Current trends and Prospects of Seaweed Farming in India

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Introduction

The Seaweeds are macrophytic algae, a primitive type of plants lacking true roots, stems and leaves. The word seaweed gives the wrong impression that it is a useless plant. Seaweeds are wonder plants of the sea and highly useful plants. Seaweeds grow in the shallow waters. Root system and conducting tissues like land plants are absent in seaweeds. Most of them have hold-fast for attachment and some drift loose in the sea. Four groups of seaweeds are recognized according to their pigments that absorb light of particular wave lengths and give them their colours of green, blue, brown and red. Most seaweed belongs to one of three divisions - the Chlorophyta (green algae), the Phaeophyta (brown algae) and the Rhodophyta (red algae). There are about 900 species of green seaweed, 4000 red species and 1500 brown species found in nature. The greatest variety of red seaweeds is found in subtropical and tropical waters, while brown seaweeds are more common in cooler, temperate waters. Economic importance Some 221 species of seaweed are utilized commercially. Of these, about 145 species are used for food and 110 species for phycocolloid production.

Natural seaweed stocks have become inadequate to meet the industrial requirements and hence cultivation of these important resources has become necessary. Asia stands as the world leader in seaweed cultivation and more than 80% is contributed by China, Korea and Japan. India has not taken up seaweed cultivation interestingly in the past though it is bestowed with a coastline of more than 17,000 km, embracing 821 species of seaweeds. Only recently, seaweed cultivation is picking up in certain coastal districts of the Tamil Nadu state. Central Salt Marine Chemical Research Institute and Central Marine Fisheries Research Institute have developed culture techniques for some of the commercially important seaweed species in India. As a result of this effort, a lot of Self Help Groups, Village Youth Groups and NGOs have come forward to promote seaweed cultivation as an alternate livelihood option for the coastal poor. Considering the great demand for these resources in the international market and availability of adequate manpower and interest in the country, seaweed cultivation has a very good prospect and it can be developed as a successful cottage or co-operative sector industry.

Uses of seaweeds

Seaweeds new renewable source of food, energy, chemicals and medicines. Provides valuable source of raw material for industries like health food, medicines, pharmaceuticals, textiles, fertilizers, animal feed etc.

Seaweeds used for production of Agar, Alginates & Carrageenan. Chemicals from brown seaweeds such as alginic acid, mannitol, laminarin, fucoidin and iodine have been extracted successfully on a commercial basis. As the alginates can absorb many times their own weight of water, have a wide range of viscosity, can readily form gels and are non-toxic, they have countless uses in the manufacture of pharmaceuticals, cosmetic creams, paper and cardboard, and processed foods. Agar-agar, agarose and carrageenan are commercially valuable substances extracted from red seaweeds and find extensive use in many industries. The greatest use of agar is in association with food preparation and in the pharmaceutical industry as a laxative or as an outer cover of capsules. With the advent of modern molecular biology and genetic engineering, agar gums producing an 'agarose' factor are used extensively in electrophoresis in most laboratories around the world. Carrageenans are generally employed for their physical functions in gelation (include for example, foods such as ice cream), viscous behavior and stabilization.

Seaweedshave been a staple food in Japan and China for a very long time. The green seaweeds *Enteromorpha, Ulva, Caulerpa* and *Codium* are utilized exclusively as source of food. These are often eaten as fresh salads or cooked as vegetables along with rice. *Porphyra* (Nori), *Laminaria* (Kombu) and *Undaria* (Wakame) are used for making fish and meat dishes as well as soups and accompaniments.

