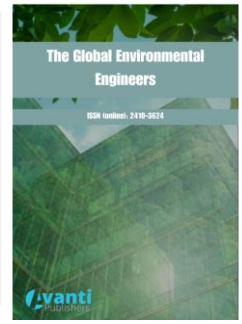
Published by Avanti Publishers

The Global Environmental Engineers

ISSN (online): 2410-3624



EDITORIAL

Seaweed-based Carbon Sequestration: A Sustainable Green Approach Towards Climate Change Mitigation

Gour Gopal Satpati*

Department of Botany, Bangabasi Evening College, University of Calcutta, 19 Rajkumar Chakraborty Sarani, Kolkata 700009, West Bengal, India

ARTICLE INFO

Article Type: Editorial Article

Academic Editor: Hongxing Dai

Keywords:
Blue carbon
Seaweed mariculture
Climate change mitigation
Seaweed carbon sequestration

Timeline:
Received: May 25, 2025
Accepted: June 20, 2025
Published: July 02, 2025

Citation: Satpati GG. Seaweed-based carbon sequestration: A sustainable green approach towards climate change mitigation. Glob Environ Eng. 2025; 12: 18-21.

DOI: https://doi.org/10.15377/2410-3624.2025.12.1

ABSTRACT

Rising atmospheric CO_2 levels threaten global biodiversity and human well-being, driving interest in sustainable, carbon-negative solutions. Seaweeds have emerged as a key blue carbon resource due to their rapid growth and high capacity for organic carbon fixation. This paper examines various seaweed-based carbon sequestration mechanisms—photosynthesis, sedimentation, and carbon-neutral product development—and introduces models for estimating net CO_2 removal in aquaculture systems. Despite their potential, seaweed ecosystems face challenges such as ocean acidification and habitat degradation. To address these, the study advocates for large-scale seaweed mariculture, restoration, and ocean afforestation, supported by public-private initiatives and aligned with the UN Sustainable Development Goals. Seaweed cultivation is presented as a viable, nature-based solution for climate change mitigation and long-term carbon storage.

*Corresponding Author
Email: gour_satpati@yahoo.co.in
Tel: +(91) 8697953925

©2025 Gour Gopal Satpati. Published by Avanti Publishers. This is an open access article licensed under the terms of the Creative Commons Attribution Non-Commercial License which permits unrestricted, non-commercial use, distribution and reproduction in any medium, provided the work is properly cited. (http://creativecommons.org/licenses/by-nc/4.0/)

High rises of atmospheric carbon dioxide (CO_2) can cause global damage to biodiversity and living society. Hence sustainable renewable energy has become an alternative to reduce carbon and directed towards climate change mitigation [1]. It has been known that the ocean is the biggest storehouse of CO_2 in terms of organic carbon fixation by marine ecosystems. In addition coastal ecosystems with dominant vegetation of seaweeds are getting into the main spotlight for fixing organic carbon and can be considered as blue carbon [2]. The protection, restoration and afforestation of seaweeds in coastal ecosystems can serve as the best livelihood for the people associated with coastal ecosystems. Hence the people become more concerned about the seaweed aquaculture or seaweed farming [3].

Seaweeds are one of the major macrophytes in marine ecosystems for their fast growth and adaptability with the marine environment. It has been reported that the seaweeds are faster growing than Amazonian forest based on their primary production [4]. There are some factors through which seaweeds can sequester carbon: 1) photosynthesis, 2) sedimentation through sinking seaweeds, 3) seaweed farming in coastal belts, 4) production of carbon-neutral or low-carbon materials like biofuels, biofertilizers, pharmaceuticals, hydrocolloids, cosmetics and livestock feed 5) raw biomass storage and harvesting, 6) seaweed products based sequestration of industrial CO_2. But the most challenging event is ocean acidification where the rapid decrease of pH in the water takes place through the high rate of CO_2 sequestration [5].

