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Earth Climate and Plants as Climate Change Mitigators

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Abstract

Climate change is one of the most potent universal environmental challenges faced by humankind with close connection for food production, natural ecosystems, freshwater supply, health, etc. The changing lifestyle (industrialization, urbanization, population explosion, changed eating habits, more fuel dependency etc.) has resulted in overburdening of the ecosystem resources and lot of greenhouse gas emissions resulting into global warming and climate change. According to recent scientific estimation, the earth's climate system has changed both universally and regionaly since pre-industrial time. Scientific data shows that most of the warming (0.1°C per decade) experiential over the last 50 years, is due to activities of man. Climate change is affecting the vegetation and leading to their habitat fragmentation, phenological variations, spread of invasive species, increased number of forest fires, pest attacks and extinctions. This review article discusses the impacts of climate change on plants and how plants could be used as mitigators of climate change. Trees can prevent climate change by sequestering carbon dioxide, a very potent greenhouse gas and storing it in their biomass, in roots, as phytoliths, bioenergy crops and by afforestation, reforestation and agroforestry practices. Thus by planting trees and leading a fuel efficient and sustainable lifestyle can further combat climate change.

Keywords: Climate change, Lifestyle, Plants, Carbon sequestration, Climate change mitigation.

Introduction

Climate system is a multifarious, interactive organization consisting of air, land, snow, ice, oceans, other water resources and living organisms. Climate change refers to an analytic substantial change in either the mean state of the climate or in its unpredictability (regarding temperature, pressure, rainfall etc.) continuing for a long period (usually decades or more).

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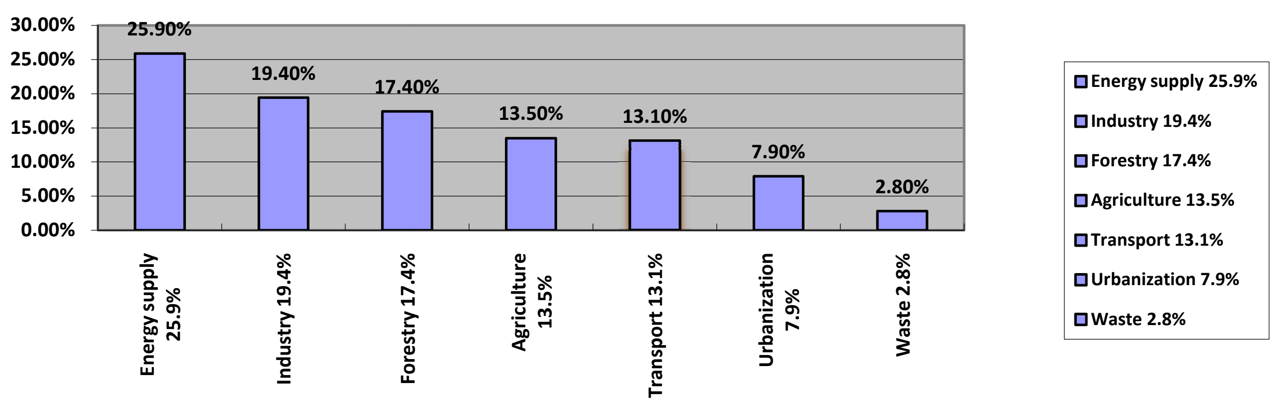

Figure-1
Sectoral GHG emission[2]

Impact of the climate change on plants: Climate is perhaps the most significant determinant of flora patterns universally and has significant control on the distribution, composition and ecology of forests. Several studies relating to climate and vegetation interaction have revealed that definite climatic regimes are related with particular plant communities and hence it may lead to supposition that changing climate would change the entire ecosystem[3].

Climate change is affecting the vegetation and leading to their habitat fragmentation, by shift in vegetation towards a higher altitude: in Nainital it is reported that species such as *Berberis asiatica, Taraxacum officinale, Jasminum officinale* found in tropical and sub-tropical zone, have shifted their distribution to higher sub-temperate zone. Climate change has also lead to spread of invasive species (*Lantana camara*, *Parthenium hysterophorous, Ageratum conyzoides*) as they have high endurance against harsh environment and greater flexibility in wide range of environmental conditions, good water, light and nutrient use efficiencies, very short dormancy period, high yield and high reproductive power[4].

