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BIOLOGICAL CARBON SEQUESTRATION THROUGH FRUIT CROPS (PERENNIAL CROPS - NATURAL "SPONGES" FOR ABSORBING CARBON DIOXIDE FROM ATMOSPHERE)

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Abstract

Rapid increase in carbon dioxide (CO_2) concentration in the atmosphere associated with other greenhouse gases (GHGs) such as nitrous oxide (N_2O) and methane (CH_4), since the industrial revolution is a major concern with respect to its impact on climate change. Therefore, there is an urgency to adopt effective measures for mitigating the threat of global climate change. Carbon dioxide (CO_2) is a major contributing gas to the greenhouse effect. So, Carbon sequestration is a natural method for the removal of carbon from the atmosphere by storing it in the biosphere. The atmospheric carbon dioxide is captured and stored in plants, soils, oceans, or atmosphere in the forms of biomass by photosynthesis process. The removal of atmospheric CO_2 by increasing the assimilation of CO_2 with terrestrial vegetation, retaining carbon and enhancing the transformation of atmospheric carbon to plant biomass and soil organic matter along with reducing GHG emission has become a worldwide strategy to mitigate climate change. However, the efficiency of carbon sequestration by various vegetations (Carbon dioxide is absorbed by trees, plants and crops through photosynthesis and stored as carbon in biomass in tree trunks, branches, foliage and roots and soils) and management in various systems differs greatly due to their physiological characteristics, growth rates, biomass accumulation, and environmental factors.

Key words: Atmosphere, Carbon sequestration, Biosphere and climate.

Introduction

Carbon sequestration is the process by which carbon dioxide (CO_2) from the atmosphere is absorbed by trees, plants and crops through photosynthesis and stored as carbon in biomass such as tree trunks, branches, foliage, roots and soils (EPA, 2010). A variety of human activities lead to the emission of CO_2 which are referred to sources of CO_2 and the removal of CO_2 refers to sinks of CO_2. However, forests and soils have a large influence on atmospheric levels of CO_2 as the forest vegetation serves as a major component of the global carbon cycle and it is estimated that the forest vegetation stores at least 350pg of carbon (Dixton *et al.,* 1994). It is also estimated that as much as 90% of the world's terrestrial carbon is stored in the forest (Houghton, 1996). Although the forest can store high levels of CO_2, the estimated carbon storage by the forest is subject to either an increase or decrease due to factors such as conversion of forest lands to other land uses, harvesting of timber, mining etc. resulting in changes in carbon fluxes to the atmosphere. Carbon sequestration rates vary by tree species, soil type, regional climate, and topography and management practice (EPA, 2010). Pine plantations of 90 years in the Southeast of USA can accumulate 2.5Mg ha-1 of carbon per year (Birdsey, 1996). The increasing carbon emission is of major concerns for entire world as well addressed in Kyoto protocol (Chavan and Rasal, 2010; Ravindranath *et al*., 1997). Biomass production in different forms plays important role in carbon sequestration in trees. These carbon pools are composed of live and dead above and below ground biomass, and wood products with long and short life and potential uses. Above-ground biomass, below-ground biomass, dead wood, litter, and soil organic matter are the major carbon pools in any ecosystem (FAO, 2005; IPCC, 2003; IPCC, 2006). Trees play an important role in the reduction of carbon dioxide from atmosphere by carbon sequestration. Active absorption of CO_2 from the atmosphere through the process of photosynthesis and its subsequent storage in different plant parts in the form ofbiomass in growing trees is the carbon storage (Baes *et al*., 1977 and Chavan *et al*., 2010). The assessment of biomass equations for the efforts to improve carbon budget estimates is based on the link between individual-tree and whole-stand biomass estimates (Clutter *et al*., 1983; Parresol, 1999) coupled with the assumption that wood mass is about 50% carbon (Birdsey, 1992).