Seaweeds were rich in minerals, vitamins, trace elements and bioactive substances, seaweeds are called medical food of the 21st century. *Digenea* sp. (Rhodophyta) produces an effective vermifuge (kainic acid). *Laminaria* sp. and *Sargassum* species have been used in China for the treatment of cancer. Anti-viral compounds from *Undaria* sp. have been found to inhibit the Herpes simplex virus, which are now sold in capsule form. Research is now being carried out into using *Undaria* sp. extract to treat breast cancer and HIV. Another red alga *Ptilota* sp. produces a protein (a lectin) that preferentially agglutinates human B-type erythrocytes in vitro. Some calcareous species of *Corallina* sp. have been used in bone-replacement therapy. *Asparagopsis taxiformes* and *Sarconema*sp. are used to control and cure goiter while heparin, a seaweed extract, is used in cardiovascular surgery. Currently there are 42 countries in the world with reports of commercial seaweed activity. China holds first rank in seaweed production, with *Laminaria* sp. accounting for most of its production, followed by North Korea, South Korea, Japan, Philippines, Chile, Norway, Indonesia, USA and India. These top ten countries contribute about 95% of the world's commercial seaweed volume. About 90% seaweed production comes from culture based practices.

Seaweed resources in India

Seaweeds grow abundantly along the Tamil Nadu and Gujarat coasts and around Lakshadweep and Andaman and Nicobar islands. There are also rich seaweed beds around Mumbai, Ratnagiri, Goa, Karwar, Varkala, Vizhinjam and Pulicat inTamil Nadu and Chilka in Orissa. Out of approximately 700 species of marine algae found in both inter-tidal and deep water regions of the Indian coast, nearly 60 species are commercially important. Agar yielding red seaweeds such as *Gelidiella acerosa* and *Gracilaria* sp. are collected throughout the year while algin yielding brown algae such as *Sargassum* and *Turbinaria* are collected seasonally from August to January on Southern coast. The surveys carried out by Central Salt and Marine and Chemical Research Institute (CSMCRI), Central Marine Fisheries Research Institute (CMFRI) and other research organizations have revealed vast seaweed resources along the coastal belts of South India. On the West Coast, especially in the state of Gujarat, abundant seaweed resources are present on the intertidal and sub tidal regions. These resources have great potential for the development of seaweed-based industries in India. Seaweed industry in India The seaweed industry in India is mainly a cottage industry and is based only on the natural stock of agar-yielding red seaweeds, such as *Gelidiella acerosa* and *Gracilaria edulis*, and algin yielding brown seaweeds species such as *Sargassum* and *Tubineria*.

Why Seaweed Farming

Remedy for non-availability of required quantity of seaweeds for various uses.

Provide occupation for the coastal people.

Provide continues supply of raw material for seaweed based industry.

Provide seaweeds of uniform quality for use in industry.

Conserve natural populations of concerned seaweeds.

Seaweed farming is aecofriendly activity.

Major tool to treat coastal pollution in the sea and reduce CO_2 in global warming.

Methods of Seaweed Farming

1. Single Rope Floating Raft method (Coir Rope & Nylon Rope).

2. Fixed Bottom long line method (Coir Rope & Nylon Rope).

3.Integrated Multi Trophic Aquaculture (IMTA) method.

Seaweed Farming in India

Central Salt and Marine Chemical Reseach Institute (CSMCRI) Marine Algal Research Station (MARS), Mandapam, Tamil Nadu a CSIR Institute developed viable and commercially sustainable methods for cultivating *Gracilaria edulis* and *Gelidiella acerosa* the two seaweed species, widely used in food and pharmaceutical industries and commanded good demand in the market. Method of cultivating Geildiella acersoa in open sea using suspended stones to enhance yield and help the growers get better returns.

Rope with seaweed fragments Anchor cable Synthetic floats Main rope Stone Single Rope Floating Raft culture technique The main culture methods involve either vegetative propagation using fragments from mother plants or by different kinds of spores such as zoospores, monospores, tetraspores and carpospores.