Changes in phenological behaviour owing to climate change have resulted in longer growing seasons, early flowering and early harvesting[2]. Increasing forest fire is predicted to increase causing blow-down and widespread decline of the world forests[5]. Increase in the pest attacks (fungi and bacteria) due to vulnerability of plants subjected to greater environmental stress[6]. Plant productivity: Increasing level of atmospheric carbon dioxide (CO_2) is expected to increase the growth pace of plants, crop yield and net primary productivity of forest and enhance their biomass. However, decline in soil water and accumulation of starch in plants may limit their growth[5]. Extinction: The plants may migrate, adapt or extirpate in this rapidly changing environment. A global study analyzed that around 3% to 38% plant species may become extinct by 2050 due to climate change. Species less likely to get extinct may be those that can adapt and migrate quickly with seeds competent of extensive dispersal, and shorter life span[6].

Carbon Sequestration

Carbon sequestration is the exclusion of CO_2 from environment into green plants (sink) where it can be stored for a long time.

Global carbon cycling relies mostly on the photosynthetic uptake of atmospheric CO_2. The total carbon in terrestrial systems (soil and plant) is estimated to be around 3170 gigatons (GT) and in the oceans is 38,000 GT[7].

Of the total carbon present in the world 99.9% is contributed by vegetation. Plants can play two basically different roles as carbon sinks by taking atmospheric CO_2 through photosynthesis and storing it as biomass. Secondly, long-term carbon sequestration can be achieved when carbon is transfered to the roots and enters the pool of soil carbon or as biochar or phytoliths[8].

Plant root and carbon sequestration: Roots act as primary vector for carbon entering the soil. The quantity of carbon stored in the soil is about four times more than that stored in the plants. The grasslands which cover 50% of the Earth's surface sequester 98% of the total carbon in roots and soil, which globally accounts for 8% of the world's soil carbon[9]. Soil carbon variability depends on factors like climate, flora type, nutrient accessibility, interruption, land use and management practices[10].

Phytoliths: Phytoliths or plant opals are silicified granules that form owing to biomineralization within plants. Plants take in silica in the form of silicic acid which accumulates all over their leaf, stem and root. The carbon concealed in phytoliths is extremely resistant to oxidation and disintegration. Some plants belonging to Poaceae (bamboo, barley, maize, rice, sorghum, sugarcane and wheat) and Cyperaceae are usually major producers of phytoliths and enhance the terrestrial sequestration of carbon. The leaf-litter of bamboos sequester up to 0.7 tonnes of CO_2 equivalents/ha/yr, which would result in biosequestration of 15.6 million tones of CO_2 equivalents per year, equal to 11% of the current rise in atmospheric CO_2[11].

In plant products: Tree wood and bamboo are used in construction of buildings, houses, furniture, and other things, hence sequester carbon over hundreds of years. US Forest Service in 2008 predicted that 90 megatons of sequestered carbon was found captured in plant products universally[9].

Bio-energy crops-Plants and Algae: Bioenergy crop is any plant used to produce bioenergy. Today, sugarcane, oil crops, maize and wheat are largest contributors to bioenergy and sequester 4.4 million grams of carbon per ha per year[9].

In India 952 million acres of land under jatropha cultivation would be required to meet the demand of 200 billion gallons of bio-diesel per year. In case of algal culture only 13 million acres area of algae ponds would be sufficient for the same. Algae comprises of three main components: carbohydrate, protein and natural oils from which the oil content may exceed 80% of biomass. Hence algae can be used to produce fuels like methane gas, ethanol, bio-diesel and electricity. Algae are capable of sequestering 1,000 tonnes of CO_2 per acre per year[12] (Figure-2).

Plants and carbon sequestration potential: Trees: It was found from the work done on computation of carbon stock of 60 trees of the Gujarat University campus, Ahmedabad that maximum carbon sequestration was in *Terminalia chebula* Retz (76.93 t) followed by *Pithecellobium dulce* (Roxb) Bth (65.88 t) *Limonia acidissima* L (61.31 t) and many more. Such trees with good carbon sequestration capacity (having high specific density, fast growing with huge canopy) can act as best mitigators of climate change. The study also concluded the trees like *Acacia nilotica* (L) Del (2.48 t) and members of family Palmae sequester least amount of carbon[13].