CO_2 removal (CDR) is one of the most important issues which depends on the amount of carbon sequestered (C_{SEQ}) by the seaweeds and the amount of carbon emitted (C_{EMIT}) (Eq. **1**). Farmed seaweeds and the natural bed seaweeds take an important part in CDR through photosynthesis [6]. Now-a-days the involvement of public and private sectors in seaweed cultivation have emerged for the basic needs of CDR and biomass valorization for circular bioeconomy. Pessarrodona and team have reported significant results of CDR when they calculated the amount of CO_2 sequestered and the amount of CO_2 emitted during cultivation [6]. Long term carbon sequestration depends on the rate of carbon fixed in the deep sea (C_{DEEP}), carbon related products like biochar (C_{PROD}), sedimented carbon in the biomass at the bottom of the sea (C_{SED}) in the form of POC (particulate organic carbon) and through the refractory dissolved organic carbon pool (C_{RDOC}) which released in the form of DOC (dissolved organic carbon) (Eq. **2**). On the other hand carbon fixation (C_{FIX}) through seaweed in aquaculture can be calculated with the help of POC and DOC (Eq. **3**) (Fig. **1**). Here the carbon released as DOC is considered as %DOC

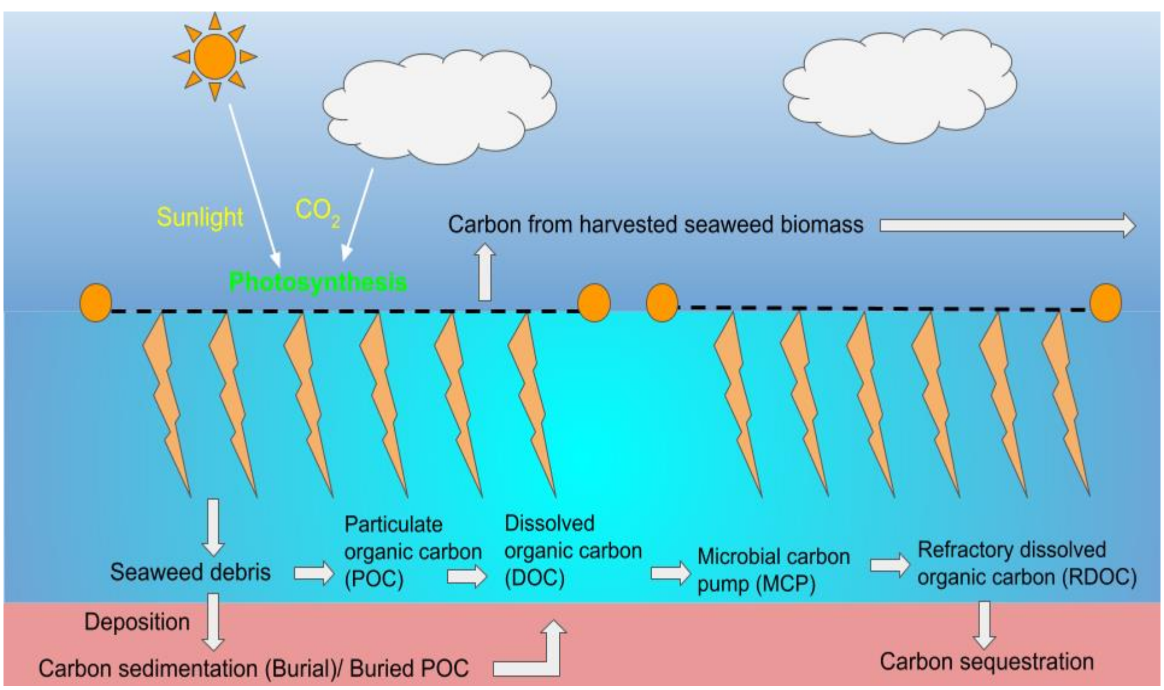


Figure 1: Mechanism of carbon sequestration by seaweeds.

and the C_{POC} is the carbon remains during harvested POC and the %POC loss (Eq. **4**). During the blooming season the amount of carbon sequestered is approximately 0.173 $Pg.C.yr^{-1}$ which is equivalent to the 0.635 $Pg.CO2.yr^{-1}$ [7]. Carbon sequestration throughout the life cycle of a seaweed has never been calculated unless the life cycle assessment (LCA) is performed [8].