Single Rope Floating Raft (SRFR) method developed by CSMCRI is suitable for culturing seaweeds in wide area and greater depth. A long polypropylene rope of 10 mm diameter is attached to 2 wooden stakes with 2 synthetic fiber anchor cables and kept afloat with synthetic floats. The length of the cable is twice the depth of the sea (3 to 4 m). Each raft is kept afloat by means of 25-30 floats. The cultivation rope (1 m long x 6 m diameter polypropylene) is hung with the floating rope. A stone is attached to the lower end of the cultivation rope to keep it in a vertical position. Generally 10 fragments of *Gracilaria edulis* are inserted on each rope. The distance between two rafts is kept at 2 m. Floating raft technology has been recommended to be used on the Kerala coast for agarophyte cultivation . Certain areas in the Gulf of Kutch have been suggested as suitable for deep-water seaweed cultivation . In addition, CMFRI has developed and perfected techniques for culturing *Gelidiella acerosa, Gracilaria edulis, Hypneamus ciformis* and *Acanthophora spicifera*, and now attempts are being made to find improved techniques for propagation and large scale culture of other economically important seaweeds. Problems and Prospects The major problems in the seaweed industry include overexploitation leading to a scarcity of raw material, poor quality raw material, labor shortages during the paddy harvesting and transplanting season, lack of technology to improve processed product quality, and a lack of information on new and alternative sources of raw materials. Despite the great number of sheltered bays and lagoons suitable for mariculture, no large-scale attempts to grow seaweed have been made in India so far. Efforts are needed to increase production through improving harvesting techniques, removal of competing species, creation of artificial habitats and seeding of cleared areas. As the technology for reliable methods for the cultivation of different commercially important seed stocks and their improvement has either already been developed or presently being in research, it needs to be disseminated effectively to the target community. Extensive surveys need to be conducted to identify suitable sites for large-scale seaweed culture. There is great potential for the agarophyte cultivation because of its low availability from the wild stock due to over-exploitation. Many edible seaweed species are available on the Indian coast; attempts should be made to develop products suitable for the Indian palate and to popularize the same amongst the public. With regard to pharmaceutical substances, heparin analogues (heparinoids) that are inhibitory to thrombin activities have been reported from Chlorophyta of Indian coasts ; this and many other important types of seaweed are available on Indian coast that can be utilized for production of many important pharmaceutical products through extraction of bioactive compounds. Attention should also be given towards developing hybrid species with superior growth and nutritional characteristics, as the same has been proved successful in countries like Japan. Rather opting for high-volume low-value seaweeds, culture of high value seaweeds should be aimed for, as part of integrated coastal and national development programmes10. Seaweed polyculture in association with molluscs and fishes seems to have good prospects to increase harvest and profits. Pond and canal culture of seaweeds (e.g. *Gracilaria*) in shrimp farming areas can help to treat the effluent water. The problem of eutrophication of culture ponds due to overfeeding and excreta released by fish/shrimp can be tackled by culturing seaweeds in such ponds. Out of estimated around US $ 3 billion global phycocolloid and biochemical business, India's share is meager. We can surely grab a bigger part in this lucrative business with sincere efforts towards large-scale cultivation of commercially important species and processing. To facilitate this, more technologically sophisticated extraction plants with easy access to markets and marketing.

The first large scale commercial cultivation of seaweeds in India has been embarked upon by Pepsi Foods Ltd. (PFL) along a 10 km stretch of the Palk Bay side towards Mandapam (Ramanathapuram Dist.) in Tamil Nadu, with technical support from MarineAlgal Research Center, CSMCRI, Mandapam. They have started cultivating *Kappaphycus alvarezii* – exotic species in an area of 100 hectares through a contract farming system in which seaweeds are grown in individual plots of 0.25 ha (40 m x 60 m). Each harvest cycle from planting to harvesting takes 45 days with an annual yield of 100 tons (wet weight) per hectare, which translates into 10 tons of dry seaweed or 2.5-3 tons of carrageenan. The company has plans to expand culture operations to over 5,000 to 10,000 ha in the near future. Furthermore, many agar and algin extracting industries have been established in different places in maritime states of Tamil Nadu, Andhra Pradesh, Kerala, Karnataka and Gujarat the seaweed industry is certainly on its way towards establishing itself well in India. Large-scale Seaweed Mariculture is carried out only in Asia, where there is a high demand for seaweed products and burgeoning populations to create market growth. Cultivation of seaweeds in Asia is a relatively low-technology business in that the whole, attached plants are placed in the sea and there is a high labor content in the operation. The demand from the phycocolloid industry of India is great but the present production from natural habitats is very low and insufficient to cater to the needs of the local industry. This gap between the demand and supply can be bridged through mariculture practices for seaweeds by cultivating the useful species on commercial scale.

