PACE Conclave 2025
ICEST 2025 INTERNATIONAL CONCLAVE ON ENGINEERING SCIENCES & TECHNOLOGY
IC-ICE INTERNATIONAL CONFERENCE IN CIVIL ENGINEERING

Algae-Driven Solutions for Soil Carbon Sequestration: A case study

M A Divyadarshini, Sanjith S Anchan, and Kanchana M S

Department of Civil Engineering, The National Institute of Engineering, Mysuru

E-mail:

Abstract

Soil carbon sequestration - capturing and storing atmospheric carbon dioxide (CO_2) in soil organic matter - has gained increasing attention as a critical strategy for mitigating climate change. This process is driven by plant photosynthesis, root exudation, and microbial activity, which together facilitate carbon incorporation into soil systems. The extent of carbon sequestration is influenced by factors such as land use, soil type, climate, and agricultural practices. Proven methods like no-till farming, agroforestry, and cover cropping enhance carbon retention by improving soil structure, increasing organic inputs, and minimizing erosion-related losses. Beyond climate benefits, soil carbon sequestration also improves soil fertility, water retention, and nutrient cycling.

This stucy explores an innovative approach by integrating algae-based carbon sequestration into soil management strategies. Specifically, the role of Chlorella vulgaris, a fast-growing microalga, in promoting soil organic matter accumulation, microbial activity, and carbon storage was investigated. Algae were cultivated under optimal conditions (adequate sunlight, temperature control, and stirring) in water for three days, then introduced to pre-saturated soil samples. A comparative approach

ISBN:97881-19905-39-3

was also adopted by directly applying algae onto dry soil samples to assess differential impacts. Experimental findings reveal that algae application promotes significant improvements in soil fertility and carbon sequestration potential. The growth of subsurface biomass beneath the algae layer enhances microbial activity and organic matter content. Moreover, the synergistic effects of Chlorella vulgaris with different soil types, including combination soil and clay loam, highlighting how algae-induced soil aggregation and microbial stimulation further boost carbon capture was examined. Significant changes were observed in organic matter and nutrient content in soil. Organic matter increased from 0.34% to 0.58% and organic carbon content increased from 0.20% to 0.38%. Nitrogen, phosphorus, and potassium, which are essential nutrients of soil, were also increased in the soil by the addition of Chlorella vulgaris algae. The soil health index increased from 0.55 to 0.59, which confirms the positive impact of algae-based carbon sequestration. These findings suggest that incorporating microalgae into soil management strategies can contribute to long-term carbon storage and sustainable agricultural practices.

1 Introduction:

Soil carbon sequestration (SCS) involves capturing and storing of carbon dioxide (CO_2) in soil via natural or anthropogenic mechanisms. This has been gaining a lot of interest over the recent past owing to climate change mitigation, soil restoration, and the promotion of agriculture. Also, with Soils that sequester Carbon and its other forms help reduce decomposition of organic materials in the atmosphere thus reducing global warming. It improves soils' architecture, economies and diversity and therefore suffices and productive ecosystems. The better fertility of the soils increases crop yields and their nutritional value. As well as these SCS manages the rate of water getting into the soil, how long water stays in the soil and even decreases the chances of either drought or flooding

Microalgae, like all the other photosynthetic organisms, take in CO_2 from the atmosphere

ISBN:97881-19905-39-3

during photosynthesis and convert it to organic compounds such as glucose which in this case is stored within the biomass of the microalgae. Microalgae also synthesizes exopolysaccharides (EPS) which are also polysaccharide but act as a carbon sink when absorbed into soil. EPS assists in joining together soil particles, creating stable clusters that sequester the carbon and inhibit its decomposition. Therefore, microalgae can improve the soil structure by producing EPS and that helps to bind soil particles together. It also reduces the soil erosion, by allowing organic matter to remain in the soil and contribute to carbon sequestration.

Chlorella vulgaris is a green microalga belonging to the Chlorellaceae family and well known for its potential in catalyzing photosynthesis. It has fast growth rate and useful organism for carbon capture, bioenergy production. Its adequate supply of chlorophyll and capacity of growing in various regions makes it one of the important organisms in ecological and industrial field. Chlorella vulgaris as a photoautotrophic organism uses CO: during the process of photosynthesis and converts it into biomass. It accumulates carbon at a rate up to 1.83 g CO:/g biomass and has high growth rate making it useful for aquaculture and fish farming. It can capture CO: from industrial gases, and helps in reducing greenhouse gas emissions.

This study investigated the impact of Chlorella vulgaris, a microalga, on soil carbon storage and nutrient enhancement through two distinct cultivation methods. In the first method, the algae were cultured in water for three days before being allowed to transform into the pre-saturated soil samples, whereas in the second method, the algae were added directly onto the saturated soil. Both the treatments were checked under controlled conditions of sunlight and temperature for healthy growth.