$$\text{Net CDR capacity} = C_{SEQ}\text{-}C_{EMIT} \qquad \text{(Eq. 1)}$$

$$C_{SEQ} = C_{DEEP}+C_{PROD}+C_{SED}+C_{RDOC} \qquad \text{(Eq. 2)}$$

$$C_{FIX} = C_{POC}/1\text{-}\%DOC \qquad \text{(Eq. 3)}$$

$$C_{POC} = \text{Harvested POC}/1\text{-}\%\text{POC loss} \qquad \text{(Eq. 4)}$$

Anthropogenic stressors are one of the obstructions for the growth of wild seaweeds. Some other challenges include overgrazing, pollution, harvesting, rising temperatures, and invasive species rapidly causing the extinction of wild seaweeds [1]. To overcome these challenges, revegetation in terms of protection and restoration of seaweeds around the seashore or coastal belt is important (Fig. **2**). Cultivating common seaweeds like *Saccharina latissima, S. japonica, Undaria pinnatifida, Catenella repens, Ulva intestinalis, U. lactuca, Kappaphycus alvarezii, Gracilaria verrucosa, Eucheuma spinosum, Caulerpa racemosa, Sargassum fusiforme* in the form of sinking biomass in the deep ocean water can results long term carbon sequestration. It has been suggested that the seaweed mariculture industry has great potential towards the progress on the United Nations Sustainable Development Goals [4]. Geoengineering of seaweed cultivation can be a best choice for seaweed-based carbon capture and storage which can also be considered as 'ocean afforestation'. Potential financial opportunities from public or private sectors can support the seaweed farming on a large scale to capture or sequester as much as carbon. In addition, technical and ecological feasibility can govern the process of seaweed aquaculture [9].