Continuous supply, improved yield and quality as well as conservation of natural seaweeds beds are some of the important advantages of seaweed mariculture.

Lakshadweep:

Gracilaria edulis, A Seventeen – fold increase in yield was obtained for Agar yielding species in 76 days in the first harvest at Minicoy Lagoon, Minicoy Island, U. T. of Lakshadweep, India during south west monsoon season by adopting single bottom coir rope method.

Hypnea valentiae, A Twenty five – fold increase in yield was obtained for Carrageen yielding species in 40 days in the second harvest at Minicoy Lagoon, Minicoy Island, U. T. of Lakshadweep during south west monsoon season by adopting single bottom coir rope method.

Acanthophora spicifera, A Thirty six – fold- increase in yield was obtained for Carrageenan yielding species in 42 days in the second harvest at Minicoy Lagoon, Minicoy Island, U. T. of Lakshadweep.

During the southwest monsoon season the lagoon water Cost effective ecofriendly seaweed culture technology developed for economically important seaweeds such as *Gracilaria edulis*, *Acanthophora spicifera*, and *Hypnea valentiae*are suitable species for farming at Minicoy Lagoon at U. T. of Lakshadweep The best method for culture is Single bottom coir rope method and single bottom nylon rope method during the southwest monsoon season at Islands of U.T. of Lakshadweep. This cost effective seaweed farming technology can be practiced by fisherman of Lakshadweep to generate income during lean fishing season of southwest monsoon (May to September) become enriched with nutrients, which help to get good growth of seaweeds.

Kerala:

A record growth of 34.42 fold increase in yield was obtained in 86 days and 30 fold increase in yield in 63 days during post monsoon period was obtained for *Kappaphycus alverizii* by adopting suspended nylon hook method at Thikkodi near Calicut, Kerala.

A maximum of 20.1 fold increase in yield in 80 days and a minimum of 13.2 fold increase in yield in 40 days was obtained for the carrageenan yielding red seaweed *Kappaphycus alverazii* by adopting raft culture method which was carried out as demonstration along with green mussels (*Pernaviridis*) – integrated farming - at Vadakkekad, Padane, Kasaragod District, Kerala.

Gujarat:

Farming of *Hypneamus ciformis* was carried out during post monsoon period using raft culture method at Chorward near Veraval. A fivefold increase in yield was obtained during August to September period in 62 days. During November and December an eight fold increase in yield was obtained in 61 days.

Seaweed culture was integrated with Sea Cage culture. *Kappaphycus alvarezii* was farmed in bags and raft with Sea Cage and the growth was found promising. A maximum of 9 fold increase in weight was obtained by adopting bag culture method in 55 days (January and February) and 11 fold increase in weight by adopting raft method in 64 days (February and March) for *Kappaphycus alvarezii* farming.

***Gracilaria* Farming**

Gracilaria spp. can be cultivated using vegetative fragments. Vegetative fragment culture of *Gracilaria* easy practice and it can be carried out throughout the year. Vegetative fragments of the plants are divided into 5 cm and these are introduced between the twists of the rope at 10 cm intervals. Fixed off bottom long line or floating raft methods can be selected. In the fixed off bottom long line method seaweed inserted ropes were tied to the posts planted in the sandy and muddy bottom of the intertidal regions. The position of the ropes is adjusted to remain at a constant depth in the tidal zone. In the raft method vegetative fragments inserted ropes were tied to the floating raft. First harvest can be made in three months and subsequent harvest in one and months. After harvest it may be dried in beaches itself for a week and kept in bales ready for shipping.

*Kappaphycusalvarezii*Farming

The farming of the seaweed *Kappaphycus alvarezii* can be a low-cost venture and a profitable one, with the right site. The technology can use family labor in either fixed off-bottom or single raft long-line culture. The more line modules, the more investment and care are needed. After tying seaweed plantlets or "seedlings" to the ropes, and the ropes staked to the sea bed by bamboo or tied to floating rafts staked to the sea bed, seaweed farming needs no more inputs. Weekly visit to the farming site to remove undesirable algae, barnacles, and attached sediments; to re-tie loose or fallen seaweed; to tighten lines; and to check for signs of "ice-ice" disease.