2 Materials and Methods:

Materials used:

ISBN:97881-19905-39-3

- **Soil samples:**
- Sample 1: Clay loam soil from Alanahalli, Mysuru, Karnataka.
- Sample 2: Combination soil from Agricultural field, Bannikuppe, Hunsuru.
- Algae species (Chlorella vulgaris): This microalgae species was selected for its high carbon sequestration potential and ability to thrive in various environments.

3 Method - 1: Algae cultivation process

1. Chlorella vulgaris algae capsules were cut open and then introduced into water medium
2. Algae was kept in sunlight for 6-8 hours a day
3. Optimum temperature of about 20-30 degrees was maintained throughout.
4. 4. The algae were periodically stirred so as to prevent any sort of clumping
5. 5. After 3 days the algae were introduced into the soil sample.

4 Method 2: Cultivation of algae on soil ample

1. Soil was saturated with the help of water for 10 hours.
2. After saturation water level in the tray was maintained for about 50mm from the surface of sample.
3. Chlorella vulgaris algae capsule were cut open and introduced directly on top of soil.
4. Each sample was kept under sunlight for about 6-8 hours.
5. A considerable algae growth was observed on day 2.

5 Results and Discussions:

The soil samples were taken before introducing the algae and seven days after introducing the algae to soil samples on December 16th and 21st respectively. Thorough the obtained soil nutrient test report, it is clear that introducing carbon sequestering algae into the

ISBN:97881-19905-39-3

soil will definitely improve carbon content in the soil which helps in increasing all other essentials nutrient content such as Nitrogen, Phosphorous, Potassium, Iron, Zinc etc. Soil carbon sequestration is a great way to reduce global warming and increase the plant growth simultaneously. From the results obtained in soil analysis we observe that the percentage organic matter has changed from 0.34W% to 0.58W%. This indicates Chlorella vulgaris algae can increase the organic matter content in minimal time to noticeable range. Also we can observe that the organic carbon content has increased from 0.20W% to 0.38W%, we know that the obtained results are comparatively lower than the required range but we can say that by using this methodology for longer duration we can achieve the required organic carbon content which indicates that carbon sequestration has taken place.

Chart 1:

Table 1:

Table 1: Results of soil analysis

Sl No.	Parameters	Dec-16	Dec-21
1	Nitrogen (kg/ha)	157	201
2	Phosphorus (kg/ha)	11.7	13.43
3	Potassium (kg/ha)	350	400
4	pH	5.66	5.2
5	Organic Carbon (%)	0.2	0.38
6	Organic Matter	0.34	0.58
7	Sulphur (mg/kg)	28.71	29.82
8	Zinc (mg/kg)	0.83	0.94
9	Boron (mg/kg)	0.51	0.7
10	Iron (mg/kg)	5	5.6
11	Manganese (ppm)	3.25	3.49
12	Copper (mg/kg)	0.42	0.6
13	Carbon Stock (T/Ha)	32	32
14	Soil Health Index (SQI)	0.55	0.59

ISBN:97881-19905-39-3

6 Conclusion:

This project majorly focuses on comprehending how the microalgae can play an important role in soil carbon sequestration. Carbon sequestration in soils is of utmost importance when it comes to the mitigation process of climate change, where soil captures atmospheric carbon dioxide and assimilates and stores it into organic matter form. The increments of carbon content of the soil make other vital elements such as NPK and organic matter increase. This results in an overall improvement in soil fertility, which further leads to higher biomass production and faster growth of plants. The increased carbon content also significantly enhances soil health and integration, thereby making the soil more productive. In this study, two soil samples were chosen for experimentation: clay loam soil from Alanahalli, Mysuru, Karnataka, and combination soil from an agricultural field in Bannikuppe, Hunsuru.

This study investigated the impact of Chlorella vulgaris, a microalga, on soil carbon storage and nutrient enhancement through two distinct cultivation methods. In the first method, the algae were cultured in water for three days before being allowed to transform into the pre-saturated soil samples, whereas in the second method, the algae were added directly onto the saturated soil. Both the treatments were checked under controlled conditions of sunlight and temperature for healthy growth. Significant changes were observed in organic matter and nutrient content in soil. Organic matter increased from 0.34% to 0.58% and organic carbon content increased from 0.20% to 0.38%. Nitrogen, phosphorus, and potassium, which are essential nutrients of soil, were also increased in the soil by the addition of Chlorella vulgaris algae. The soil health index increased from 0.55 to 0.59, which confirms the positive impact of algae-based carbon sequestration. These findings suggest that incorporating microalgae into soil management strategies can contribute to long-term carbon storage and sustainable agricultural practices.

ISBN:97881-19905-39-3