25. GLOBAL WARMING - PHYSIOLOGICAL EFFECTS ON CROP PRODUCTIVITY

GLOBAL WARMING (Green house Effect)

In general, delicate plants which require protection from weather are grown in green house (glass house). In green house so many gases are produced like CO_2, water vapour, methane, oxides of nitrogen and chloro fluoro carbon (CFC). These gases are produced from plants and accumulated inside the glass house; as a result glass house gets warming. In natural atmosphere also the same effect occurs i.e. global warming (due to the release of gases from plants).

But in glass house, glass roof is present to prevent the escape of gases from the glass house. In natural atmosphere, the gases such as ozone, water vapour, CO_2 methane etc. form a layer on the lower atmosphere and this layer prevents the heat escaping from the earth. If heat is released or escaped from earth, the temperature of earth would be below freezing point. The accumulation of heat or gases causes the warming of earth surface and leads to global warming.

Global warming leads to the following effects:

1. Rise in temperature
2. Average rise in the level of sea (about 6 cm/decade) due to melting of polar ice.
3. Steady increase (enrichment) in the CO_2.

Atmosphere – (5.1 x 10^{18}kg)
Lithosphere - (1.5 x 10^{22} kg) are in a dynamic equilibrium
Hydrosphere – 1.4 x 10^{22} kg)
Biosphere – 1.2 x 10^{15} kg (dry wt.)

CO_2 fixation by green plants

Total area of green plants 510 x10^6 km^2

CO_2 fixed – 1.39 x 10^{14} kg $year^{-1}$ (0.27 kg m^{-2} $year^{-1}$)

Light utilization:

A small portion of radiant energy (400 – 700 nm) is reaching the earth's surface

0.1 – 1.0 % utilized under natural vegetation or ordinary agriculture

2.0 – 2.5 % under intensive agriculture

6.0 – 10.0 % in some crop plants

20.0 – 25.0 % under laboratory condition

Biosphere:

O_2 in atmosphere - 1.1×10^{18} kg

O_2 released by photosynthesis - 5.1×10^{14} kg $year^{-1}$

CO_2 content - 5×10^{16} kg (mostly dissolved in sea)

CO_2 consumed by photosynthesis - 7×10^{14} kg $year^{-1}$

Human activities disturbed the global ecosystem (MST- mesospheric, Stratospheric, Troposphere)

Landscape modification

Resource exploitation

Effluent flow

High temperature

Rainfall redistribution

Increased UV-B radiation due to stratospheric O_3 depletion

Increased level of atmospheric CO_2

Other green house gases

Transparent to incoming short wave radiation

Absorb short wave and emit long wave radiation

Net emission of CO_2

Bacterial fermentation in the anaerobic rice fields generate 120 million ton CH_4 every year

Ruminant gut bacteria produce 78 m tons of CH_4 every year and are released by Flatulence

Green house gases

CO_2, CH_4, NO, NO_2, N_2O, (N_xO_x), $CFCl_3$, CF_2Cl_2, CFMs, O_3, H_2O

Fossil fuel reserves are large enough for climatic changes to occur, if these reserves continue to be exploited at a higher rate in future

CO_2 enrichment and crop productivity

1. CO_2 enrichment leads to increased photosynthesis and productivity
2. CO_2 enrichment also decreases stomatal conductance by closing the stomata, thee by decrease the transpiration / unit area of the leaf.
3. In C_3 plant the efficiency of RuBP carboxylase enzyme is increased
4. Increased CO_2 concentration inhibits photorespiration in plants
5. CO_2 enrichment increased the yield and yield components.

Other green house gases

1. Oxides of nitrogen (NO, NO_2, N_2O molecular N_2) cause phototoxic, bleaching and necrosis (drying of tissues) in plants.
2. Ozone (O_3) causes ozone injury to the plants.

