ISSN No:-2456-2165

Baseline Survey Report on Seaweed Cultivation, Processing, and Marketing for Employment Generation in Bangladesh's Coastal Poor Communities

Aysha Akhtar[1], Md. Suzan Khan[2*], Mohammad Hasan[3],
A.M. Farhaduzzaman[4], Mahadi Hasan Osman[5], Md. Neamul Hasan Shovon[6]

[1]Associate Professor; Institute of Marine Sciences, University of Chittagong, Bangladesh.
[2]Assistant Manager (Fisheries); Integrated Agricultural Unit, Palli Karma-Sahayak Foundation (PKSF), Bangladesh.
* Corresponding author
[3]Fisheries Officer; Integrated Development Foundation (IDF), Bangladesh
[4]Manager (Program); Integrated Agricultural Unit, Palli Karma-Sahayak Foundation (PKSF), Bangladesh,
[5]Assistant Manager (Fisheries); Integrated Agricultural Unit, Palli Karma-Sahayak Foundation (PKSF), Bangladesh.
[6]Assistant Manager (Fisheries); Integrated Agricultural Unit, Palli Karma-Sahayak Foundation (PKSF), Bangladesh.

Abstract:- Seaweed is a group of marine plants with a growing potential for economic growth in the world's coastal states. Recently, Bangladesh has also been making strides toward social and economic benefits and a healthy environment, which will help the blue economy advance. As raw materials for bio-chemicals (agar, agarose, algin, and carrageenan), dyes, food, feed, enzymes, drugs, hormones, etc., this marine biota has grown its reputation among coastal communities and businesses. This subsector provides a means of subsistence and income and creates job opportunities. However, quality and safety concerns are currently among the most significant concerns. This study sought to identify the opportunities and constraints for practical seaweed farming and the establishment of a seaweed economy in Cox's Bazar regarding cost-effectiveness and producers' and traders' willingness to pay. The study site has the potential for establishing practical seaweed farming and marketing, provided that government policies and sector control are maintained. Before such establishment, the relevant authorities' official demarcation or zoning of seaweed farming sites (e.g., BARI, BFRI, DoF, BORI) is essential in terms of legal constraints and compliances. In addition, coordination among developing organizations must be ensured to reduce redundancy. Utilizing a scientific method to process seaweed is essential for maintaining the quality standard of the seaweed. Also, the right training and technical support should be kept up so that patients have access to better technologies, more research, and effective treatments.

Keywords:- *Seaweed, Coastal Communities, Cox's Bazar, Bangladesh.*

Abbreviations and Acronyms:
BARI: Bangladesh Agriculture Research Institute
BFRI: Bangladesh Fisheries Research Institute
DoF: Department of Fisheries
BORI: Bangladesh Oceanographic Researh Institute
NGOs: Non-Government Organizations
BARC: Bangladesh Agricultural Research Council
IDF: Integrated Development Foundation
RIC: Resource Integration center

I. INTRODUCTION

Seaweeds are non-flowering, non-photosynthetic marine plants that have been historically harvested globally through wild collection and aquaculture. Approximately 33 genera of primarily red and brown seaweeds are harvested and farmed commercially (McHugh, 2003). Due to its nutritional value or flavoring, the majority of seaweed production is consumed directly by humans in the form of sushi, salads, soups, desserts, and condiments (Klnc *et al*., 2013). The remainder of the seaweed harvest is utilized in the cosmetic, medical, and food industries, in addition to fertilizers, animal feed additives, water purifiers, probiotics in aquaculture, and biotechnology applications.

Seaweed is rich in essential nutrients, particularly trace elements, and other bioactive compounds. The high-quality seaweed protein contains all essential and non-essential amino acids. Unsaturated lipids in minute amounts provide protection against cardiovascular pathologies. Beta-carotene, the precursor of vitamin A, and the vitamins of the B group, including B12, C, D, E, and K, are abundant in seaweed. The extremely high levels of enzyme activity in seaweed aid in the assimilation of these vital elements.

As a source of income, seaweed cultivation has gained popularity among coastal communities. Ecological suitability is crucial to cultivation (Agyarko, 2017). Typically, seaweed is cultivated in shallow intertidal areas where water flushes are utilized frequently for optimal growth. In comparison to

other forms of aquaculture, seaweed farming requires minimal amounts of feed and fertilizer, as well as minimal technological and financial support. In addition, growth cycles in this culture are typically less than sixty days long. Due to these exceptional qualities, seaweed farming has generated significant socioeconomic benefits for marginalized coastal communities in developing nations. In some communities, seaweed farming has become the only viable means of subsistence (Valderrama, 2012).

About 710 kilometers of Bangladeshi coastline face the Bay of Bengal in the south. In recent years, approximately 200 species of red, green, and brown algae have been recorded in the coastal and estuarine areas of Bangladesh (Aziz *et al*., 2015). Bangladesh, particularly in the last two decades, has witnessed the emergence of a number of initiatives aimed at promoting the socioeconomic development of marginalized coastal communities (Zafar, 2007; Islam *et al*., 2017). However, there are significant knowledge gaps and insufficient documentation of sociocultural dimensions, economic opportunities, sustainability, potential risks and challenges, as well as future changes in the resilience and way of life of the coastal people in relation to seaweed production (Krishnan & Kumar, 2010).

