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Review- IMPORTANCE OF ASSESSING CARBON SEQUESTRATION POTENTIAL IN FOREST AND URBAN AREAS

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ABSTRACT:

World is facing tremendous pressure due to increasing concentrations of carbon dioxide and other greenhouse gases (GHG) in the Earth's atmosphere have the potential to enhance the natural greenhouse effect, which may result in climatic changes. The main anthropogenic contributors to this increase are fossil fuel combustion, land use conversion, and soil cultivation. It is clear that overcoming the challenge of global climate change will require a combination of approaches, including increased energy efficiency, energy conservation, alternative energy sources, and carbon capture and sequestration. Sequestration is a major tool for managing carbon emissions. The present study appraised the importance of assessing carbon sequestration potential in both forest and urban areas in terms of i. Above ground biomass (Both litter and wood stock), ii. Below ground biomass (roots), iii. Soil carbon, iv. Air Pollution Tolerance Index of each species. At present, not much information is available on the estimates of carbon sequestration potential in forest and urban areas; therefore more detailed studies are needed for assessing the ultimate changes that are happening in both forest and urban areas. Nowadays the forest are converting into built up areas and urban areas are losing its carbon sequestering potential by converting woody parks into horticulture parks (Flowering parks). Forests itself cannot mitigate or sequester atmospheric carbon; even urban areas should play major role in mitigating regional climate change or global warming.

KEY WORD: *Climate change, Carbon sequestration, Forest, Biomass, Urbanization.*

INTRODUCTION:

The Earth's atmosphere contains carbon dioxide (CO_2) and other greenhouse gases (GHGs) that act as a protective layer, causing the planet to be warmer than it would otherwise be. This heat retention is critical to maintain habitable temperatures. If there were significantly less CO_2 in the atmosphere, global temperatures would drop below levels to which ecosystems and human societies have adapted. As CO_2 levels rise, mean global temperatures are also expected to rise as increasing amounts of solar radiation are trapped inside the "greenhouse". Carbon dioxide is among the most important anthropogenic greenhouse gases (Houghton *et al.*, 1990 and Sundquist, 1993). The concentration of CO_2 in the atmosphere is determined by a continuous flow among the stores of carbon in the atmosphere, the ocean, the earth's biological systems, and its geological materials. As long as the amount of carbon flowing into the atmosphere (as CO_2) and out (in the form of plant material and dissolved carbon) are in balance, the level of carbon in the atmosphere remains constant.

Benefits of urban trees are Amelioration of urban climate extremes, Mitigation of urban heat islands, Store and sequester carbon, Reduce noise pollution, Improve air quality, Reduce consumption of electricity for heating and cooling, Aesthetic contribution, scenic beauty, visual amenity, Improve property value, Improve general livability and quality of urban life and Contribute to human health and relaxation, reduce stress and anxiety levels. This article reviews the data collection and methodology required to assess the importance of carbon sequestration potential in forest and urban areas.

1. IMPORTANCE OF CARBON SEQUESTRATION

Carbon sequestration is a phenomenon for the storage of CO_2 or other forms of carbon to mitigate global warming and its one of the important clause of Kyoto Protocol, through biological, chemical or physical processes; CO_2 is captured from the atmosphere. The Kyoto Protocol to the UN Framework Convention on Climate Change (UNFCCC, 1997) has provided a vehicle for considering the effects of carbon sinks and sources, as well as addressing issues related to fossil fuels emissions. Carbon sequestration is a way to mitigate the accumulation of greenhouse gases in the atmosphere released by the burning of fossil fuels and other anthropogenic activities. Potential actions to mitigate fossil fuel emissions include increased energy conservation and efficiency, employment of renewable energy systems and use of alternative fuels (NAS, 1991). Other greenhouse gas mitigation options include sequestration of CO_2 in biological 'sinks' such as plant biomass. Alternatively, biomass from terrestrial systems can be used as an energy source and offset fossil fuel CO_2 emissions.