The amount of carbon sequestered continuously by a tree increases substantially over the time and age of tree till it matures. The process of carbon capture in photosynthesis is influenced by different factors including the tree age, leaf area and photosynthetic efficiency. The increasing carbon emission is of major concerns all over the world; it has been well addressed in Kyoto protocol (Ravindranath *et al*., 1997; Chavan and Rasal, 2010). The rate of carbon storage increases in young tree species, whileit declines after full growth as the stand ages (Jana *et al*., 2009). Above Ground Biomass (AGB)of treeincludes all living biomass of all its parts above the soil, while Below Ground Biomass (BGB) includes all the plant biomass of live roots excluding the fine roots of sizes <2mm diameter (Ravindranath and Ostwald, 2008). The objective of this review is to briefly elucidate the Carbon sequestration through growing fruit trees is known to be a cost-effective option for mitigation of global warming, global climatic change and additional income for the formers- Perennial crops - Natural "Sponges" for absorbing carbon dioxide from atmosphere.

Carbon is found in all living organisms and is the major building block for life on earth. In the environment, carbon exists in many forms – predominately as plant biomass, soil organic matter, geologic deposits and as the gas carbon dioxide (CO_2) in the atmosphere and dissolved in seawater. Carbon sequestration is the long-term storage of carbon in oceans, soils, vegetation (especially forests), and geologic formations. High levels of fossil fuel combustion and deforestation have transformed large pools of carbon from fossils (oil and coal deposits) and forests into atmospheric carbon dioxide.

Although oceans store most of the earth's carbon, soils contain approximately 75% of the carbon pool on land – three times more than the amount stored in living plants and animals. Soils therefore play a major role in maintaining a balanced global carbon cycle. Since most scientists believe that there is a direct relationship between increased levels of CO_2 in the atmosphere and rising global temperatures, interest in soil carbon sequestration is attracting the attention of researchers, policy makers, farmers, and the general public.

Review on Climate change and horticulture

Climate change may have beneficial as well as detrimental consequences for horticulture. Some research indicates that warmer temperatures lengthen growing seasons and increased carbon dioxide in the air results in higher yields from some crops. A warming climate and decreasing soil moisture can also result in production patterns shifting northward and an increasing need for irrigation. With increased carbon dioxide and higher temperatures, the life cycle of grain and oilseed crops will likely progress more rapidly. The marketable yield of many horticultural crops, such as tomatoes, onions and fruits, is very likely to be more sensitive to climate change than grain and oilseed crops. Climate change is likely to lead to a northern migration of weeds. Many weeds respond more positively to increasing carbon dioxide than most cash crops. Disease pressure on crops and domestic animals will likely increase with earlier springs and warmer winters. Climate change-induced shifts in plant species are already under way in rangelands. The establishment of perennial herbaceous species is reducing soil water availability early in the growing season. Higher temperatures will very likely reduce livestock production during the summer season, but these losses will be partially offset by warmer temperatures during the winter Season (Backlund *et al*., 2008).

The recent trend of an increase in the concentration of greenhouse gases (GHGs) in the atmosphere has led to an elevated concern and urgency to adopt measures for carbon (C) sequestration to mitigate the climate change. Among all GHGs, carbon dioxide (CO_2) is the most important one which occurs in the greatest concentration and has the strongest radiative forcing among all. Reducing the release of CO_2 to the atmosphere through "green energy" technologies or fossil fuel energy alternatives, such as wind, solar and hydraulic energies, is a major challenge. However, removal of atmospheric CO_2 by terrestrial ecosystems via C sequestration and converting the sequestered C into the soil organic C has provided a great opportunity for shifting GHG emission to mitigate the climate change. Soil is an ideal reservoir for storage of organic C since soil organic C has been depleted due to land misuse and inappropriate management through the long history. To optimize the efficiency of C sequestration in agriculture, cropping systems, such as crop rotation, intercropping, cover cropping, etc., play a critical role by influencing optimal yield, total increased C sequestered with biomass, and that remained in the soil. As matter of fact, soil C sequestration is a multiple purpose strategy. It restores degraded soils, enhances the land productivity, improves the diversity, protects the environment and reduces the enrichment of atmospheric CO_2, hence shifts emission of GHGs and mitigates climate change. (Qingren Wang *et al*., 2010). These GHGs absorb the thermal radiation emitted by the earth's surface, thus rising temperature of earth which called as Global warming. Concentrations of GHGs in the atmosphere could lead to a change in energy balance and eventually the world's climate. The CO_2 is by far the largest contributor to the man-made enhanced greenhouse effect (IPCC 2007).