This study was conducted in Cox's Bazar in order to assess the socioeconomic and historical context of the seaweed farmers, identify the potential seaweed species and culture area, evaluate the current status of seaweed processing and market value, identify the risk factors and mitigation measures, and evaluate intervention ideas for practical seaweed farming and marketing. It was determined that the project's intended beneficiaries are low-income households, including women and unemployed youth, as well as fishermen who are primarily dependent on fisheries. Seaweeds generate new optimism for the blue economy's growth curve. Moreover, climatic stressors pose a danger to the communities. In this regard, ensuring seamless seaweed production throughout the value chain would be the optimal scenario for seaweed farmers' economic return and sustainable livelihood. Both export and domestic markets demand an alternative method of seaweed cultivation. Considering the rising volume of seaweed production and the local communities' reliance on it for their livelihoods, it can provide a platform for the private sector and microentrepreneurs to invest and improve the economy in various ways.

II. METHODS OF THE STUDY

A. *Study sites*

The study was conducted at 4 locations in the coastal Cox's Bazar district of Bangladesh (Fig.1).

Table 1: Geographic Distribution of the Study

District	Farming Location	Types of Seaweed culture
Cox's Bazar	Nazira Tek, near Cox’s Bazar town, by the river Bakkhali	Project-based cultivation
	Nuniarchara in Cox’s Bazar town near fishery Ghat	Project-based cultivation
	Reju Khal	Small commercial, Project-based
	Shah Parir Dwip,Teknaf	Small commercial, Project-based

B. *Data collection*

To collect data, respondents from various segments of the seaweed value chain were chosen. In this study, fifty producers were directly interviewed between February and March of 2021. In addition, traders, processors, entrepreneurs, academics, researchers, and government officials with an interest in this subsector were consulted to gain a comprehensive understanding of the industry. In order to conduct the study, a comprehensive literature review was conducted, and the research team conducted regular participant observations at farming sites and associated markets. Producer-level interviews, interviews with key informants, and focus groups were some of the tools used to identify existing and potential seaweed trade and value chains that have the potential to deliver the expected results of the project.

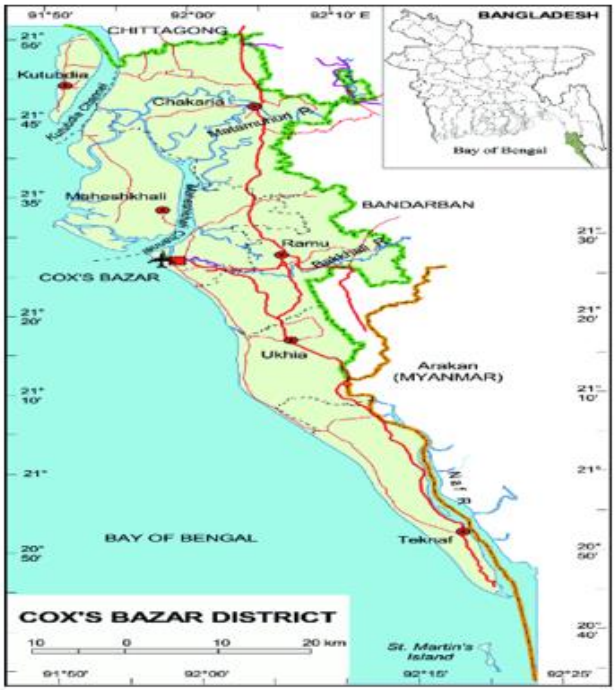

Fig. 1. Map of Cox’s Bazar district, Bangladesh

C. Data processing and analysis

Microsoft Excel (version 2019) was used to graphically present all gathered information after it was totaled, reviewed, and analyzed thoroughly.

III. LITERATURE REVIEW

Along the south-eastern coast of Bangladesh, particularly near St. Martin's Island, a natural abundance of seaweed has been observed. Sarkar *et al.,* (2016) examined the status and utilization of Bangladesh's naturally occurring seaweed flora. In the coastal region of Bangladesh, this study identified 193 species of seaweed, including 19 economically significant species, belonging to 94 genera. Aziz *et al.,* (2015) examined the sub-littoral seaweed flora collected from 0.5 to 10 m depth at six locations around St. Martin's Island in Bangladesh. They discovered 39 seaweed taxa, including some new records: 12 under the *Rhodophyceae*, 11 under the Chlorophyceae, and 16 under the *Phaeophyceae*. Hoq and Islam (2016) investigated the physicochemical parameters of seaweed culture sites and the viability of seaweed culture (*Hypnea sp.*) in Bakkhali and Inani on the coast of Cox's Bazar, Bangladesh. They discovered that the locations were suitable for seaweed cultivation.

In many coastal regions, seaweed cultivation is regarded as an economically viable means of subsistence. To comprehend the appropriate potential of this expanding industry and to promote the socioeconomic development of marginalized coastal communities, it is essential to comprehend sociocultural dimensions and economic opportunities, as well as future changes in the resilience and means of subsistence of the coastal population in relation to seaweed farming. Namudu and Pickering (2006) identified socioeconomic factors that can be used as predictors of project impact by employing the results of social survey techniques, particularly for Pacific island communities, to support decisions regarding a community's suitability for seaweed farming. Narayanakumar and Krishnan (2013) evaluated the socioeconomic status of seaweed farmers in Tamil Nadu, India, where significant structural changes have occurred in the socioeconomic status of many fishermen who have taken up seaweed farming in the past decade. Krishnan and Kumar (2010) investigated the socioeconomic aspects of seaweed farming in India, focusing on industry-institutional ties and the expansion of community participation in seaweed cultivation and trade. In Tanzania, Msuya *et al.,* (2007) conducted a comparative economic analysis of the traditional peg and line off-bottom method and the deep-water floating line method for seaweed farming. Crawford and Shalli (2007) investigated the farming practices of two distinct types of seaweed, 'cottonni' and'spinosum' – in order to promote the expansion of the seaweed sector – as well as the relative advantages and disadvantages of the two types of farmed seaweed in Tanzania. Bindu (2010) assessed the level of empowerment of coastal communities in the cultivation and processing of *Kappaphycus alvarezii* in Kerala, India, via a project-oriented capacity development initiative, and correlated the results and outcomes of the scientific data to the development and welfare of the regional community's grass-roots level.