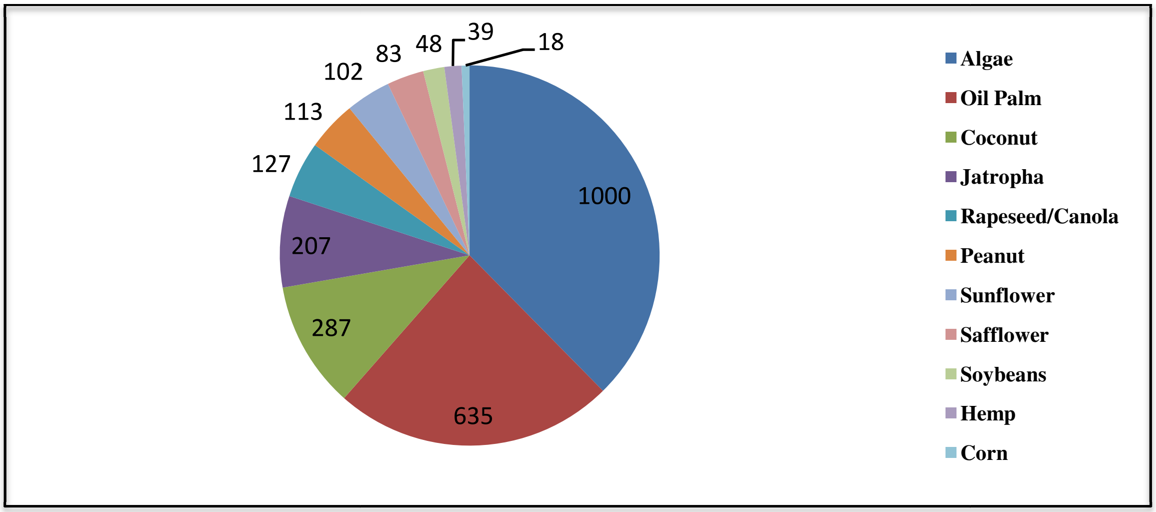

Figure-2
Comparison of some sources of biofuel[12]

The largest proportion about 55 percent of carbon sequestration occurs in the tree biomass, 35 percent in the soil, 7 percent with litter and around 3 percent by the by products. Scientists have reported that forest ecosystems dominated by conifers store carbon more proficiently than ecosystems dominated by deciduous trees. Conifers have leaf canopy throughout the year hence carbon loss is less by respiration and leaf fall which is more in case of deciduous trees[14]. Negi *et al.* from their experiment on biomass also concluded that the maximum carbon is stored by conifers followed by deciduous trees, then evergreen trees and least by bamboos[15].

Shrubs: Shrubs like *Atriplex*, *Ephedra*, *Hippophae*, *Sophora*, *Tanacetum*, *Rosa*, *Berberis*, *Myricaria* and *Tamarix* have a high carbon sequestration potential as their biomass increases very fast[16].

Grass: Grasslands contribute to soil organic matter; mostly in the form of soil and roots (70 t ha^{-1}) much of this can remain un-oxidised for long periods. Bamboo grass grows very fast and produces enormous amount of biomass which is equivalent to 15 km of usable pole of 30 cm diameter within 35 years[11].
Vetiveria zizanioides (L.), a C_4 grass is used in soil conservation, land rehabilitation, pollution mitigation and producing fuel like ethanol and biofuels like dimethylfuran18 owing to its fast-growing roots sequestering 100–120 tonnes of carbon/ha/year[8]. Similarly, switch grass (*Panicum virgatum* L.) was found to increase soil carbon of degraded land by 12% in ten years[17].

C_3, C_4 and CAM plants: C_4 plants, including switchgrass, *Miscanthus* and *Vetiveria* grass have significantly higher light saturation points, they are more competent than C_3 plants in converting light energy to biomass, C_4 plants flourishing in tropical and subtropical areas, have developed enzymatic and anatomical features that concentrate CO_2 at the site of rubisco and C_4 plants show least or no photorespiration[9]. The chlorophyll content in C_4 plants is more in comparision to C_3 and CAM plants[18].

Afforestation, reforestation: CO_2 emissions from deforestation are about 2 billion tC/year which is thrice the emission from automobiles. Reforestation is a significant cost effective and practical method for climate change mitigation. Climate change problem could be solved just by planting 500 million hectares of plantations.