As more photosynthesis occurs, more CO_2 is converted into biomass, reducing carbon in the atmosphere and sequestering it in plant tissue above and below ground (Gorte, 2009; IPCC, 2003) resulting in growth of different parts (Chavan and Rasal, 2010). In the global carbon cycle biomass is an important building block, significally carbon sequestration and is used to help quantify pools and changes of Green House Gases from the terrestrial biosphere to the atmosphere associated with land-use and land cover changes (Cairns *et al.*, 2003; IPCC, 2001). Biomass production in different forms plays important role in carbon sequestration in trees. Above-ground biomass, below-ground biomass, dead wood, litter, and soil organic matter are the major carbon pools in any ecosystem (FAO, 2005; IPCC, 2003; IPCC, 2006).

Carbon Sequestration and Fruit crops:

Carbon sequestration in the agriculture sector refers to the capacity of agriculture, horticulture and forests to remove carbon dioxide from the atmosphere. Carbon dioxide is absorbed by trees, plants and crops through photosynthesis and stored as carbon in biomass in tree trunks, branches, foliage and roots and soils (EPA, 2008). Forests and stable grasslands are referred to as carbon sinks because they can store large amounts of carbon in their vegetation and root systems for long periods of time. Soils are the largest terrestrial sink for carbon on the planet. The ability of agriculture lands to store or sequester carbon depends on several factors, including climate, soil type, type of crop or vegetation cover and management practices. The amount of carbon stored in soil organic matter is influenced by the addition of carbon from dead plant material and carbon losses from respiration, the decomposition process and both natural and human disturbance of the soil. By employing farming practices that involve minimal disturbance of the soil and encourage carbon sequestration, farmers may be able to slow or even reverse the loss of carbon from their fields. Carbon in trees can be stored in trunks, branches, leaves, flowers, fruits and roots, Schaffer *et al.* (1999) reported that exposure of tropical and subtropical fruit trees (avocado, banana, mangosteen, citrus and mango) to elevatedconcentration of CO_2 significantly increased the rate of photosynthesis and consequently an increase in tree biomass.Photosynthesis in mangosteen increased by 40 to 60% when exposed to 800 ppm for one year compared to when exposed to ambient CO_2 concentration (Schaffer *et al*., 1999).

Fruit based system a viable alternative for carbon sequestration:

The fruits based system is a self-sustainable system where solar energy can be harvested at different heights, soil resources can be efficiently used and cropping intensity is increased. The system consists of three main components viz., main crop, filler crop and inter crops which occupy three different tiers in space of the production system. (Upadhyaya*et al.,* 1999). Carbon in trees can be stored in trunks, branches, leaves, flowers, fruits and roots, Schaffer *et al*. (1999) reported that exposure of tropical and subtropical fruit trees (avocado, banana, mangosteen, citrus and mango) to elevated concentration of CO_2 significantly increased the rate of photosynthesis and consequently an increase in tree biomass.Photosynthesis in mangosteen increased by 40 to 60% when exposed to 800 ppm for one year compared to when exposed to ambient CO2 concentration (Schaffer *et al*., 1999). Prolific flowering and fruiting abilities of trees increase carbon removal from atmosphere and store substantial amount of carbon as cellulose (Bickford, 2007). Fruit orchards can positively contribute to a sustainable development under climate change scenario in the tropics considering the current expansion of agriculture and high level of poverty (FAO, 2010) which continue to shrink forest resources.