The global seaweed industry provides a variety of products with direct or indirect human applications. Klnc et al. (2013) compiled a global review of the historical context of seaweed use, significant sources, the nutritional value of seaweeds, and their diverse industrial applications. Siddiqui *et al.,* (2019) examined the cultivation of commercially significant seaweeds and its potential for Cox's Bazar, Bangladesh's coastal areas.

Rebours *et al.,* (2014) observed distinct seaweed harvesting circumstances in European, Canadian, and Latin American nations. They examined the requirements of long-term and ecosystem-based management plans for the sustainable use of their natural seaweed resources, with an emphasis on integrated and participative governance regimes. Kambey *et al.,* (2020) conducted a systematic analysis of policy frameworks, including legislation, regulatory tools, and national standards, in order to assess the current capacity for biosecurity in seaweed aquaculture in Indonesia and identify significant challenges facing the industry in order to implement biosecurity policies in practice for improving the health and sustainability of the seaweed culture sector. Alema *et al.,* (2019) described the current status and future prospects of the seaweed aquaculture industry in Latin America, including a discussion of regulations in the primary countries of the region and potential strategies to encourage new strains and culture methodologies, species diversification, market expansion, and domestic demand growth. Zulham *et al.,* (2018) provided information about seaweed cultivation in Nunukan, Indonesia, for the purpose of enhancing the management and sustainability planning of the seaweed business. They suggested that the local government develop seaweed cultivation zoning in order to avoid conflict over sea area utilization, improve marine water quality, and ensure the viability of seaweed investment and business.

Campbell *et al.,* (2019) identified the current knowledge gaps associated with a developing seaweed aquaculture industry and outlined research priorities to address these gaps. Grebe *et al.,* (2019) discussed the environmental and social impacts of kelp farming in various temperate coastlines by recommending defining ecosystem and management boundaries, evaluating ecosystem services and environmental carrying capacity, implementing socially justifiable eco-engineering, and protecting the health and genetic diversity of wild kelp beds. Eggertsen and Halling (2020) examined the potential direct and indirect negative effects of seaweed farming. They provided a summary of the current scientific knowledge regarding the negative environmental effects of Eucheumatoid seaweed farming, such as changes to benthic macrophyte habitats and the loss of native biodiversity in the Western Indian Ocean region.

IV. RESULTS AND DISCUSSION

Specific observations and discussions on various socioeconomic factors related to seaweed farming in the coastal vicinity of Cox's Bazar were produced by this study. The purpose of the following findings summary is to bring together strategic ideas and provide consistent institutional and financial support for the interventions required to

improve the lives of seaweed farmers and contribute to the expansion of Bangladesh's blue economy.

➢ *Demographics of the Seaweed Farmers*

Seaweed farmers ranged in age from 24 to 60 years old. The respondents' average age was determined to be 38 years old. The majority of respondents (46%) were between the ages of 30 and 39. Nearly three-quarters of the respondents (74%) were female, while only 26% of the interviewed seaweed farmers were male.

44% of respondents represented self-headed households (male 61% and female 39%), while the remainder (all females) reported that their respective husbands (52%) and sons (4%) are household heads. The average number of people per household remained at 6.05, with a maximum of 12 and a minimum of 3.

