in coastal communities of Mexico and Jamaica. *In* Y. Breton, D. Brown, B. Davy, M. Haughton & L. Ovares, eds. *Coastal resource management in the wider Caribbean: resilience, adaptation, and community diversity*, pp. 172–190. Kingston, Ian Randle/IDRC. 265 pp.

Romero, C. 1994. *Economía de los recursos ambientales y naturales*. Madrid, Alianza Editorial. 189 pp.

Samonte G.P.B., Hurtado-Ponce, A.Q. & Caturao, D.R. 1993. Economic analysis of bottom line and raft monoline culture of *Kappaphycus alvarezii* var. *tambalang* in Western Visayas, Philippines. *Aquaculture*, 110: 1–11.

Shang, Y.C. 1990. *Aquaculture economic analysis: an introduction*. Baton Rouge, Louisiana, USA, The World Aquaculture Society. 211 pp.

SIAVI. 2010. *Sistema de información arancelaria vía Internet*. México, Secretaría de Economía, Gobierno de México. (also available at www.economia-snci.gob.mx:8080/siaviWeb/siaviMain.jsp).

Zertuche-González, J.A. 1988. *In situ life history, growth and carrageenan characteristics of Eucheuma uncinatum (Setchell and Gardner) Dawson from the Gulf of California*. Stony Brook, USA, State University of New York. (PhD thesis).

Zertuche-González, J.A., ed. 1993. *Situación actual de la industria de macroalgas productoras de ficocoloides en América Latina y el Caribe*. Programa Cooperativo Gubernamental FAO-Italia GCP/RLA/102/ITA. Proyecto Aquila II, Documento de Campo N° 13. México. (also available at www.fao.org/docrep/field/003/AB483S/AB483S00.htm#TOC).

Zertuche-González, J.A. 1996. Feasibility for establishing a carrageenan industry in Mexico. *Hydrobiologia*, 326/327: 381–386.

Zertuche-González, J.A. & García-Esquivel, J. 1989. *Promoción del cultivo de* Gracilaria *sp*. Proyecto FAO-AQUILA, GCP/RLA/075/ITA. Rome, FAO. 35 pp.

Zertuche-González, J.A., García-Lepe, G., Pacheco-Ruíz, I., Chee, A., Gendrop, V. & Guzmán, J.M. 2001. Open water *Chondrus crispus* Stackhouse cultivation. *Journal of Applied Phycology*, 13: 249-253.

Carrageenan is a gelling agent extracted from red seaweeds and it has multiple applications in the food processing and other industries. Increasing demand for carrageenan has led to rapid expansion of carrageenan seaweed (primarily *Kappaphycus* and *Eucheuma*) farming in tropical areas. This expansion is expected to continue, but many issues need to be addressed to enable the sector to develop its full potential in contributing towards sustainable livelihoods, human development and social well-being. Including six country case studies and a global synthesis, this document provides a comprehensive and balanced assessment of the economic, social and governance dimensions of carrageenan seaweed farming. Information and insights provided by this document should facilitate evidence-based decision-makings in both the public and private sectors.

ISBN 978-92-5-107746-7 ISSN 2070-7010

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I3344E/1/06.13