Remedial measures for green house effect

- Reduction in the use of fossil fuel
- Use of alternative sources of energy (renewable energy)
- Afforestation and community forestry
- Avoiding the use of CFCs and nuclear explosions
- Environmental awareness

Direct effect of CO_2 increase in the absence of climatic change

- Doubling of CO_2 from 340 to 680 ppm increases 0 – 10 % increase in yield of C_4 plants(maize, sorghum, sugarcane) and 10 – 50 % increase in yield in C3 plants (wheat, soybean, rice) depending upon specific crop and growing conditions
- Greater yield benefit accrue to the regions where the C_3 rather than C_4 crops dominate
- Higher CO_2 conc. reduces stomatal aperture, thereby reducing transpiration and WUE
- Doubling of CO_2 will cause about 40 % decrease in stomatal conductance in short term

Law of limiting factor:

- When other environmental factors such as water, light, minerals & temperature limit yield, then higher conc. of CO_2 will have little or no effect.
- This generalizing concept has been challenged
- In certain stressful environments, the relative photosynthesis increased with increased in CO_2 conc.

C_3 – 95 % of world's biomass is of the C_3 category

- In C_3, O_2 compete with CO_2 for the site of Rubisco – In C_4, O_2 is not compete with CO_2 for the site of PEPCase
- At 340 ppm CO_2, in the absence of O_2 Rubisco operating only at ½ to ¾ of its substrate – saturated capacity
- PEPCase has high affinity for CO_2 than Rubisco – PEPCase is close to CO_2 saturation at the present atmospheric CO_2 conc., no significant enhance of C_4 crop growth from increased CO_2 so far as PEP Case is concerned

Carbon Sequestration

Climate change is one of the most important global environmental challenges, with its implications on food production, water supply, healthy energy etc… are detrimental. Historically the responsibility of green house gas emission increase lies largely with the industrialized world and the developing countries are contributing very less amount only. (Jayant & Santhaye, 2006)

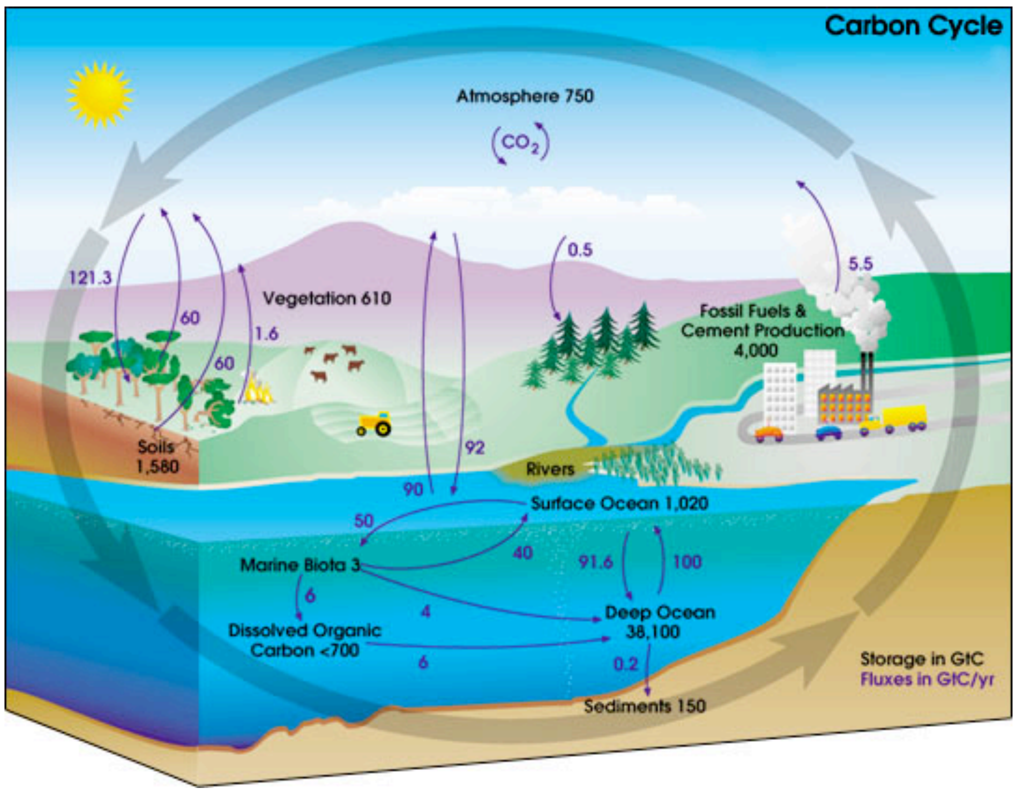
The increase in atmospheric concentration of CO_2 by 31% since 1950 from fossil fuel consumption and land use change indicates the threats of global warming since industrial revolution increases the global emission of carbon, estimated at 270 ±30 billion ton emission due to land use change include those by deforestation, due to agriculture and land use changes contributes 78 ± 12 billion ton of carbon to the atmosphere. Well planned management practices enhances bio mass production, purifies surface and ground waters and reduces the rate of enrichment of atmospheric CO_2 due to fossil fuel (Lal, 2004)