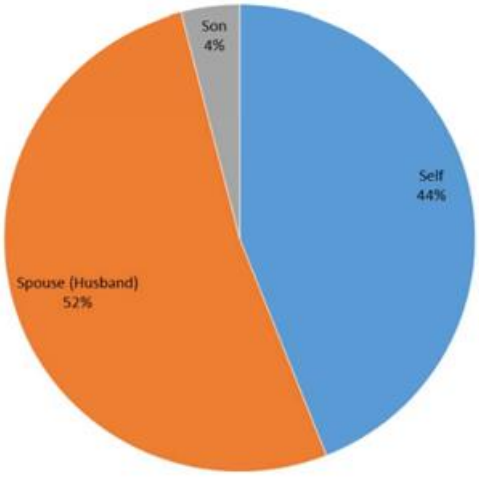

Fig. 2. Heads of Households by percentage

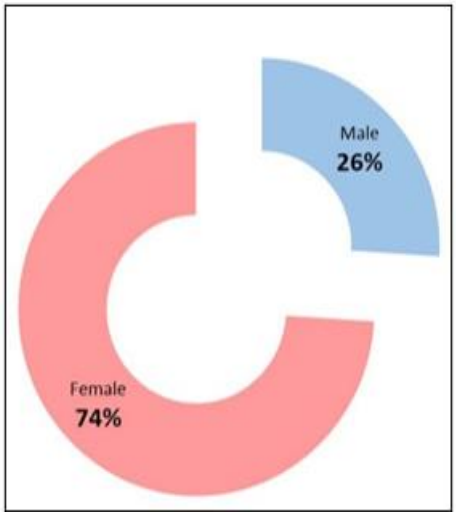

Fig. 3. Sex Ratio of Respondents by Percentage

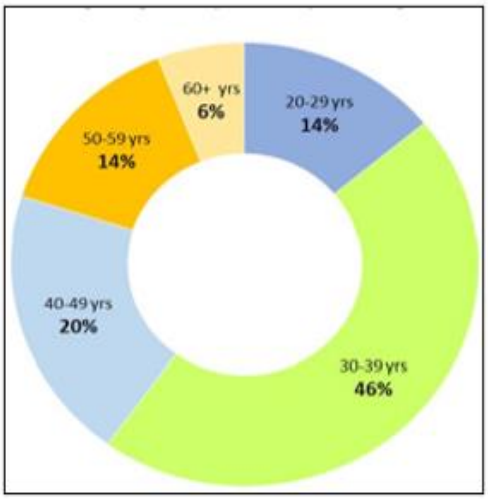

Fig. 4. Age Range of Respondents by Percentage

➢ *Level of Education*

The educational infrastructure and facilities in Bangladesh's rural coastal areas must be improved. The current investigation also revealed that 58% of respondents did not receive a formal education, while only 8% were able to access secondary education up to various grades. Presented here are the respondents' educational levels. On the other hand, it was found that 32% of the studied households have children who do not attend school, primarily due to poverty.

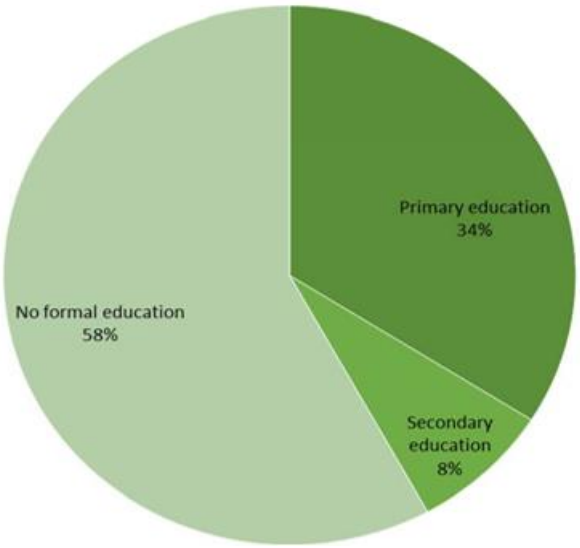

Fig. 5. Respondents' Level of Education by Percentage

➢ *Income of the Households*

On average, approximately 35% of household members participated in activities that generated income. In other words, the average number of earning household members is 2.12, while the average number of total household members is 6.04. The average annual income of the respondents from seaweed farming and trade is BDT 35,895. According to this study, the maximum and minimum income from seaweed were BDT 3,000.00 and BDT 1,500.00, respectively. It should be noted that respondents are engaged in seaweed farming and manual collection.

ISSN No:-2456-2165

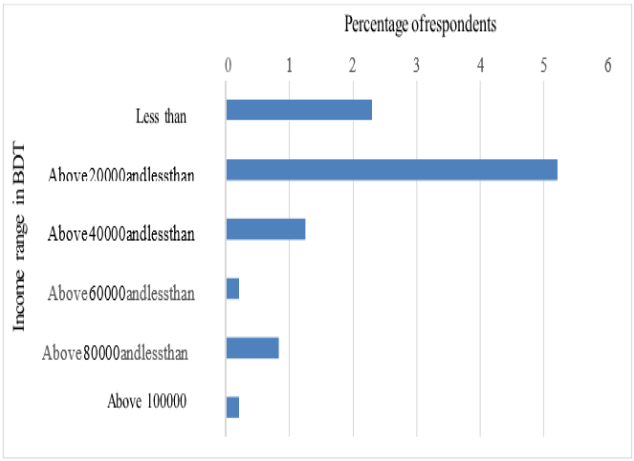

Fig. 6. Income Range of Respondents

Those with the highest incomes are engaged in agriculture, processing, trading, input supplies, and related services, among other occupations. In contrast, respondents in the lower income bracket have been cultivating seaweed for less than a year. Due to the seasonal nature of seaweed farming and related activities in the coastal region of Bangladesh, the majority of seaweed farmers were engaged in numerous other professions or income-generating activities. Here are several significant sources of income.

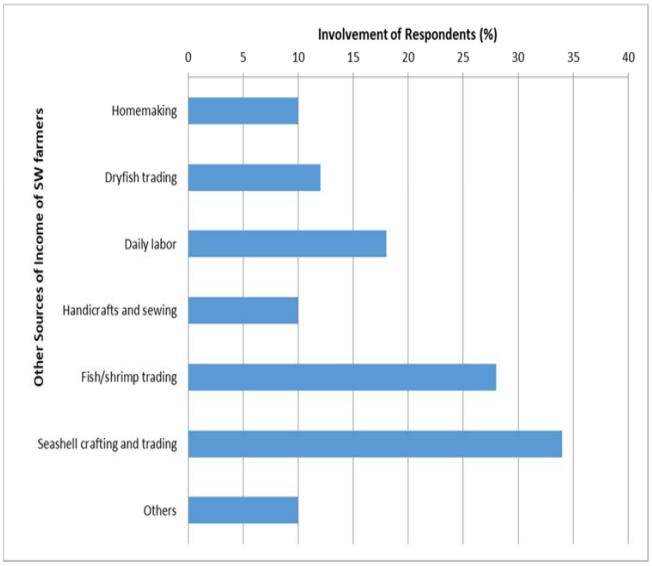

Fig. 7. Income source of the seaweed farmers

➢ *Living Standard and Assets*

The majority of the seaweed farmers in Nuniarchara and Nazirartek are migrants from Kutubdia, Moheshkhali, and other parts of the region in search of employment opportunities. Near the coast, these people are temporarily residing on "Khas Land," which is owned by the government. As they have no legal rights to the land, they run the risk of being expelled at any time by the authorities. This harsh reality has made the future of seaweed farming in these regions uncertain.

