Carbon stores in tree biomass, are distributed in different proportions throughout the tree, in the stump, trunk, crown and roots as shown above, and differ for softwood (Pine, Cedar etc.) and hardwood (Teak, Oak etc.) species. The actual rate of carbon sequestration is varying with species, climate and site, but mostly, younger and faster growing trees have higher annual sequestration rates. Considering that one half of the weight of dried wood is carbon, trees in a forest hold a lot of carbon. When the enormous amount of carbon stored in forest soils is added to the trees' carbon, it becomes obvious that forests are major carbon storage reservoirs.

Carbon sequestration: A life saving process on earth
Aradhana Mishra* and Nistha Mishra
Division of Plant Microbe interaction, CSIR-NBRI, Lucknow-INDIA-226001
*mishramyco@yahoo.com

Carbon on the earth
Carbon derived from Latin word carbo "coal", is a non-metallic element with chemical symbol C. It is the 15th and 4th most abundant element in the earth crust and in the universe by mass respectively. Carbon exist naturally as carbon-12 that makes up virtually ninety nine percent of the carbon within the universe; Carbon-13 that makes up concerning one percent; and Carbon-14 that shares very small quantity of carbon, however it is incredibly important in geological dating of organic objects. The component was known to ancient people as charcoal. Carbon is present on earth in the form of carbon dioxide (approximately 36,810 gigatones of carbon), hydrocarbons (coal, petroleum and natural gases) and methane hydrates etc and it is maintained through carbon cycling. The carbon cycle is interlinked with plants, soil and atmosphere which can be clearly exhibited in the Fig.1. Carbon dioxide is utilised by the plants for photosynthesis which in turns gives oxygen for cellular respiration of living organisms. This is the natural carbon cycle in the atmosphere. Due to increased population and industrialisation processes the natural carbon cycle has been disturbed which must be controlled through carbon sequestration processes. There are various other major sources of carbon dioxide emissions in the worldwide areas which is shown in Fig 2. The carbon dioxide released due to anthropogenic activities is consumed by other living systems and is depicted in Fig.3.

![Carbon cycle diagram](image-url)

**Fig-1 Flow of carbon among plant, microbes and soil**
Carbon Sequestration

Carbon sequestration is the process of removal and storage of carbon in its various forms from the atmosphere. It helps in the mitigation of higher carbon-dioxide emissions due to anthropogenic activities. Plants play a major role in carbon cycling, but increased global population and urbanization has disturbed the nutrient cycling resulting higher green house gas emissions.

Global climate change is shaping up to be the defining environmental issue of the 21st century (Srivastava et al. 2012). Its cause has been attributed at least in part to the emission of greenhouse gases, namely carbon dioxide, from the burning of fossil fuels, such as natural gas, oil, and coal for the provision of energy. If human-caused climate change is to be slowed enough to avert the worst consequences of global warming, carbon dioxide emissions from coal-fired power plants and other pollutants will have to be captured and injected deep into the ground to prevent them from being released into the atmosphere. IPCC (Inter Governmental Panel on Climate Change) has taken in the consideration to minimise the global warming due to green house gas emissions. Carbon sequestration, also known as carbon capture and storage, (CCS), to be implemented globally in the coming decades and on such a wide scale that it helps to vastly reduce greenhouse gas emissions.

CCS can be one of the alternatives of many solutions for reducing greenhouse gas emissions in the atmosphere.

There is an urgent need to minimise the global climate change caused by green house gas emissions due to anthropogenic activities.

Types of Carbon Sequestration

(1) Terrestrial Carbon Sequestration

- By improving the agricultural practices such as crop rotation and use of cover crops such as clover and small grains. These agricultural practices are used for protection and improvement of soil between periods of regular crop production.
- By use of less chemical fertilizers which effects soil microbial diversity resulting in the alteration of soil carbon dynamics.
- By using bio-fertilizers which enrich soil microbial diversity and helps in proper nutrient cycling.

(2) Geological Carbon Sequestration

- Storage of CO₂ underground in rock formations able to retain large amounts of CO₂ over a long time period.

(3) Ocean Carbon Sequestration

- Carbon sequestration by direct injection into the deep ocean involves the capture, separation, transport, and injection of carbon-di-oxide from land or tankers.
Ocean has 50 times more carbon than the atmosphere.