Kappaphycus farming - Technology profile

(1) Get and select good quality seedlings; these are brittle, shiny and young branches with sharp pointed tips, no traces of grazing or whitened thallus (sign of beginning "ice-ice" disease), and 100-150 grams. (2) For fixed off-bottom culture While on land, tie seaweed seedlings 15-20 cm apart to the cultivation rope 10-20 m long with soft plastic string (commonly called "tie-tie"). Carry the ropes to the site at the lowest tide and tie both ends to stakes already placed 1-meter apart on the seabed. For single raft long-line method, tied seedlings as above but anchor ropes to a bamboo raft. A raft unit consists of four bamboos in a square arrangement as support with two ends tied in turn to anchor lines which are staked to the seabed. A longer raft long-line (50-70 m long) can be made floats are regularly spaced in this instance to add buoyancy to the raft.In deeper waters (5-10 m), the hanging long-line may be best; less bamboo support is used but a good concrete block anchor is necessary.(3) Visit the farm two to three times a week. Remove undesirable algae, barnacles, or attached sediments. Re-tie loose or fallen seaweed. Check and tighten loose rope or stake. Check for signs of diseases; totally harvest crops immediately if present. Use new set of seedlings, change farming site / method, and use lower stocking density.(4) Harvest in 45-60 days. Seaweed can be sold wet or dry to processors. Dried seaweed brings more income if it is clean and with moisture content of 35-39%. It is best to keep harvested seaweeds off the ground (remember that the carrageenan is bound for products for human consumption). Use a layer of mat, fish net, or coconut leaves and constantly turn seaweeds to accelerate drying; or dry seaweeds in a platform or hangings lines. Sun-dry for 2-3 days. (5) Tie the seaweed in bales, then store in a clean, cool, dry and well-ventilated place while awaiting buyers.

Why *Kappaphycus alvarezii* farming

- High return on investment
- Demand for seaweeds is high in the local and international markets
- Culture period could be as short as 45 days under optimal conditions
- Environment-friendly method

- Could be a source of supplemental income for small fisherfolk associations and people's cooperatives
- The farming of *Kappaphycus* can be a low-cost venture and a profitable one

Conclusion

In India, Mariculture is a sunrise enterprise. Technologies that have attracted the imagination of coastal stakeholders include mussel farming, seaweed farming and sea cage culture. Mussel (*Perna viridis*) farming technology has diffused along the Malabar coast (southwest India), and seaweed (*Kappaphycus alverezii*) farming prevails along the Coromandel coast (southeast India), after it found a niche in the Gulf of Mannar. Having proven their potential as empowerment platforms for coastal women, the theatres where these technologies were adopted raised a number of issues in the realm of a gendered political ecology. The aim of this paper is not only to diagnose these issues but juxtapose them with some of the epistemological concerns being brought by "gender lens" scholarship, especially in the neo-liberal context of global fisheries. A paradox brought out by the present study is the ambivalence of the State in manifesting itself as a positive "bargaining" force in the intra-household domestic space (by providing State-sponsored platforms through the Self Help Groups) while leaving the "common access resource" space, from which these platforms gain sustenance, less amenable to its democratic ideals.

Seaweed farming based primarily on the culture of *Kappaphycus* species has grown significantly in the Philippines and Indonesia over the last two decades, with growth also taking place at a smaller scale in India and a few other developing countries. Unlike other forms of aquaculture, seaweed farming foregoes the use of feed and fertilizers and has minimum technological and capital requirements. In addition, grow out cycles are short, normally lasting less than two months. Given these unique characteristics, seaweed farming has generated substantial socio-economic benefits to marginalized coastal communities in developing countries, most of which have reduced access to alternative economic activities. In some communities, seaweed farming has emerged as the most relevant livelihood strategy. Given the rising global demand for seaweed-derived products, seaweed farming has the potential to generate further socio-economic benefits to coastal communities in tropical regions.