The majority of homes were constructed from bamboo, mud, and corrugated sheets. Some of them utilize tarps as roofs or as shade. Their dwellings contained between two and five rooms per household. 79% of households had electric fans, while the majority (approximately 95%) owned mobile phones. 30% of the interviewed households possessed televisions. Only a small number of homes were found to have refrigerators and stereo systems.

Some of the studied households owned rickshaw vans, battery-powered auto rickshaws, compressed natural gas (CNG)-powered auto rickshaws, bicycles, and motorcycles. The majority of respondents obtain their drinking water from tube wells, though they have occasionally boiled water. All respondents were found to use latrines, the majority of which were pit latrines.

➢ *Seaweed Farming Sites and Resources*

Along the coast of Bangladesh, seaweed cultivation sites were observed at St. Martin's Island, Shah Paris Dwip, Reju Khal estuary, Inani, Nuniarchhara, Charpara, and Chaufaldandi of Cox's Bazar. According to key informants, the southeast (Cox's Bazar) and southwest regions contain suitable and potential seaweed farming sites with suitable salinity regimes and ecological parameters (Khulna). However, this requires extensive research and investigation.

The most widely cultivated species of seaweed in Bangladesh is *Hypnea sp.*, followed by *Enteromorpha sp.*, *Ulva sp.*, *Hypnea sp.*, etc. Even though there are numerous seaweed species in Bangladesh that could be used for aquaculture, the farmers have not yet investigated the viability of cultivating these species.

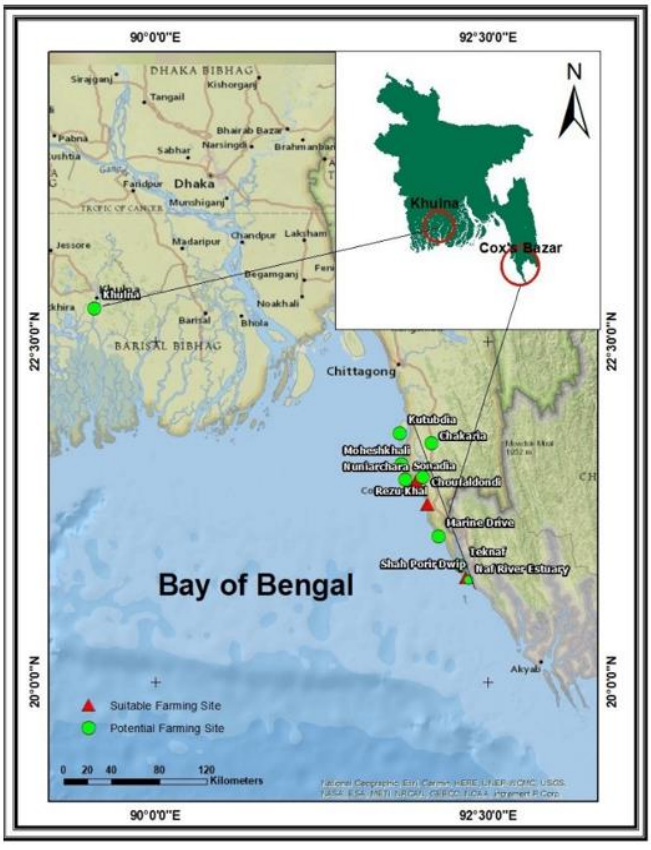

Fig. 8. Potential seaweed farming site in Bangladesh

The species *Hypnea* are used for commercial purposes as agarophytes. *Hypnea* is used for applications where the gel strength is not crucial, such as food products. In other instances, Gelidium or Gelidiella, alone or in combination with *Hypnea*, are used to produce bacteriological-grade agar. On many of our shores, Enteromorpha, a bright green filamentous seaweed, is commonly observed. At certain times of the year, seaweed may dominate certain shorelines, forming a bright green, furry, short-pile carpet over rocks and stones. Occasionally, clumps are observed in sandy regions. Some species are consumed by humans, and the fine mossy varieties are used as garnishes in Japan and parts of China. Due to their antibacterial properties, they are also used as animal feed, fertilizer, and medicine. Ulva is an edible green alga belonging to the Ulvaceae family. It is used to prepare salads, soups, and meats.

➢ *Seaweed Culture Method*

The most common practices in seaweed culture were the net method (floating or submerged) and the long-line method. During the study, it was seen that the long-line method is the most dominant practice among the seaweed farmers in Cox's Bazar. In this method, at first, seaweed seeds are collected from their natural habitat. The wild seeds are then planted in a twisted rope (long-line) of 25-30 meters length, with a distance interval of 10 inches (25 cm) between each seed along the rope. The ropes are then tied to bamboo poles in the low-tide zone, where they can be submerged during high tide. In the net method, a square frame made of coir or nylon ropes – usually measuring 5×5 m^2 – with a mesh size of 25 cm is placed in the lower intertidal zone using the support of bamboo poles. The wild seeds are planted between the twists of the net ropes with the same distance interval maintained in long-line practices. Depending on the species diversity and mass growth, the seaweeds are harvested for 15–30 days during the production season.