How is carbon sequestered in trees and soils?

Through the process of photosynthesis, plants assimilate carbon and return some of it to the atmosphere through respiration. The carbon that remains as plant tissue is then consumed by animals or added to the soil as litter when plants die and decompose. The primary way that carbon is stored in the soil is as soil organic matter.Soil organic matteris a complex mixture of carbon compounds, consisting of decomposing plant and animal tissue, microbes (protozoa, nematodes, fungi, and bacteria), and humus – carbon associated with soil minerals (William, 1999). Carbon can remain stored in soils for millennia, or be quickly released back into the atmosphere through respiration by soil microbes. Climatic conditions, natural vegetation, soil texture, drainage, and human land use all affect the amount and length of time carbon is stored in soil (ESA, 2006).

Methodology of Carbon Sequestration

Carbon sequestration through fruit trees is mainly depends on age of the trees, diameter of trees and land area.The rate of carbon storage increases in young tree species, while it declines after full growth as the stand ages (Jana *et al.*, 2009). The amount of carbon sequestered continuously by a tree increases substantially over the time and age of tree till it matures. The process of carbon capture in photosynthesis is influenced by different factors including the tree age, leaf area and photosynthetic efficiency. Prolific flowering and fruiting abilities of trees increase carbon removal from atmosphere and store substantial amount of carbon as cellulose (Bickford, 2007).

Biophysical measurements: The height and diameter at breast height (DBH) are two main biophysical measurements which measuredfor each tree sample. The fruit tree height measured by Theodolite instrument follower the proceduregiven elsewhere (Chavan and Rasal, 2010; Chavan and Rasal, 2012). The tree diameter was measured atbreast height (DBH) by using diameter measure tape.

Estimation of Aboveground biomass:(wood, bark, branches, twigs, leaves and fruits): Above-ground biomass includes all living biomass above the soil. The aboveground biomass (AGB) has been calculated by multiplying volume of biomass and wood density (Ravindranath and Ostwald, 2008). The volume was calculated based on diameter and height.

AGB (g) = Volume of biomass (cm^3) × wood density (g/cm^3)

Estimation of Belowground biomass(roots) : The below Ground Biomass (BGB) includes all biomass includes all biomass of live roots excluding fine roots having <2mm diameter (Chavan and Rasal, 2011).The belowground biomass (BGB) has been calculated by multiplying above-ground biomass taking 0.26 as the root to shoot ratio (Cairns *et al*. 1997; Ravindranath and Ostwald, 2008).

Belowground biomass (tha^{-1}) = 0.26 × above-ground biomass (tha^{-1})

Statistical Analysis:

Carbon storage (Mt) = Biomass × Carbon% (Negi *et al*., 2003). As per factor standardized by Carvallo *et al*., (1998); Lal and Singh (2000), 0.45 was taken as carbon per cent in plants.Biomass equations are used to estimate the weights of the tree based on DBH and height of the trees in the sample area. Biomass equations are available only for some dominant commercial tree species. The equations which are available are often only species specific and also location specific. Neither, biomass equations developed using mature trees can be used for younger trees, nor the equations of younger trees for mature trees. Biomass equations are not available for most local or native tree species in many regions. It makes desirable to develop biomass equations wherever possible to suite the local tree species and age of the stand trees in different study regions (Ravindranath and Ostwald, 2008; Chavan and Rasal, 2011).

Results and Discussion

The estimation of the aboveground and belowground biomass in the selected tree species was performed by estimating carbon percentage and by measuring the tree height, DBH and wood density. The carbon concentration of different tree parts was rarely measured directly, but generally assumed to be 50% of the dry weight on the basis of literature (Chavan and Rasal, 2011; Jana *et al.*, 2009) as the content of carbon in woody biomass in any component of forest on average is around 50% ofdry matter (Paladinic *et al.,* 2009; Chavan and Rasal, 2011; 2012a; 2012b).

