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Carbon Sequestration to Mitigate Climate Change

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Introduction

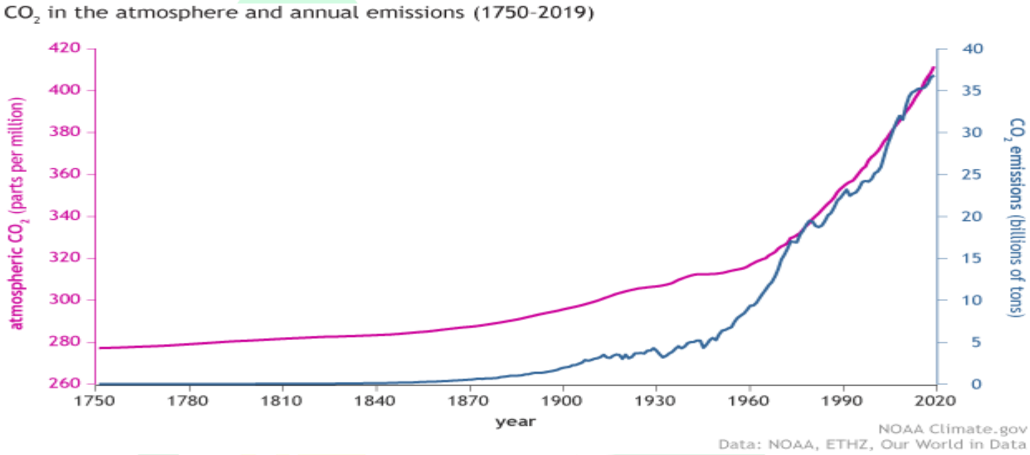
- Carbon sequestration is the process of capture and long-term storage of atmospheric carbon dioxide in oceans, soils, vegetation (forests) and geological formations to mitigate global warming and to avoid dangerous impacts of climate change.
- In other words, it also refers to the process of removing carbon from the atmosphere and depositing it in a reservoir. This carbon storages or reservoirs are also known as carbon pools.
- Carbon pool refers to a system or mechanism which has the capacity to accumulate or release. It can be natural or human induced. Examples are forest biomass, wood products, soils, and the atmosphere.

Why carbon sequestration is important?

- CO_2 capture and sequestration could play an important role in reducing greenhouse gas emissions into the atmosphere.
- It enables low-carbon electricity generation from power plants.
- As reported by INCCA in their report, Green House Gas Emission, 38% of CO_2emissions in India is done from electric power generation. This carbon share can be reduced by using carbon sequestration technology.
- Carbon sequestration technologies can dramatically reduce CO_2 emissions by 80-90% from power plants that burn fossil fuels.
- Another reason of importance is forests, which act as carbon sinks and store CO_2 in large amount.
- The use of forests is a financially viable technique to reduce emission. It could also bring significant benefits to local communities involved and consequently helps in reducing poverty.
- Forestry projects can bring social, economic and local environmental benefits to millions of people (Dhanwantri *et al.*, 2015).

Carbon dioxide

- CO_2 is one of the main greenhouse gases that is causing global warming and forcing climate change.
- When fossil fuels are burnt for transportation, heating, cooking, electricity, and manufacturing, we are effectively realizing more carbon into the atmosphere than it is being removed naturally. Ultimately we are causing more carbon concentration into atmosphere.
- As a result we are proceeding on the path of global warming and climate change.



- One of the approaches to reducing CO_2 concentration in the atmosphere is carbon sequestration.