➢ *Seaweed Harvesting and Processing*

Typically, seaweeds are harvested by hand from cultural sites. Occasionally, farmers use knives or sickles to harvest their crops. After being washed with clean water, the products are dried in the sun. Some farmers use air-drying if there is insufficient sunlight during processing. The items are then placed in polyethylene bags. According to the type of consumption and demand, both fresh and dried seaweed products are sold.

➢ *Seaweed Market Systems*

In the coastal region of Bangladesh, seaweed farming, collection, marketing, and processing still need to be better organized. There is no legal requirement to collect and sell seaweed from the wild. Farmers or collectors of seaweed typically become intermediaries through traders or agents, who play a crucial role in the seaweed supply chain and market systems. Seaweeds are sourced from the market through three primary channels: 1) collection of seaweed from wild stocks by locals; 2) independent or contract farming of seaweed with the aid of various cultural methods; and 3) enterprise or commercial farming of seaweed by employing wageworkers. Regarding the selling points for seaweed, numerous responses were obtained from farmers.

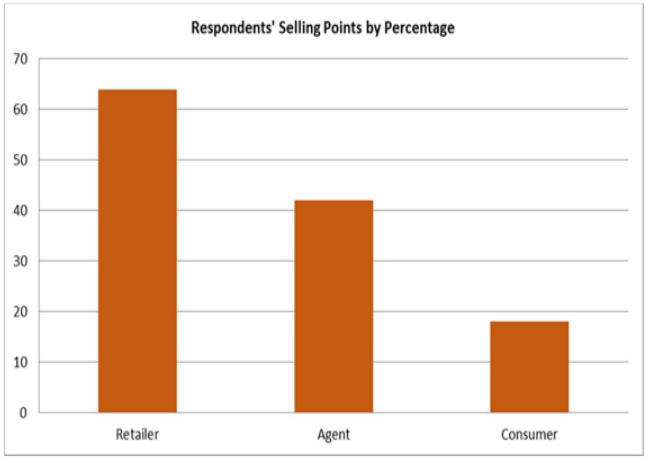

Fig. 9. Seaweed market actors

Sixty-four percent of seaweed farmers sell their products to retailers. Some agents (42%) and local consumers (18%) are also listed as purchasers of seaweed.

Fresh seaweed sold for 30–50 BDT per kilogram at the farmer's end, while dry seaweed sold for 200–300 BDT per kilogram. The harvested seaweed was sold to retail customers, local stores and markets, and agents in Cox's Bazar, Bandarban, Bhola, and Barishal. There were exports to Myanmar, China, India, and South Korea.

➢ *Socioeconomic Impacts*

Observing the socioeconomic effects of seaweed farming by analyzing the changes in the respondents' means of subsistence. 74% of seaweed farmers joined different community groups for savings and credit benefits, facilitated by various NGOs, research and development agencies, or projects such as BARC, IDF, RIC, Coast Trust, Asha, Shakti Foundation, BARI, ECO FISH, etc. Using the income generated from seaweed, some individuals could purchase or renovate a home. Similarly, only a few members of the study group were able to acquire or lease land for agricultural farming or kitchen gardening. Additionally, seaweed farming enhanced the capacity of seaweed farmers to acquire livestock, quality clothing, and consumer durables. Additionally, respondents gained confidence in utilizing various electronic appliances. Due to the income generated by seaweed culture, some households were able to resolve marriage and family conflicts and prevent their children from dropping out of school. The cultivation of seaweed has emerged as a new, sustainable means of subsistence for coastal communities in the study area. In addition, the respondents demonstrated an increased awareness of the health benefits of seaweeds. 82% of the farmers surveyed were aware of the beneficial effects of seaweeds on gastrointestinal, cardiovascular, hormonal, diabetic, and other health complications. They stated that aggressively promoting the benefits of seaweed would accelerate the growth of this potential business. With the proper policy, financial, technical, and institutional support, seaweed aquaculture is expected to prevent the overexploitation of marine fisheries and other natural resources. Here are the socioeconomic effects of seaweed farming on the farmers' means of subsistence.

ISSN No:-2456-2165

Table 2: Socio-economic impacts of seaweed farming on various livelihood assets

Livelihood Assets	Socio-economic Impacts
Financial	▪ Membership in community groups for savings and/or credit benefits by NGOs
Physical	▪ Purchase livestock, quality clothing and consumer durables ▪ Purchase or restore the existing house ▪ Purchase or lease land for agricultural farming
Human	▪ Confidence in using different electronic appliances. e.g. Android phones etc. ▪ Awareness raised on the health benefits of seaweeds.
Social	▪ Relieved to settle marriage issues ▪ Able to settle family disputes ▪ Prevent children's school drop-out
Natural	▪ Vast coastal areas are suitable for seaweed farming, offering a sustainable livelihood option.

V. CONSTRAINTS ANALYSIS

The study team consolidated the constraints of seaweed aquaculture and its economy by categorizing the same according to their association with different market actors along the value chain.