The organic carbon content and biomass was gradually increasing from 5 to 20 years of all the tree species studied. Pandya *et al*. (2013) reported, as the diameter of species (when age increases) increases, its biomass and carbon storage capacity increases which also enhance more carbon sequestration, removes more carbon dioxide from atmosphere. The highest total organic carbon and carbon stock was recorded in teak followed by sapota, mango and coconut. Whereas standing biomass, standing carbon and equivalent CO_2 was recorded high in teak followed by coconut, mango and sapota. Koppad (2013) reported significant increase in different year teak plantations of standing biomass and the results obtained are similar. Chavan and Rasal (2011 a) reported similar values for mango and sapota. The results given in the table was calculated for total number of trees which can be planted in a hectare. Whereas the standing biomass per tree of teak, mango, sapotaand coconut will be 0.37, 0.36, 0.154 and 1.14 tons per tree that a high leaf fruit ratio assures a sufficient storage supply for better crop and photosynthesizing organs known as sourcesmainly leaves produce photosynthates mainly carbohydrates, translocated by the sieve tubes of the phloem to non photosynthetic organs (fruits, roots and immature leaves) known assinks and this capacity to generate photosynthates is governed by a reliable canopy, numberof leaves, certain leaf area per fruit or fresh weight unit.

Carbon Storage Potential: The more the diameter, the more was the value of carbon storage bydifferent parts of plant such as fruits, leaves, stem, bark, branches, twigs, and roots. Suchfindings may be due to differential of production/utilization of energy reserve of the plant. Asthe age of the tree advances, owing to the phasic change of juvenility to maturity, diversion ofnutrients sets in towards reproductive phase *i.e.* towards flowers and fruits, leaves, stem,bark, branches, twigs etc. Being supportive to fruits they also utilizes considerable amount ofnutrients reserve of the plant. Nadir (1973) and Dasberg (1987) reported that the largestproportion of total tree biomass was constituted by fruits which represented 30% of the totalbiomass of sweet orange.

Future Stratigies:

The potential of fruit trees in carbon sequestration and environmental services remain unexploited. Since the limited research studies in quantifying carbon sequestration capacities in diverse fruit tree species. The new thinking should be to develop and identify suitable propagation protocols, management systems and suitable species to maximize carbon storage and to optimize fruit productivity. More research studies are needed to quantify CO2 sequestration potential in diverse fruit trees including indigenous fruit tree species to local communities.

Conclusion

Carbon reservoirs -The use of woody fruit trees on homesteads and cultivated fields can offer a cheaper payment for environmental services including carbon credits if piloted. Food and Nutritional security - Furthermore, fruit trees can provide this benefit while feeding a growing population and returning a profit to farmers. Improvement of soil status.

References

Anonymous (2012). Indian Horticulture Database, Published from National Horticulture Board, Gurgaon, (Haryana) Pp.64.

Carbon Sequestration in Soils (1999). Science. William H. Schlesinger. 25 June, vol. 284.

Carvallo, J.A., N. Hinduri, T.M. Araujo and J.C. Santos (1998) Combustioncompleteness in a rainforest clearing experiment in Manaus, Brazil, *Journal of Geophysics Research-Atomsphere,* **103**: 13195-13199.

Carvallo, J.A., N. Hinduri, T.M. Araujo and J.C. Santos (1998). Combustioncompleteness in a rainforest clearing experiment in Manaus, Brazil, *Journal of Geophysics Research-Atomsphere,***103**: 13195-13199.

Chavan, B.L. and G.B. Rasal (2011). Potentiality of Carbon Sequestration in six year ages young plant from University campus of Aurangabad. *Global Journal of Researches in Engineering,* **(7)**:15-20.