2. FORESTS

Forest ecosystem plays very important role in the global carbon cycle. Forest ecosystems can be net sources or sinks of CO_2, depending on dominant biological or physical factors, including: (1) state of the soil and vegetation (i.e. is the system undisturbed, disturbed or recovering); (2) management practices at the site level; (3) environmental conditions (e.g. climatic, edaphic, fire, pests); and (4) atmospheric deposition of pollutants and other compounds, some of which (e.g. CO_2 and nitrogen) can serve as nutrients (Kauppi *et al.*, 1992, Cropper *et al.*, 1993). Alongside forest ecosystem, recognizing the importance of urban trees, the interest in preserving and maintaining the urban trees is increasing. Carbon sinks can be increased by planting additional areas of new trees or by increasing the growth rate of existing forest ecosystems. Management practices to foster C sequestration include: afforestation, reforestation and establishment of agroforestry systems (Dixon *et al.*, 1993b, c, Trexler *et al.*, 1993).

3. URBAN GREEN SPACES

Urban green spaces are a vital component of our cities and towns as they provide many essential ecosystem services, including carbon storage, benefits to human health, flood mitigation, food and biofuel production. At present urban green spaces is an undervalued and underused resource. Tree canopies provide a cooling effect on microclimate directly by shading the ground surface and indirectly through transpiration (Scott *et al.*, 1999). Roadside trees, because of their proximity to the generation of vehicle emissions, are important in reducing pollution. Beckett *et al.*, 2000, found that roadside trees capture more large-size particulate matter than trees not near the road. These effects have implications for air quality standards. Roadside trees additionally have high emotional and aesthetic value to residents and high ecological value to urban areas as part of our green infrastructure. Urban trees perform important ecological function in cities by sequestering carbon and reducing automobile pollution. The net save in carbon emissions that can be achieved by urban planting can be up to 18 kg CO_2/year per tree and this benefit corresponds to that provided by 3 to 5 forest trees of similar size and health (Francesco *et al.*, 2011).

Cities account for 78% of carbon emissions. In 1800, there was only one city, Beijing, in the entire world that had more than a million people; we have 326 such cities 200 years later (Brown, 2001). Indeed, such rapid has been the pace of growth that in 1900 just 10% of the global population was living in urban areas which now exceeds 50% and is expected to further rise to 67% in the next 50 years (Grimm *et al.*, 2008). Rapid urbanization in India is bringing complex changes to ecology, economy and society (DeFries *et al.*, 2010). During the last 50 years the population of India has grown two and a half times, but the urban population has grown nearly five times (Taubenbock *et al.*, 2009). About 60% of this urban population growth is attributable to natural growth, and the remaining 40% is due to migration and spatial expansion (Sivaramakrishnan *et al.*, 2005). In India, except for a few cities, urban forests are not well-studied. There are, however, some studies on Bangalore (Sudha *et al.*, 2000, Nagendra *et al.*, 2010), Mitra, 1993 and Madan, 1993 on urban forest of Vishakapatnam City, Chandigarh (Chaudhary, 2006; Chaudhary *et al.*, 2010a, b; FSI, 2009) and Delhi (FSI, 2009). Similar studies such as biodiversity and carbon storage are also available for Bhopal (Dwivedi *et al.*, 2009), Delhi (Khera, 2009), Jaipur (Verma, 1985 and Dubey *et al.*, 1993), Mumbai (Zerah, 2007) and Pune (Patwardhan *et al.*, 2001). A few studies are also available for specific locations within the urban ecosystems, such as NEERI Campus, Nagpur (Gupta *et al.*, 2008), Indian Institute of Science Campus, Bangalore (Mhatre, 2008) and Bangalore University Campus at Jnanabharathi, (Nandini *et al.*, 2009). Many policy and robust scientific evidences in last two decades have emphasized the critical necessity of green areas within urban social-ecological systems to ameliorate several problems of city-living; however the trend of urban ecology and application of its principles is still lagging behind.

4. ABOVE AND BELOW GROUND BIOMASS

According to Ravindranath *et al.*, (1997) the standing biomass (as above and below ground biomass) in India is estimated to be 8,375 million tons for the year 1986, of which the carbon storage would be 4,178 million tonnes. The total carbon stored in forests, including soil is estimated to be 9578 m t. On the other hand, carbon emissions from fossil based energy production and consumption activities in India have been estimated at 152-205 m t per year.