Table 3: Seaweed market actors functions and constrains

Market Actors	Function	Constraints
Farmers/ collectors	• Cultivate seaweed using rope and net method • Collect naturally grown seaweed • Process seaweed to make them suitable to sell	They need to gain proper knowledge about the processing method of seaweed. Most of them are unaware of the fact that seaweed is the green gold of our country. They cultivate them effortlessly but need more pay-off from the buyers.
Buyers/wholesalers/ retailers	• Buy seaweeds from producers (both in raw and dried form)	They need to get the proper marketplace to sell the product. The transportation cost restrains the selling process.
Development agency/ enterprises	• Provide essential loans and farming instruments to the farmers • Provide adequate training to the farmers to farm seaweed	They provide essential equipment and loans to the farmers for seaweed cultivation but need to provide a marketplace or solution to sell the product.
Government research institutions	• Deploy advanced culture methods (pilot project) to make seaweed farming popular among mass people • Take initiatives to train farmers to adapt essential processing methods • Initiate interventions to encourage seaweed farming among the coastal people	BFRI and DOF commission several projects on seaweed cultivation in Cox's Bazar (Reju Khal, Shah Parir Dwip, Nuniarchara). However, there are no steps on seaweed processing and marketing yet. The entire journey is limited to farming so far.
Consumer	• Local ethnic (tribal) communities consume seaweed in edible form (such as salad, pickles, and soup) • Local community consume seaweed with betel leaf and makes salad, curry and soup	Local ethnic (tribal) communities occasionally consume seaweeds for their medicinal value. The local people of Nuniarchara take seaweed in raw and cooked form. However, it is not popular among the people in other regions of the country.

VI. SWOT ANALYSIS OF SEAWEED FARMING AND MARKETING

Table 4: SWOT Analysis of Seaweed Farming and Marketing

Strength	Weakness
• Signature product from the coastal area • Requires less effort • Cheap to cultivate • Cheap labour cost • A suitable environment for vast growth • Grows naturally in our coastal area • An asset to add medicinal advancement • It takes a short life cycle to mature • Quickly grows in an integrated environment • A breeding ground for marine biodiversity • Grows naturally in salt-bed	• Prone to damage caused by natural or anthropogenic action • Lack of awareness among the farmers • Cheap product value • Expensive processing method • Absence of a regular diet at the national level • Comparatively unfamiliar among seafood • Small domestic market • Line up with industry yet to establish
Opportunity	**Threats**
• New hope in the blue economy • A GDP product of our coastal area • Can be a rising employment sector • Will be a sector for women's empowerment • An alternate employment sector for coastal community • Scope to expand market both national and internal level • Investment opportunities in research for product development	• Land use conflicts (e.g., Extension of Airport, Falcon Intl.) • Environmental pollution • Lack of knowledge in the local community • Volatile and unfair farm gate price • Lack of technical know-how and training • Lack of stability in the supply chain • Limited buyers • Farming/zone not demarcated

VII. RECOMMENDATIONS

To ensure the growth and sustainability of seaweed aquaculture and its market in Bangladesh, the research team determined that vigorous activities based on pragmatic strategies should be implemented. All able parties must come forward to initiate the planning required to carry out the potential interventions in this regard. Several essential suggestions are mentioned briefly below.

- Expansion of current capacity development efforts; Development of field trials and experiments for new or alternative seaweed production technologies;
- Technical improvement and effective transfer of knowledge for seaweed processing and manufacturing of value-added products;
- Establishing stronger market links and long-lasting communication channels for seaweed producers, traders, manufacturers, and others along the value chain is essential; as is regulating and monitoring the prices of seaweed products at the farm gate and ensuring fair trade throughout the supply chain.
- Developing designated sales centers or outlets with access for farmers; focusing on the nutritional, medical, industrial, social, and environmental benefits of seaweeds in marketing and dissemination efforts;
- Ensuring that policymakers, R&D partners, manufacturers, and other stakeholders have the appropriate level of coordination and synergy in order to facilitate better access to financing through the implementation of cost-effective financial schemes and relevant incentives.

VIII. CONCLUSION

Seaweeds are an abundant source of renewable natural resources in our coastal communities. It has been demonstrated that seaweed aquaculture is an economically viable means of subsistence for rural communities, offering hope for women's empowerment along the coastal belt. In this regard, a sustainable market structure can facilitate the cultivation of seaweed. Cox's Bazar's coastline is suitable for seaweed cultivation and a marketing-based industry that contributes to the blue economy. Good governance should ensure synchronized interaction between policymakers, research and development partners, producers, and other stakeholders in order to realize the socioeconomic advantages and environmental resilience of seaweed farming. Therefore, the seaweed industry in Bangladesh has sufficient growth potential.

ACKNOWLEDGEMENT

The information in this report is derived from the baseline survey of the "Learning and Innovation Fund to Test New Ideas (LIFT)" program of the Palli Karma-Sahayak Foundation (PKSF), which was established by the Government of Bangladesh (GoB) as the top tier development organization in the country.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request to the corresponding author

REFERENCES

[1]. Agyarko, K.A. (2017). Assessing the Socio-economic Benefits of Seaweed Production to the Rural Coastal Areas in Ghana. *International Journal of Advances in Science Engineering and Technology, 5*(3):32-36.

[2]. Alemañ, A.E., Robledo, D., & Hayashi, L. (2019). Development of seaweed cultivation in Latin America: current trends and future prospects, *Phycologia*, *58*(5): 462-471. DOI: 10.1080/00318884.2019.1640996.

[3]. Aziz, A., Towhidy, S., & Alfasane, M.A. (2015). Sublittoral Seaweed Flora of the St. Martin's Island, Bangladesh. *Bangladesh J. Bot., 44*(2): 223-236.

[4]. Bindu, M.S. (2010). Empowerment of coastal communities in cultivation and processing of Kappaphycus alvarezii—a case study at Vizhinjam village, Kerala, India. *J Appl Phycol*. DOI: 10.1007/s10811- 010-9597-4.