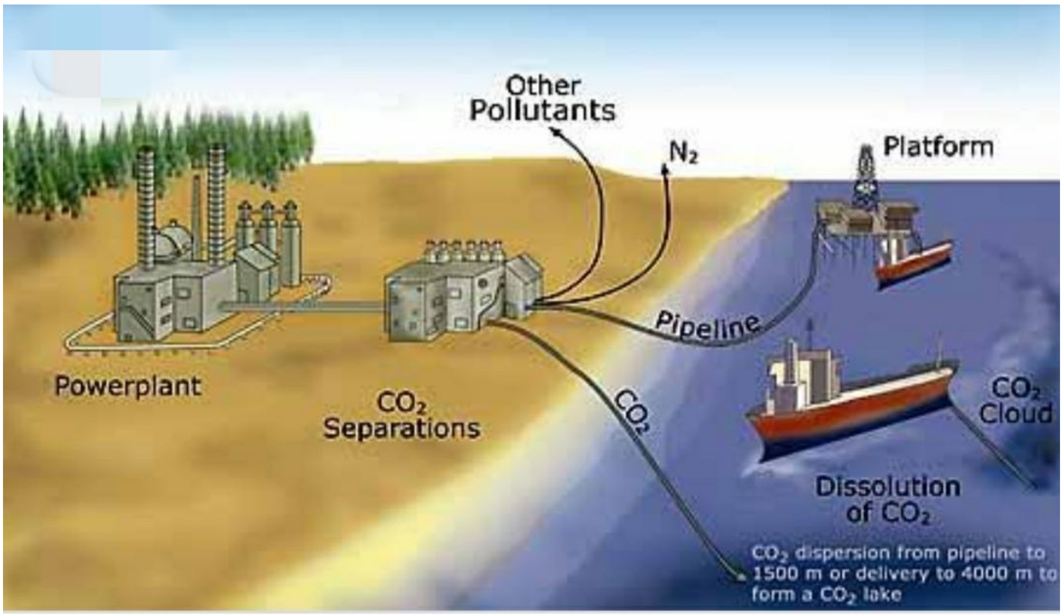
1. Abiotic Sequestration

- Abiotic sequestration is based on physical and chemical reactions and engineering techniques without intervention of living organisms (e.g. plants, microbes).
- The abiotic strategy of C sequestration in oceanic and geological structures has received considerable attention because theoretically abiotic sequestration has a larger sink capacity than biotic sequestration.

a) Ocean Injection

- Carbon sequestration by direct injection into the deep ocean involves the capture, separation, transport, and injection of CO_2 from land or tankers.
- Liquefied CO_2 separated from industrial sources can be injected into the ocean by one of the following four techniques:

a. It is injected below 1000 m from a manifold lying at the ocean floor, and being lighter than water, it rises to approximately 1000 m depth forming a droplet plume.
b. It is also injected as a denser CO_2 seawater mixture at 500–1000 m depth, and the mixture sinks into the deeper ocean
c. It is discharged from a large pipe towed behind a ship (Lal, 2007).



