Seaweed Farming as a Climate-Friendly Aquaculture System

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ABSTRACT

Seaweed farming is emerging as one of the most sustainable and climate-friendly aquaculture systems. Unlike traditional agriculture, seaweed cultivation requires no freshwater, fertilizers, or arable land, making it an environmentally efficient food production method. Seaweeds absorb carbon dioxide through photosynthesis and can contribute to carbon sequestration, helping mitigate climate change. Additionally, seaweed farms improve water quality by absorbing excess nutrients and supporting marine biodiversity. This paper examines the role of seaweed aquaculture in climate change mitigation, its ecological and economic benefits, cultivation methods, challenges, and future prospects. The study highlights seaweed farming as a promising nature-based solution for sustainable aquaculture and environmental protection.

INTRODUCTION

Aquaculture plays an important role in global food production, providing nutrition and livelihoods for millions of people. However, conventional aquaculture systems may contribute to environmental problems such as nutrient pollution and greenhouse gas emissions. As a result, researchers are exploring sustainable alternatives to improve the environmental performance of aquaculture.

Seaweed farming has gained global attention as a climate-friendly aquaculture system because it requires minimal inputs and offers several environmental benefits. Seaweeds are photosynthetic marine algae that grow rapidly and absorb carbon dioxide from seawater, contributing to carbon sequestration and climate change mitigation (Duarte *et al*., 2017).

Seaweed aquaculture has expanded significantly over the past decades, especially in Asian countries such as China, Indonesia, and South Korea. It is now one of the fastest-growing sectors in marine aquaculture.

Overview of Seaweed Aquaculture

Seaweed aquaculture involves the cultivation of marine macroalgae in coastal waters for food, industrial products, and environmental services.

Major Cultivated Seaweed Groups

Seaweeds are broadly classified into three groups:

1. **Brown algae (Phaeophyceae)** – e.g., *Laminaria*, *Sargassum*
2. **Red algae (Rhodophyceae)** – e.g., *Gracilaria*, *Kappaphycus*
3. **Green algae (Chlorophyceae)** – e.g., *Ulva*

These seaweeds are widely used in food products, pharmaceuticals, fertilizers, cosmetics, and biofuel production (World Wildlife Fund).

Seaweed cultivation can occur in coastal waters, open ocean farms, or integrated aquaculture systems.

Role of Seaweed Farming in Climate Change Mitigation

1. **Carbon Sequestration:** Seaweeds absorb carbon dioxide during photosynthesis and convert it into biomass. A portion of this biomass sinks to the ocean floor, where carbon can be stored in sediments for long periods.

Studies indicate that seaweed cultivation may sequester significant amounts of carbon annually. For example, global estimates suggest that seaweed aquaculture can store about **1500 tonnes of CO^2 per square kilometer per year** (Duarte *et al*., 2017).

Research also shows that seaweed farms may remove **0.1–2 tonnes of CO^2 per hectare annually** depending on environmental conditions (Fakhraee & Planavsky, 2026).

2. **Reduction of Ocean Acidification:** Seaweed absorbs dissolved carbon dioxide in seawater, which can reduce ocean acidity and improve water conditions for marine organisms such as shellfish and corals.

3. **Replacement of High-Emission Products:** Seaweed biomass can be used to produce biofuels, biodegradable plastics, fertilizers, and animal feed. Replacing fossil-fuel-based materials with seaweed products can reduce greenhouse gas emissions.

Environmental Benefits of Seaweed Farming

1. **Nutrient Removal and Water Purification:** Seaweeds absorb excess nutrients such as nitrogen and phosphorus from coastal waters. This helps reduce eutrophication and improves water quality in aquaculture environments.

2. **Habitat for Marine Biodiversity:** Seaweed farms create complex habitats that support fish, invertebrates, and other marine

organisms. These habitats act as nursery grounds for many species.

3. **Low Resource Requirements:** Seaweed farming is environmentally sustainable because it:

- Requires no freshwater
- Does not need fertilizers or pesticides
- Uses minimal energy inputs

These characteristics make seaweed cultivation more environmentally friendly compared to many terrestrial agricultural systems (Duarte *et al.*, 2017).

Seaweed Farming Techniques

Several methods are used for seaweed cultivation depending on environmental conditions and species.

1. Off-Bottom Culture Method

Seaweed is attached to ropes fixed between wooden stakes in shallow waters.

2. Floating Raft Method

Seaweed is cultivated on floating structures anchored in coastal waters.

3. Long-Line Method

Seaweed seedlings are attached to long ropes suspended in deeper waters.

4. Integrated Multi-Trophic Aquaculture (IMTA)

Seaweed is grown alongside fish and shellfish. Waste nutrients from fish farming are absorbed by seaweed, improving overall environmental sustainability (Duarte *et al.*, 2017).

Economic Importance of Seaweed Farming

Seaweed farming provides several economic benefits:

1. Food Production

Seaweed is widely consumed as food, especially in Asian countries.

2. Industrial Applications

Seaweed is used to produce:

- Agar
- Carrageenan
- Alginate

These compounds are widely used in food processing, pharmaceuticals, and cosmetics (World Wildlife Fund).

3. Employment Opportunities

Seaweed farming provides livelihood opportunities for coastal communities and small-scale fishers.

Challenges in Seaweed Aquaculture

Despite its benefits, seaweed farming faces several challenges.

1. Climate Change Impacts

Rising sea temperatures and extreme weather events may affect seaweed growth and productivity.

2. Disease and Pest Outbreaks

Seaweed farms may experience disease outbreaks or infestations that reduce yields.

3. Market and Infrastructure Limitations

Limited processing facilities and market access can restrict the growth of seaweed aquaculture in some regions.

4. Environmental Concerns

Large-scale seaweed farming may alter marine ecosystems if not properly managed.

Future Prospects of Seaweed Aquaculture

The future of seaweed farming is promising due to increasing demand for sustainable food and bio-based products.

Potential future developments include:

- Offshore large-scale seaweed farms
- Seaweed-based biofuels and biodegradable plastics
- Carbon credit systems for seaweed farms
- Integration with climate mitigation policies

Studies suggest that expanding global seaweed aquaculture could remove significant amounts of carbon dioxide from the atmosphere while providing sustainable food and economic benefit (Duarte *et al*., 2017; Fakhraee & Planavsky, 2026).

CONCLUSION

Seaweed farming represents a highly sustainable and climate-friendly aquaculture system. It offers multiple environmental benefits including carbon sequestration, nutrient removal, and biodiversity enhancement. In addition to ecological advantages, seaweed aquaculture provides economic opportunities for coastal communities and supports the production of sustainable food and industrial products. Although challenges remain, continued research, technological innovation, and supportive policies can help expand seaweed farming as a nature-based solution for climate change mitigation and sustainable aquaculture development.

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