The Kyoto protocol is a positive first step to prevent climatic change at global level and the responsibility going to each and every human being (Ravindranath, 2006).

The annual soil organic carbon (SOC) enrichment of atmospheric CO_2 has to be reduced. The annual SOC sequestration potential is only 0.9 ±0.3 Pg C/year. The CO_2 level in atmosphere increase at the rate of 2.0-2.6 Pg C / year. So soil carbon sequestration methodologies plays significant role in reducing atmospheric CO_2 control (Lal, 2004)

Besides the artificial CO_2 capture and storage methods also play a significant role to cut down the increasing atmospheric CO_2 concentration. (IPCC, 2001)

Even though all the industrial and other carbon emissions cannot be controlled by soil carbon sequestration, it may be a viable method until a permanent solution found out.



A **carbon dioxide (CO_2) sink** is a carbon dioxide reservoir that is increasing in size, and is the opposite of a carbon dioxide "source". The main natural sinks are (1) the oceans and (2) plants and other organisms that use photosynthesis to remove carbon from the atmosphere by incorporating it into biomass and release oxygen into the atmosphere. The process by which carbon dioxide sinks (natural and artificial) remove CO_2 from the atmosphere is known as carbon sequestration.

Storage in vegetation and soils

Carbon stored in soils oxidizes rapidly; this, in addition to high rainfall levels, is the reason why tropical jungles have very thin organic soils. The forest eco-system may eventually become carbon neutral. Forest fires release absorbed carbon back into the atmosphere, as does deforestation due to rapidly increased oxidation of soil organic matter.

The dead trees, plants, and moss in peat bogs undergo slow anaerobic decomposition below the surface of the bog. This process is slow enough that in many cases the bog grows rapidly and fixes more carbon from the atmosphere than is released. Over time, the peat grows deeper. Peat bogs inter approximately one-quarter of the carbon stored in land plants and soils.

Under some conditions, forests and peat bogs may become sources of CO_2, such as when a forest is flooded by the construction of a hydroelectric dam. Unless the forests and peat are harvested before flooding, the rotting vegetation is a source of CO_2 and methane comparable in magnitude to the amount of carbon released by a fossil-fuel powered plant of equivalent power.

Oceans

Oceans are natural CO_2 sinks, and represent the largest active carbon sink on Earth. This role as a sink for CO_2 is driven by two processes, the solubility pump and the biological pump.[6] The former is primarily a function of differential CO_2 solubility in seawater and the thermohaline circulation, while the latter is the sum of a series of biological processes that transport carbon (in organic and inorganic forms) from the surface euphotic zone to the ocean's interior. A small fraction of the organic carbon transported by the biological pump to the seafloor is buried in anoxic conditions under sediments and ultimately forms fossil fuels such as oil and natural gas.