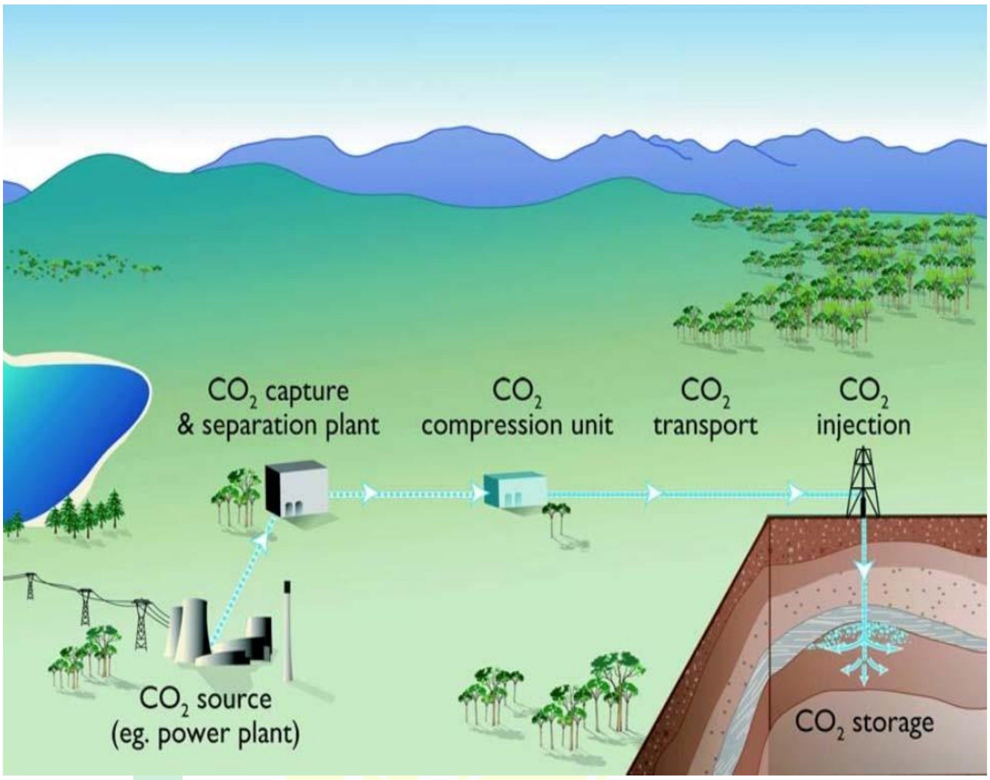
a) Geological Sequestration

- Geological storage involves capturing anthropogenic CO_2 before it enters the atmosphere and injecting it into underground formations.
- Once CO_2 is injected deep underground (typically more than 800 m) it is trapped in minute pores or spaces in the rock structure.
- Underground storage includes injecting CO_2 into:Oil fields, Gas fields, Saline formations, Unminable coal seams have been suggested as storage sites (Lal, 2007)
- CO_2 is captured as concentrated high Pressure fluid.
- CO_2 is shipped as supercritical fluid via pipeline to a selected permitted injection site.
- CO_2 injected at pressure into pore space at depths below and sequestered.

Major storage sites in the world geological injection

- Sleipner, Norwegian north sea
- Altmark, Germany

- Weyburn, Canada

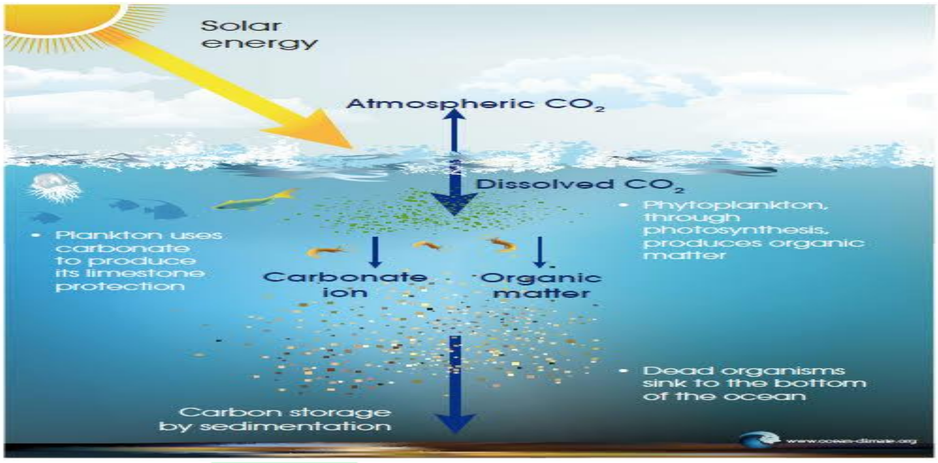


1. **Biotic sequestration**

- Biotic sequestration is based on managed intervention of higher plants and micro-organisms in removing CO_2 from the atmosphere.
- It differs from management options which reduce emission or offset emission.
- Increasing use efficiency of resources is another option for managing the terrestrial C pool
- Some biotic sequestration options are briefly described below.

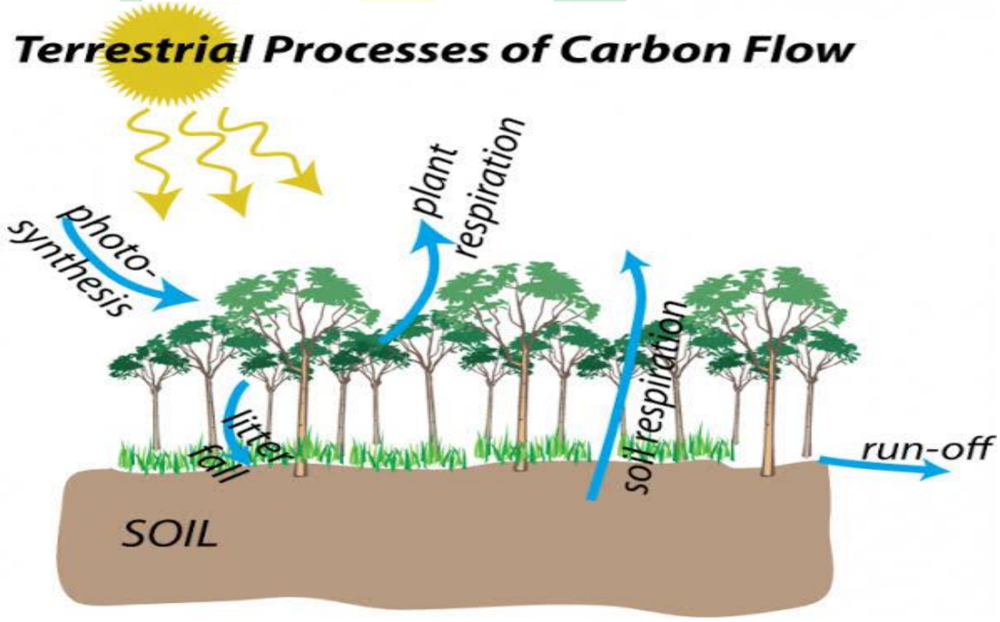
a) **Oceanic sequestration**

- There are several biological processes leading to C sequestration in the ocean through photosynthesis.
- Phytoplankton photosynthesis is one such mechanism, which fixes approximately 45 Pg C yr^{-1}.
- Some of the particulate organic material formed by phytoplankton is deposited at the ocean floor and is thus sequestered (Falkowski *et al.*, 2000).