[5]. Campbell, I., Macleod, A., Sahlmann, C., Neves, L., Funderud, J., Øverland, M., Hughes, A.D., & Stanley, M. (2019). The Environmental Risks Associated with the Development of Seaweed Farming in Europe - Prioritizing Key Knowledge Gaps. *Front. Mar. Sci. 6*(107). DOI: 10.3389/fmars.2019.00107

[6]. Crawford, B.R., & Shalli, M.S. (2007). *A Comparative Analysis of the Socio-Economics of Seaweed Farming in Two Villages along the Mainland Coast of Tanzania The Sustainable Coastal Communities and Ecosystems Program*. Coastal Resources Center, University of Rhode Island and the Western Indian Ocean Marine Science Association. 9p.

[7]. Eggertsen, M., & Halling, C. (2020) Knowledge gaps and management recommendations for future paths of sustainable seaweed farming in the Western Indian Ocean. *Ambio*. https://doi.org/10.1007/s13280-020-01319-7

[8]. Grebe, G.S., Byron, C.J., Gelais, A.S., Kotowiczc, D.M., & Olson, T.K. (2019). An ecosystem approach to kelp aquaculture in the Americas and Europe, *Aquaculture Reports, 15*. https://doi.org/10.1016/j.aqrep.2019.100215

[9]. Hoq, M.E., Haque, M.A., & Islam, M.M. (2016). Feasibility of Seaweed Culture in Inani and Bakkhali Coast of Cox's Bazar, Bangladesh. *Pakistan Journal of Marine Sciences, 25*(1&2): 27-36.

[10]. Islam, M.M., Khan, M.S.K., Hasan, J., Mallick, D., & Hoq, M.E. (2017). Seaweed *Hypnea sp.* culture in Cox's Bazar coast, Bangladesh. *Bangladesh J. Zool. 45*(1): 37-46.

[11]. Kambey, C.S.B., Campbell, I., Sondak, C.F.A., Nor, A.R.M., Lim, P.E., & Cottier-Cook, E.J. (2020). An analysis of the current status and future of biosecurity frameworks for the Indonesian seaweed industry. *Journal of Applied Phycology*. https://doi.org/10.1007/s10811-019-02020-3.

[12]. Kılınç, B., Cirik, S., Turan, G., Tekogul, H., & Koru, E. (2013). Seaweeds for Food and Industrial Applications. http://dx.doi.org/10.5772/53172. In: *Food Industry*

[13]. http://cdn.intechopen.com/pdfs/41694/InTech-Seaweeds_for_food_and_industrial_applications.pdf

[14]. Krishnan, M., & Kumar, R.N. (2010). *Socio economic dimensions of Seaweed Farming in India*. CMFRI Special Publication No. 104. Central Marine Fisheries Research Institute, Kochi. ISSN 0972 – 2351.

[15]. McHugh, D.J. (2003). *A Guide to the Seaweed Industry*. FAO Fisheries Technical Paper 441. FAO.

[16]. Mouritsen, O.G. (2013). *Seaweeds Edible, Available & Sustainable*. The University of Chicago Press, Chicago & London, 287 pp.

[17]. 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. 27p.

[18]. Namudu, M.T., & Pickering, T.D. (2006). Rapid survey technique 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.

[19]. Narayanakumar, R., & Krishnan, M. (2013). Socio-economic assessment of seaweed farmers in Tamil Nadu - A case study in Ramanathapuram District. *Indian J. Fish., 60*(4): 51-57.

[20]. Rebours, C., Marinho-Soriano, E., Zertuche-González, J.A., Hayashi, L., Vásquez, J.A., Kradolfer, P., Soriano, G., Ugarte, R., Abreu, M.H., Bay-Larsen, I., Hovelsrud, G., Rødven, R., & Robledo, D. (2014). Seaweeds: an opportunity for wealth and sustainable livelihood for coastal communities. *J Appl Phycol*, 26:1939–1951.

[21]. Sarkar, M.S.I., Kamal, M., Hasan, M.M., & Hossain, M.I. (2016). Present status of naturally occurring seaweed flora and their utilization in Bangladesh. *Res. Agric. Livest. Fish. 3* (1): 203-216.

[22]. Siddiqui, A.A.M., Kashem, M.A., Mondal, M.A.I., & Shafiuddin, M. (2019). Commercially important seaweed cultivation and its potentials for the coastal areas of Cox's Bazar, Bangladesh. *International Journal of Fisheries and Aquatic Studies, 7*(5): 463-470.

[23]. Valderrama, D. (2012) Social and Economic Dimensions of Seaweed Farming: A Global Review. In: *Visible Possibilities: The Economics of Sustainable Fisheries, Aquaculture and Seafood Trade*: Proceedings of the Sixteenth Biennial Conference of the International Institute of Fisheries Economics and Trade, July 16-20, Dar es Salaam, Tanzania. Edited by Ann L. Shriver. International Institute of Fisheries Economics and Trade (IIFET), Corvallis.

[24]. Zafar, M. (2007). *Seaweed culture (Hypnea sp.) in Bangladesh- Seaweed Culture Manual-1*. Institute of Marine Science and Fisheries, University of Chittagong, Chittagong, Bangladesh. 14p.

[25]. Zulham, A., Muawanah, U. Shafitri, N., & Wijaya, R.A. (2018). Socio economic assessment of seaweed farming in Nunukan Regency, North Kalimantan. *IOP Conf. Series: Earth and Environmental Science, 216*(012050).