One way to increase the carbon sequestration efficiency of the oceans is to add micrometre-sized iron particles in the form of either hematite (iron oxide) or melanterite (iron sulfate) to certain regions of the ocean. This has the effect of stimulating growth of plankton. Iron is an important nutrient for phytoplankton, usually made available via upwelling along the continental shelves, inflows from rivers and streams, as well as deposition of dust suspended in the atmosphere. Natural sources of ocean iron have been declining in recent decades, contributing to an overall decline in ocean productivity (NASA, 2003). Yet in the presence of iron nutrients plankton populations quickly grow, or 'bloom', expanding the base of biomass productivity throughout the region and removing significant quantities of CO_2 from the atmosphere via photosynthesis. A test in 2002 in the Southern Ocean around Antarctica suggests that between 10,000 and 100,000 carbon atoms are sunk for each iron atom added to the water. More recent work in Germany (2005) suggests that any biomass carbon in the oceans, whether exported to depth or recycled in the euphotic zone, represents long-term storage of carbon. This means that application of iron nutrients in select parts of the oceans, at appropriate scales, could have the combined effect of restoring ocean productivity while at the same time mitigating the effects of human caused emissions of carbon dioxide to the atmosphere.

Because the effect of periodic small scale phytoplankton blooms on ocean ecosystems is unclear, more studies would be helpful. Phytoplankton have a complex effect on cloud formation via the release of substances such as dimethyl sulfide (DMS) that are converted to sulfate aerosols in the atmosphere, providing cloud condensation nuclei, or CCN. But the effect of small scale plankton blooms on overall DMS production is unknown.

Other nutrients such as nitrates, phosphates, and silica as well as iron may cause ocean fertilization. There has been some speculation that using pulses of fertilization (around 20 days in length) may be more effective at getting carbon to ocean floor than sustained fertilization.

There is some controversy over seeding the oceans with iron however, due to the potential for increased toxic phytoplankton growth (e.g. "red tide"), declining water quality due to overgrowth, and increasing anoxia in areas harming other sea-life such as zooplankton, fish, coral, etc.

Soils

Methods that significantly enhance carbon sequestration in soil include no-till farming, residue mulching, cover cropping, and crop rotation, all of which are more widely used in organic farming than in conventional farming. Because only 5% of US farmland currently uses no-till and residue mulching, there is a large potential for carbon sequestration.[26]

Conversion to pastureland, particularly with good management of grazing, can sequester even more carbon in the soil.

Terra preta, an anthropogenic, high-carbon soil, is also being investigated as a sequestration mechanism. By pyrolysing biomass, about half of its carbon can be reduced to charcoal, which can persist in the soil for centuries, and makes a useful soil amendment, especially in tropical soils (*biochar* or *agrichar*).
Savanna

Artificial sequestration

For carbon to be sequestered artificially (i.e. not using the natural processes of the carbon cycle) it must first be captured, *or* it must be significantly delayed or prevented from being re-released into the atmosphere (by combustion, decay, etc.) from an existing carbon-rich material, by being incorporated into an enduring usage (such as in construction). Thereafter it can be passively stored *or* remain productively utilized over time in a variety of ways.

For example, upon harvesting, wood (as a carbon-rich material) can be immediately burned or otherwise serve as a fuel, returning its carbon to the atmosphere, *or* it can be incorporated into construction or a range of other durable products, thus sequestering its carbon over years or even centuries. One ton of dry wood is equivalent to 1.8 tons of Carbon dioxide.

Geological sequestration

The method of *geo-sequestration* or *geological storage* involves injecting carbon dioxide directly into underground geological formations. Declining oil fields, saline aquifers, and unminable coal seams have been suggested as storage sites. Caverns and old mines that are commonly used to store natural gas are not considered, because of a lack of storage safety.

Mineral sequestration

Mineral sequestration aims to trap carbon in the form of solid carbonate salts. This process occurs slowly in nature and is responsible for the deposition and accumulation of limestone (calcium carbonate) over geologic time. Carbonic acid in groundwater slowly reacts with complex silicates to dissolve calcium, magnesium, alkalis and silica and leave a residue of clay minerals. The dissolved calcium and magnesium react with bicarbonate to precipitate calcium and magnesium carbonates, a process that organisms use to make shells. When the organisms die, their shells are deposited as sediment and eventually turn into limestone. Limestones have accumulated over billions of years of geologic time and contain much of Earth's carbon. Ongoing research aims to speed up similar reactions involving alkali carbonates.