The biomass of a tree is the sum of the biomass of its roots, trunk, branches, leaves and reproductive organs- flowers and fruits. For an accurate measure of biomass the tree would have to be felled. To avoid this, the standing woody biomass can be estimated in the following manner: The height of the tree is to be measured using ocular or non-instrumental and instrumental methods. Mark the tree at the height (154 cm, assumed to be 1.5 m or 5 ft). Then, from that distance of about 3 meters from the tree base, the number of 1.5 m sections from tree base to tree top to be counted and multiplied by 1.5 to get the height of the tree in meters. Since this method can lead to errors, the following precautions were taken: -

- Height estimation was practiced with trees growing next to multi-storey buildings (to get a scale and for easy verification –1 storey = 10 ft =3m approx.)
- Height classes were created for ease in calculations True trees are defined by girths at breast height (GBH) of more than 30 cm.

The corresponding GBH (Girth at Breast Height) and height for each individual tree to be noted. Biomass and stored carbon for each vegetation type was calculated as per the standard procedure. The girth of the tree to be measured at breast height (1.3m). The trees with girth above 30 cm to be considered. Besides, saplings with a girth of over 20cm were to be taken into consideration, as young saplings sequester carbon at a faster rate and their chance of survival is high.

The following precautions should be taken while measuring the girth: -

- If the tree is branched below breast height, the girth must be taken for individual branches, and must be noted separately.
- All branches with a girth above 10 cm were taken into account.
- If the tree is at an incline, stand in the upper slope while taking the girth.
- If the tree branches at GBH, then measure the girth slightly below the swell.

Biomass was estimated by multiplying the bio volume by the green wood density of tree species.

Basal area = $(GBH)^2/4\pi$
Biovolume = Basal area x Height
AGB = Biovolume x wood density
BGB = AGB x 0.26
AGC = AGB/2
Where,
GBH = Girth at Breast Height
AGB = Above Ground Biomass
BGB = Below Ground Biomass
AGC = Above Ground Carbon

The wood density of the tree species, the standard average of 0.45 gm/ cm^3 or 450 kg/ m^3 can be taken (Reyes *et al.*, 1992).

The quantum of carbon was then converted to the quantum of carbon dioxide using the following formulae (Ajay *et al.*, 2003).

$$\text{Quantum of } CO_2 = \frac{\text{Quantum of carbon x 44}}{12}$$

Where,
44 is the molecular weight of CO_2
12 is the atomic weight of the carbon

5. SOIL CARBON

Carbon is sequestered in the part of the soil called humus, which provides more stable storage of carbon than biomass. Humus is made up of a collection of organic matter that results from decomposition of animal and vegetative litter. It composes a relatively stable carbon pool (Brady, 1996). Some of the more stable compounds found in the humus may not turn over for hundreds to thousands of years (DOE, 1999). Most importantly, scientists can encourage increases in humus carbon content by stimulating natural processes that bond carbon chemically to other elements in the soil or increase resistance to microbial decomposition. Soil scientists also hope to increase sequestration by adopting agricultural processes that reduce soil erosion by wind and water and oxidation of soil from frequent turnover.

Terrestrial ecosystems and soils can be a source of carbon as well as a sink. Tillage practices involve significant soil turnover, which exposes the soil to air and generates soil releases of carbon through CO_2 as a result of oxidation. Wind and water erosion lead to further releases of carbon. On average, for the U.S. uncultivated land would contain about 1329 MMTC more than cultivated land. Worldwide, poor agricultural practices now account for five percent of the yearly increase in the greenhouse carbon dioxide. Schlesinger estimates the annual global net release of carbon from agriculture activities at 800 MMTC/yr (Lal, 1998a). The 90-230 MMTC emitted annually from arable land and pastures in the tropics accounts for the largest portion of that global amount (Crookshank, 1999). The basic premise behind the reduction of emissions through the sequestration of carbon in soils relies on the restoration of original carbon levels.