**Carbon Sequestration in plants**

The improved agricultural practices can also help in carbon sequestration such as crop rotation with less input of pesticides and herbicides as it disturbs the natural carbon cycling through microbes. Microbes present near the rhizospheric region of plants helps in nutrient cycling of the plants. Mycorrhizal fungus can be used as an additive in disturbed nutrient cycling agricultural areas for proper carbon sequestration (Clemmen Sen et al. 2015, Farrelly et al. 2013). System that uses crop rotation and bio-fertilizers has shown improved level of carbon cycling resulting in reduction of green house gas emissions ultimately minimizing the climate change. Less tillage cropping system must be used as tillage disturbs natural microbial diversity. Fodder crops such as bean sprout etc. must be grown in increased order to sequester carbon for energy use. These crops can accumulate natural carbon dioxide by photosynthesis resulting in their increases biomass, thus the biomass of these crops is used for the feed stock of the animals for energy use. Green manure can also be an alternative approach for replacing the chemical fertilizers which helps in maintaining the natural nutrient cycling of the plants.

**Forest a Carbon sequester:**

Unlike many plants and most crops which have short lifecycle, there are various trees known for good carbon sequestration such as Teak, Eucalyptus, Sal, Poplar etc. forest biomass accumulates carbon over decades and centuries. Tropical forests store approximately 470 billion tonnes of carbon in their biomass and soil are responsible for about one-third of global terrestrial primary productivity. Due to richness in bio-diversity it shows fast nutrient cycling. But due to intense anthropogenic activities and industrialisation the rate of deforestation is increasing which results in higher carbon di oxide emissions and disturbed nutrient cycling in nature.

Reforestation is needed for change climatic scenario. Forest plays a vital role in carbon sequestration. Forest biological systems store more than 80% of all earthly over-the-ground C and more than 70% of all soil organic C (Jobbågy and Jackson, 2000). The annual carbon di oxide exchange amongst forest and the atmosphere by means of photosynthesis and breath is ≈50 Pg C/yr, i.e. 7 times the anthropogenic C discharge (Richards et al. 2004, Sedjo et al 2012, Houghton Richard, 2013). An increase in soil respiration would expand the carbon di oxide emissions from timberland biological communities. Keeping in mind the end goal to relieve environmental change, more C ought to be sequestered in woods biological communities and techniques for an adjusted timberland administration are looked for (Brown et al., 1996).

**High Carbon Capturing Trees**

Teak (*Tectona grandis*) is an important C sequestering plant in forest (Sreejesh et al. 2013). The teak is indigenous to India, Burma, Sri Lanka and the Malaysia 8. It grows over a wide area in the Peninsular India and planted in Uttar Pradesh, Bihar, Orissa and W. Bengal Total area under teak forest in India is about 7,285,000 h.a. of which 3,119,000 h.a. being in Madhya Pradesh. It grows as one of the natural components of deciduous forests and there are plantations of teak in different states. Carbon content of teak is stored in wood, bark, branches and root. Teak is also an important timber tree.

The second important tree in this context is Sal (*Shorea robusta*). The Sal is indigenous to India. There is an unbroken Sal-belt in the Terai region from Ambala in Hariana running straight to the Darrang district of Assam. A patch of Sal forest is also found in Kangra district of Himachal Pradesh to the West, while Sal forests are also seen in Garo hills, Newgong, Kamrup, Khasi and Jaintia hills, Tippera and in Mymensingh district of Bangladesh. Timber of Sal is used in various ways. It is in great demand for sleeper wood, poles and posts, beams and rafters, floor-planks, pit props, bridge, carriages and wagons, wheels, agricultural implements, tent pegs, liquid storage vats, and also for fuel.

**Temperate Forest in Carbon sequestration**

Temperate forest is found in four different climatic seasons a well defined winter and regular precipitation. These are rapid in carbon storage as deforestation has been stopped in this zone. Reforestation helps in increasing biodiversity richness which helps in carbon sequestration and recreation opportunities. These are specified by coniferous species and rich animal and plant diversity.

**Role of Temperate Grasslands in Carbon Sequestration**

A significant area of temperate grassland has been cleared for agriculture so there is need of minimising the human interference in natural vegetation for the prevention of carbon loss.

In the forest community the grassland occurs as the preliminary successional ecosystems. Although the rate of precipitation is low in grassland to support trees but they form natural vegetation (Woodward et al.2004). Although the rate of precipitation in grassland is higher than that of deserts, but it's not enough to support trees, though some natural vegetations are found (Woodward et al. 2004). Due to limited supply of nutrient and water, plants allocate much of their biomass underground and forms slowly decomposing roots. Herbivores increases carbon cycling of large amount of the leaf biomass present in grassland through the process of consumption, respiration and excretion. This is more easily decomposable organic carbon as compared to leaf and
root litter of grasses. Although the plant biomass is lower in temperate grasslands as compared with the forest ecosystems but their soil organic carbon stocks are more than those of temperate forests (Amundson 2001).