Forests play a major role in climate change as they emit as well as sequester CO_2. It stores about 80% of all above-ground and 40% of all below-ground terrestrial organic carbon. Forests sequester 20 to 100 times more carbon per unit area than agricultural fields. The carbon pool for the Indian forest is predicted to be 2026.72 million tones. It is likely that organizing the world's vegetation could turn the terrestrial biosphere from a source of carbon (0.1-4.2 Pg carbon per year) to a carbon sink (1.3-3 Pg carbon per year)[19].

Forests with nitrogen-fixing trees (*Albizzia*, *Leucaena*, *Casuarina, Prosopis* and *Acacia*) accumulate more carbon in soils than similar forests without N–fixing trees. Soils beneath N–fixing trees sequestered 0.11 kg/m^2/year of total soil organic carbon compared with no change under non-nitrogen fixers (*Eucalyptus*)[20]. *Prosopis juliflora* grown in semi-arid region on salt-affected soils in north-west India enhanced the soil organic carbon pool from 10 t ha^{-1} to 45 t ha^{-1} over an eight year period[17].

The Kyoto Protocol recognizes three probable 'flexibility mechanisms' for countries to meet the emission reduction target: joint implementation, clean development mechanism (CDM) and emission trading. The CDM would make possible carbon sequestration and storage investments in the reforestation, afforestation and in cutting down deforestation to be eligible for emission reduction credits[21].

Agroforestry: Carbon sequestration through biomass is an economical and feasible option. On comparision of carbon sequestration potential of plantation, agroforestry and rainforest for 20-30 years it was concluded that plantations sequester 100-200t/ha, agroforestry 90-150t/ha and rainforest 300-400t/ha of carbon. Forest and plantation sequester maximum carbon but cannot be expanded to huge areas due to urbanization and agricultural lands. Hence, agroforestry is the best method of carbon sequestration, biodiversity conservation and is also a source of financial profit to the society[22].

Agroforestry plantation of willow and poplar in Nubra Valley (Trans-Himalayan region) have been found to sequester more than 75,000 tonnes of carbon. According to Intergovernmental Panel on Climate Change (IPCC) agroforestry practices may remove 40-80 Pg of the carbon in the next 50–100 years[16].

Plants as bio-sinks to pollutants: Plants not only absorb CO_2 and O_2 but also take in many pollutants during photosynthesis and respiration. D. Saha in 1998 found that the crop species *Zea mays*, *Apium gravelous*, *Citrus* spp. can tolerate 2 ppm/8 hrs of SO_2, while, tree species like *Anogeissus latifolia*, *Azadirachta indica*, *Bauhinia racemosa* can tolerate around 2-5 mg/g dry weight of SO_2. N_2O, the third most potent greenhouse gas has been found to be absorbed by crops like barley, wheat, sugarcane, grapes, tomato and maize at the rate of 40-150 kg/h. *Ginkgo biloba*, *Quercus pendunculata*, *Taxus baccata*, *Pinus austriaca* can tolerate nitrogen oxides at a concentration of 10ppm/4-8hrs and *Carissa carandas*, *Codiam variegatum*, *Juniperus coniferatas* can tolerate 15 ppm/4hr of nitrous oxides. Ozone (O_3) another greenhouse gas is found to be absorbed by beet, Geranium, cucumber, cotton, lettuce, bur oak and Siberian elm at the rate of 53-56ppm/4hrs[23].

Religious taboo: Humans intuitively gain aesthetic and divine happiness from biodiversity. Recent studies have confirmed that our emotional health is improved by the propinquity of natural beauty. This is the very reason, we may put forward for the worship of *Ficus benghalensis, Ficus religiosa, Ocimum sanctum* and many more such plants which was done by our ancestors and is still being followed by us. This is a very good way by which we tag a plant to be religious and hence it can be conserved from being cut down.

Conclusion

Climate change is affecting the vegetation and leading to their habitat fragmentation, phenological variations, spread of invasive species, increased forest fires, pest attacks and extinctions. This review article discusses the impacts of climate change on plants and how plants could be used as mitigators of climate change. The tree not only provide us with timber, pulpwood, energy biomass but also control long-term erosion, improve water quality, storing carbon in biomass help in energy and wildlife conservation and restore natural diversity. Trees can prevent climate change by sequestering carbon dioxide, a very potent greenhouse gas and storing it in their biomass, in roots, as phytoliths and by afforestation, reforestation and agroforestry practices. Thus by planting trees and leading a fuel efficient and sustainable lifestyle can further combat climate change.

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