6. AIR POLLUTION TOLERENCE INDEX (APTI)

The atmosphere is a complex, dynamic natural gaseous system that is essential to all living things. There are some substances in the atmosphere which may impair the health of plants and animals. Air pollution is the human introduction into the atmosphere of chemicals, particulate matter, or biological materials that cause harm or discomfort to humans or other living organism, or damage the environment (Anonymous, 2008). Air pollution is a major problem arising mainly from industrialization. Pollutants could be classified as either primary or secondary. Pollutants that are pumped into the atmosphere and directly pollute the air are called primary pollutants while those that are formed in the air when primary pollutants react or interact are known as secondary pollutants (Anonymous, 2008).

Plants are an integral basis for all ecosystems and also most likely to be affected by airborne pollution which are identified as the organisms with most potential to receive impacts from ambient air pollution. Also the effects are most often apparent on the leaves which are usually the most abundant and most obvious primary receptors of large number of air pollutants. Bio monitoring of plants is an important tool to evaluate the impact of air pollution. Hence in the latest years urban vegetation became increasingly important not only for social reasons but mostly for affecting local and regional air quality. The response of plants towards air was assessed by air pollution tolerance index. The usefulness of evaluating APTI for the determination of tolerance as well as sensitiveness of plant species were followed by several authors (Agrawal *et al*.,1997; Dwivedi *et al*., 2007; Liu *et al*., 2008; Dwivedi *et al*., 2008). These studies provided valuable information for landscapers and greenbelt designers to select the sensitive as well as tolerant varieties of plant species for using them to identify the pollution loads of urban/industrial areas, and also to use the tolerant varieties for curbing the menace of air pollution.

Air pollutants can directly affect plants via leaves or indirectly via soil acidification. It has also been reported that when exposed to air pollutants, most plant experience physiological changes before exhibiting visible damage to leaves (Dohmen *et al*., 1990). Previous studies also showed the impact of air pollution on ascorbic acid content (Hoque *et al.*, 2007), chlorophyll content (Flowers *et al.*, 2007), leaf extract pH (Klumpp *et al.*, 2000) and relative water content (Rao, 1979). These separate parameters gave conflicting results for same species (Han *et al.*, 1995). However, the air pollution tolerance index (APTI) based on all four parameters has been used for identifying tolerance levels of plants species (Singh *et al.*, 1993; Singh *et al.*, 1991). Several contributors agree that air pollutants effect plant growth adversely (Rao, 2006; Bhatia, 2006; Sodhi, 2005; Henry *et al.*, 2005; Horsfall, 1998). Air pollution tolerance index is used by landscapers to select plant species tolerance to air pollution (Yan-Ju, 2007). APTI can be done using the following method of Singh *et al.*, 1983. The formula of APTI is given as

$$APTI = \frac{A\,(T+P) + R}{10}$$

Where,

A = Ascorbic acid content (mg/g)
T = Total chlorophyll mg/g
P = pH of leaf extract
R = Relative water content of leaf %.

CONCLUSIONS:

Urban dwellers need to recognize and articulate the importance of urban trees as a vital component of the urban landscape. There is a need for greater attention to be paid to the selection of trees in cities. For increased carbon sequestration and longer term storage to take place, improved management of land is required. In order to continuously store and capture carbon, landscape connectivity is required as it is for habitats and the wildlife that they support. Destruction of habitat through urban sprawl, the draining of wetlands, or other similar actions will not only release carbon stores, it will also reduce the ability of these habitats to provide valuable services including sustaining fish and wildlife populations. Increased habitat protection and restoration can increase carbon storage and sequestration and have multiple other social, economic, and environmental benefits. Smart growth policies provide social and economic benefits, while at the same time protecting and maintaining natural systems that can continue to store and sequester carbon in habitats, which provide corresponding social, economic, and ecological benefits. Future policy should recognize the tie between healthy ecosystems and productive carbon storage/sequestration projects by requiring the use of diverse, preferably native species, in the restoration of existing communities, the protection of ecosystem services, and the maintenance of connectivity. The use of non-native or potentially invasive species must be regulated as it could encroach on native species and create imbalance within a habitat. This includes genetically-modified trees or plants that may spread across a landscape. Monocultures should also be used cautiously within diverse landscapes, as they lack the diversity required to sustain a variety of animals that help maintain a healthy ecosystem.

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