**Desert and dry shrub lands**

A global significance is given to the dry land carbon sequestration in spite it having low carbon density as compared to the large surface area it covers. It is assumed that as the most of the dry land soil are degraded they have the ability to sequester higher amount of carbon as they are far from saturation.

The moisture content available determines the carbon cycling in this ecosystem. Owing to low moisture the decomposition process is slowed down resulting in higher content of carbon rich dead organic matter i.e both plant and animal bodies. The vegetation here is sporadic and as the moisture content is low and water availability is limited the plants growing here are succulent in nature having tough tissues to prevent water loss and decomposition. Carbon content of the desert soil has been estimated to be between 14 and 100 tonnes per hectare as estimated by Amundson (2001) which is almost half to that of dry shrub lands where it is estimated to be 270 tonnes per ha (Grace 2004)

Distinctive nations have different perspectives on the most proficient method to number carbon sequestered or discharged from woods. By and large, nations with broad and extending timberslands (e.g., Russia, Canada, Brazil, and the United States) lean toward a full bookkeeping, while nations with less forestland (e.g., numerous European nations) are worried about the possibility to exaggerate the carbon advantages of ranger service administration practices and land utilize changes that improve carbon sequestration. Article 3.3 of the Kyoto Protocol allows counting the carbon effects (both sequestration and release) of afforestation, reforestation, deforestation, other forestry and land use changes that have occurred since 1990, if the change in carbon stock is verified. Verification requires a system for estimating the carbon effects—because a census of carbon changes on every forested acre is infeasible—and for reporting the carbon effects.

For countries with carbon commitments (rather than for projects), the surest, easiest system for verifying the change in carbon levels is to measure the change in the levels from the beginning to the end of the relevant time period—1990 (the baseline) and 2008-2012 (the Kyoto Protocol commitment period); however, this is a very slow and expensive approach. A variety of models can be used for estimating carbon level changes. The two basic approaches are - a "land-based" approach, which begins by identifying the acceptable activities for sequestering carbon and estimating the carbon consequences of those activities, and then monitors the lands to determine the extent to which those activities occur; and an "activity-based" approach, which also begins by identifying the acceptable activities for sequestering carbon and estimating the carbon consequences of those activities, and then monitors the activities to determine the extent to which those activities occur. Tropical timberland assumes a key part in the worldwide carbon cycle because of the expansive measure of carbon at present put away there. Woodland environments contain more than three fourth of the earthbound vegetation carbon, which is put away in stems, branches, foliage what's more, underlying foundations of trees (Bolin and Sukumar 2000).

**Variables of carbon in forest**

- **Live Biomass**: It directly helps in accumulation of carbon-di-oxide during the photosynthesis. Woody Debris and litter are decomposed by microbes and recycled in soil. Microbes help in recycling of nutrients which is taken by plants for its growth and development.

- **Soil Organic Matter**: The primary mode of carbon storage in soil is in form of soil organic matter which is formed by the decomposition of plant and animal residues at various stages by microbes (protozoa, bacteria, fungus and nematodes). Carbon can remain stored in soils for millennia, or be quickly released back into the atmosphere. Climatic conditions, natural vegetation, soil texture and drainage all affect the amount and length of time carbon is stored.

**Activities which increases carbon sequestration in forest**

- **Reduce use of forestland to non forest use**: The forestland must be maintained for the plants as due to urbanisation forest are cut and land are used for making recreational places.

- **Improve forest management**: Forest management is an important activity that affects the global carbon stock, and therefore needs to be studied to further understand how its different practices can aid in greenhouse gas reduction efforts.

- **Increase agro forestry**: Agro forestry or agrosylviculture is a land utilizing system in which trees or bushes are developed around or among yield or pastureland. It joins bushes and trees in agrarian and ranger service advancements to make more various, gainful, beneficial, solid, naturally stable and reasonable land-utilizing system.