b) Terrestrial sequestration

- The process through which CO_2 from the atmosphere is absorbed naturally through photosynthesis and stored as carbon in biomass and soils.
- Terrestrial ecosystems constitute a major C sink owing to the photosynthesis and storage of CO_2 in live and dead organic matter. Owing to its numerous ancillary benefits (e.g. improved soil and water quality, restoration of degraded ecosystems, increased crop yield), terrestrial C sequestration is often termed as win–win or no-regrets strategy
- There are three principal components of terrestrial C sequestration: forests, soils and wetlands (Lal *et al.*, 2003).



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c) Forest ecosystems

- Forest ecosystems store C as lignin and other relatively resistant polymeric C compounds.
- Presently, the net rate of C sequestration in forest ecosystems (other than those being deforested) is 1.7±0.5 Pg C yr^{-1}.
- The forest C is sequestered not only in the harvestable timber, but also in woody debris, wood products and other woody plants encroaching upon grasslands (Lal., 2007).

d) Wetlands

- Wetlands and the associated soils or histosols constitute a large pedologic pool estimated at approximately 450 Pg.
- Wetland soils may contain as much as 200 times more C than the associated vegetation.
- It is estimated that C sequestration in wetlands since the post-glaciation period resulted in the C accumulation at the rate of 0.1 Pg C yr^{-1} over 10,000–18,000 years.
- Restoration of wetlands can lead to reversal of the process and make restored wetlands once again a sink of atmospheric CO_2. However, there is a long time lag after the restoration until processes in restored wetlands become similar to those of natural wetlands (Garnett *et al.*, 2001).

e) Soil Carbon Sequestration

- It is the process of transferring carbon dioxide from the atmosphere into the soil through crop residues and other organic solids, and in a form that is not immediately reemitted.
- This transfer or sequestering of carbon helps off-set emissions from fossil fuel combustion and other carbon–emitting activities while enhancing soil quality and long term agronomic productivity.

- Soil carbon sequestration can be accomplished by management systems that add high amounts of biomass in soil, cause minimal soil disturbance, conserve soil and water, improve soil structure, and enhance soil faunal activity.
- Eg. -continuous no-till crop production is a prime example.

Benefits of Soil C sequestration

- Similar to the terrestrial pool, increase in the SOC pool also has numerous ancillary benefits affecting local, regional and global processes.
- Principal benefits of SOC sequestration to soil quality are:

  i. Improvement in soil structure
  ii. Reduction in soil erosion
  iii. Decrease in non-point source pollution,
  iv. Increase in plant-available water reserves
  v. Increase in storage of plant nutrients
  vi. Increase in soil quality
  vii. Increase in agronomic productivity
  viii. Moderation of climate
  ix. Increase in aesthetic and economic value of the soil.

Need of terrestrial Carbon sequestration

- The role of soil the ecosystem is increasingly being recognized with the realization that it has the capacity of reducing the concentration of carbon dioxide (CO_2) in the atmosphere through sequestration of organic carbon in the soil.
- Globally, the soil contains a large carbon pool estimated at approximately 1500 Gt of organic carbon in the first 1 m of the soil profile. This is much higher than the 560 Gt of carbon (C) found in the biotic pool and twice more than atmospheric CO_2.
- By holding this huge carbon stock, the soil is preventing carbon dioxide build up in the atmosphere which will compound the problem of climate change (Abdullahi *et al.,* 2018)
- Also, expected food demand by 2050 is 300 million tones of cereals and must be met from the shrinking land resource base.

- Secondly, there are severe problems of degradation of soil and water resources leading to reduction in use efficiency of inputs
- Emission of greenhouse gases (GHGs) from soil/terrestrial/aquatic ecosystems into the atmosphere.
- Thus, the objective of sustainable development is to increase production per unit area, time and input.
- To enhance quality of soil and water resources and sequester carbon (C) in terrestrial and aquatic ecosystems leading to improvements in quality of natural resources.