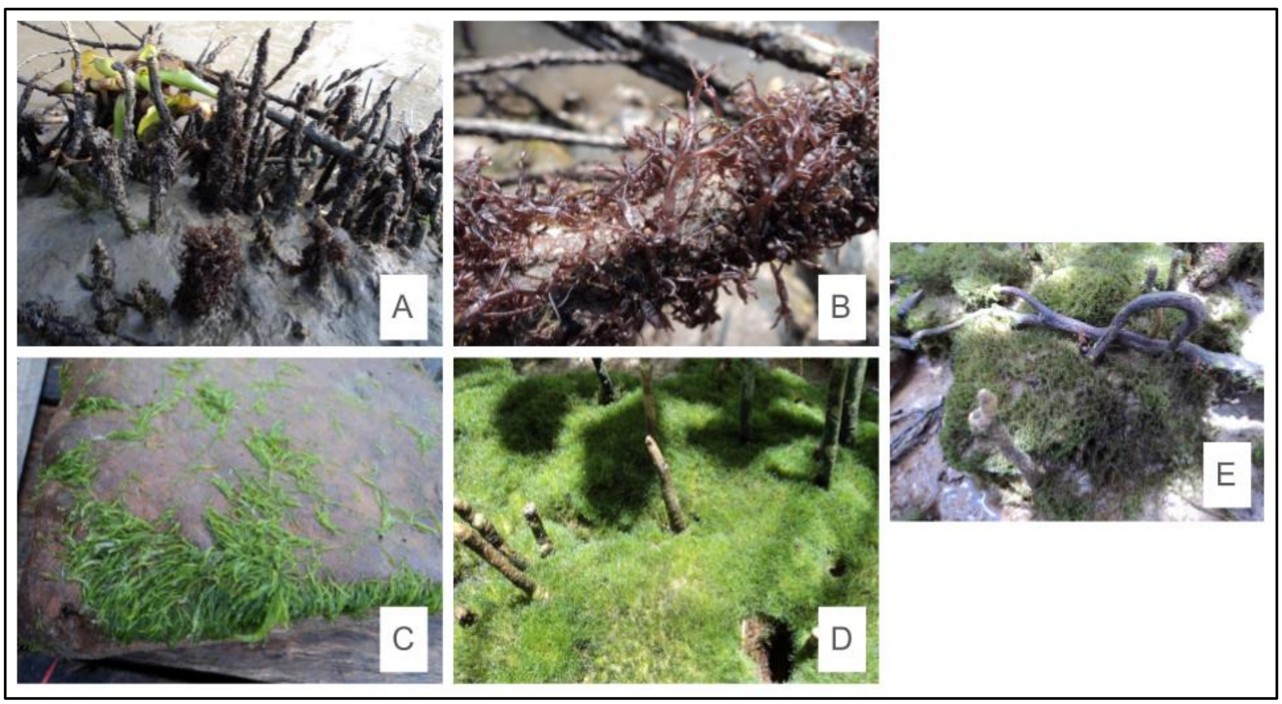


Figure 2: Common seaweeds and macrophytes at the coastal area of Sundarbans, India. **A-B**: *Catenella repens*, **C**: *Ulva gujratensis*, **D**: *Cladophora nitellopsis*, **E**: *Rhizoclonium africanum*.

Conflict of Interest

Author declares that there is no conflict of interests.

References

[1] Ross FWR, Boyd PW, Filbee-Dexter K, Watanabe K, Ortega A, Krause-Jensen D, *et al*. Potential role of seaweeds in climate change mitigation. Sci Total Environ. 2023; 885: 163699. https://doi.org/10.1016/j.scitotenv.2023.163699

[2] Gorain PC, Sengupta S, Satpati GG, Paul I, Tripathi S, Pal R. Carbon sequestration in macroalgal mats of brackish-water habitats in Indian Sundarbans: potential as renewable organic resource. Sci Total Environ. 2018; 626: 689-702. https://doi.org/10.1016/j.scitotenv.2018.01.106

[3] Behera DP, Vadodariya V, Veeragurunathan V, Sigamani S, Moovendhan M, Srinivasan R, *et al*. Seaweeds cultivation methods and their role in climate mitigation and environmental cleanup. Total Environ Res Themes. 2022; 3-4: 100016. https://doi.org/10.1016/j.totert.2022.100016

[4] Duarte CM, Gattuso JP, Hancke K, Gundersen H, Filbee-Dexter K, Pedersen MF, *et al*. Global estimates of the extent and production of macroalgal forests. Glob Ecol Biogeogr. 2022; 31: 1422-39. https://doi.org/10.1111/geb.13515

[5] Satpati GG. Ocean acidification: positive and negative impacts on seaweeds. Exam Mar Biol Oceanogr. 2023; 6: 1-2. http://dx.doi.org/10.31031/eimbo.2023.06.000631

[6] Pessarrodona A, Howard J, Pigeon E, Wernberg T, Filbee-Dexter K. Carbon removal and climate change mitigation by seaweed farming: a state of knowledge review. Sci Total Environ. 2024; 918: 170525. https://doi.org/10.1016/j.scitotenv.2024.170525

[7] Fujita RM, Collins JR, Kleisner KM, Rader DN, Augyte S, Brittingham PA. Carbon sequestration by seaweed: background paper for the Bezos Earth Fund - EDF workshop on seaweed carbon sequestration. New York, NY: Environmental Defense Fund; 2022; pp. 1-26. Available from: https://www.edf.org/sites/default/files/2022-10/Carbon%20Sequestration%20by%20Seaweed.pdf (Accessed on 1 June 2025).

[8] Lian Y, Wang R, Zheng J, Chen WX, Chang L, Li C, Yim SC. Carbon sequestration assessment and analysis in the whole life cycle of seaweed. Environ Res Lett. 2023; 18: 074013. https://doi.org/10.1088/1748-9326/acdae9

[9] Ross F, Tarbuck P, Macreadie PI. Seaweed afforestation at large-scales exclusively for carbon sequestration: critical assessment of risks, viability and the state of knowledge. Front Mar Sci. 2022; 9: 1-15. https://doi.org/10.3389/fmars.2022.1015612