**Carbon sequestration in aquatic ecosystem**

Almost 50% of the worldwide essential efficiency happens in the vast sea — overwhelmingly exceptionally close to the surface. The sequestration of carbon in the seas happens by two procedures. It might happen by the solubility pump; and by photosynthesis. The solvency pump misuses the dissolvability of carbon di oxide in water. As carbonates are shaped in the water, convection
streams and sea ebbs and flows transport water exceptionally packed with CO$_2$ into the profound sea where it stays for drawn out stretches of time. CO$_2$ is exchanged from the environment to the surface of the seas, and minute plants called phytoplankton (that make the sea look green) devour carbon from the sea Fig-4. This procedure is totally undifferentiated from earthbound utilization of CO$_2$ by trees and plants. Be that as it may, the extremely dynamic nature of the seas the streams and waves – make understanding where and for to what extent the carbon is sequestered in the sea an exceptionally difficult issue (Doney et al. 2012). We do realize that lone approx 10% of the CO$_2$ consumed at the surface sinks to 100m, where it may be held for a couple of decades. Notwithstanding, just approx 0.1% of the CO$_2$ is really sequestered at the base of the sea.

surrounding water; gradually dissolving into that water over time.

Another method is geological sequestration where the carbon dioxide is pumped into underground chambers such as old oil reservoirs, aquifers and coal seams that are unable to be mined.

Mineral sequestration is also being considered. In this method, carbon dioxide is injected into areas rich in Magnesium or Calcium. The carbon dioxide will react with those elements and combine to form calcium carbonate (limestone) and magnesium carbonate (magnetite).

**Urge and status of Carbon Sequestration**

Carbon sequestration is needed for changing climatic conditions to maintain biogeochemical cycling of carbon element. Researchers progressively comprehend the components by which different land-utilize practices can sequester carbon. Such practices incorporate the presentation of cover yields on neglected land, the change of routine culturing to protection culturing, and the retirement of land from dynamic creation to a grass cover or trees. Be that as it may, the strategy plan for executing carbon sequestration exercises is as yet being produced, and noteworthy vulnerabilities remain concerning the cost adequacy of carbon sequestration with respect to other environmental change relief methodologies. Some of the major carbon sequestering trees is described below:

**Management of Carbon Sequestration**

There is two approaches of carbon sequestration, natural and artificial which are already mentioned above. Artificial carbon sequestration refers to a number of processes whereby carbon emissions are captured at the point of product and then, well, buried.

One proposed method is ocean sequestration whereby carbon dioxide is injected deep into the ocean, forming lakes of CO$_2$. In theory, the carbon dioxide will stay down deep due to the pressure and temperature of the
### Abstracts

**Does canopy nitrogen uptake enhance carbon sequestration by trees?**

Richard K. F. Nair, Micheal P. Perks, Andrew Weatherall, Elizabeth M. Baggs, Maurizio Mencuccini

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Temperate forest 15N isotope trace experiments find nitrogen (N) addition-driven carbon (C) uptake is modest as little additional N is acquired by trees; however, several correlations of ambient N deposition against forest productivity imply a greater effect of atmospheric nitrogen deposition than these studies. We asked whether N deposition experiments adequately represent all processes found in ambient conditions. In particular, experiments typically apply 15N to directly to forest floors, assuming uptake of nitrogen intercepted by canopies (CNU) is minimal. Additionally, conventional 15N additions typically trace mineral 15N additions rather than litter N recycling and may increase total N inputs above ambient levels. To test the importance of CNU and recycled N to tree nutrition, we conducted a mesocosm experiment, applying 54 g N/15N ha⁻¹ yr⁻¹ to Sitka spruce saplings. We compared tree and soil 15N recovery among treatments where enrichment was due to either (1) a 15N-enriched litter layer, or mineral 15N additions to (2) the soil or (3) the canopy. We found that 60% of 15N applied to the canopy was recovered above ground (in needles, stem and branches) while only 21% of 15N applied to the soil was found in these pools. 15N recovery from litter was low and highly variable. 15N partitioning among biomass pools and age classes also differed among treatments, with twice as much 15N found in woody biomass when deposited on the canopy than soil. Stoichiometrically calculated N effect on C uptake from 15N applied to the soil, scaled to real-world conditions, was 43 kg C kg N⁻¹, similar to manipulation studies. The effect from the canopy treatment was 114 kg C kg N⁻¹. Canopy treatments may be critical to accurately represent N deposition in the field and may address the discrepancy between manipulative and correlative studies.

**Reclamation patterns vary carbon sequestration by trees and soils in an opencast coal mine, China**

Ye Yuana, Zhongqiu Zhaoa, Zhongke Baia, Huaiquan Wanga, Yingzhe Wanga, Shuye Niua

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Reforestation is often recommended for ecological restoration in mining areas because of tree's high stand-level productivity and satisfied carbon (C) and other nutrient sequestration objectives. However, the C sequestration efficiency of different plantation patterns or