Chavan, B. L. and G. B. Rasal (2009). Carbon storage in Selective Tree Species in University Campus at Aurangabad, Maharashtra, India. Proceeding of International conference & Exhibition on RAEP, Agra, India, 119-130.

Chavan, B. L. and G. B. Rasal (2012). Carbon Sequestration potential of young Annona reticulate and Annonasquamosa from University of Aurangabad, *International Journal of Physical and Social Sciences,* **3**: 2249-2496.

Chavan, B.L. and G.B. Rasal (2012). Carbon sequestration potential of *Mangiferaindica* in its various growth phases, 99th Indian Science Congress, Bhuvaneshwar, India

Dasberg, S. (1987). Nitrogen fertilization in Citrus orchards. *Plant and Soil,* **100(v)**: 1-9.

Ecological Society of America, 1707 H Street, NW, Suite 400, Washington, DC 20006. (202) 833-8773. Esahq@esa.org; http://esa.sdsc.edu.

FAO. (2005). *Support to national forest assessments*. FAO Forestry Department website (www.fao.org/forestry/site/24673/en).

Fischer, G., M. Almanza, J. Pedro and F. Ramirez (2012). Source –Sink relationship infruit species. A review.Revista Columbiana de Cicencias Horticolas, *Bogota, July/Dec. ISSN,* **6(2)** : 2011-2173.

Gorte, R.W. (2009). U.S. Tree Planting for Carbon Sequestration, Congressional Research Service report for congress, http://www.crs.gov.

Hartmann, H.T. and D.E. Kester (2002). Plant propagation principles and practices (4thEdn.), Prentice Hall of India Private Limited, New Delhi, pp 377-379.

IPCC (Intergovernmental Panel on Climate Change) (2003). Good practice guidance or land use, land-use change and forestry. Institute for Global Environmental Strategies (IGES), Hayama.

IPCC (Intergovernmental Panel on Climate Change) (2003). Good practice guidance or land use, land-use change and forestry. Institute for Global Environmental Strategies (IGES), Hayama.

IPCC (Intergovernmental Panel on Climate Change) (2006). Guidelines for national greenhouse gas inventories. Vol. 4, Agriculture, Forestry and other land use (AFLOLU). Institute for Global Environmental strategies, Hayama, Japan.

IPCC (Intergovernmental Panel on Climate Change) (2006). Guidelines for national greenhouse gas inventories. Vol. 4, Agriculture, Forestry and other land use (AFLOLU). Institute for Global Environmental strategies, Hayama, Japan.

IPCC (2001). Climate Change (2001): Working Group I: The Scientific Basis. Cambridge University Press, New York.

Kozlowsky, T.T. and S.G. Pallardy (1997). In Growth control in woody plants. AcademicPress Inc, San Diego, Tokyo.

Lal, M. and R. Singh (2000). Carbon sequestration potential of

Indian forests. *Environment Monitoring and Assessment,* **60**: 315-327.

Lal, M. and R. Singh (2000). Carbon sequestration potential of Indian forests. *Environment Monitoring and Assessment,* **60**: 315-327.

Nadir, M. (1973). Partitioning and level of mineral elements in different parts of producingcitrus trees. *Proceedings of the International Society of Citriculture,* **1**:193-205.

Negi, J.D.S., R.K. Manhas and P.S. Chauhan (2003). Carbon Allocation in Different Components of Some Tree species of India: A new approach for carbon estimation. *Current Science,* **85(11)**: 1528-1531.

Qingren, Wang., Li1 Yuncong and Ashok Alva (2010). Cropping Systems to Improve Carbon Sequestration for Mitigation of Climate Change. *Journal of Environmental Protection*, **1**: 207-215.

Rasal, G. B., M.G. Babare and B.L. Chavan (2011). Sequestered carbon stalk in young *Annonareticulata* plant in Aurangabad, International conference on Climate change and social issues at Colombo, Srilanka.

Ravindranath, N.H. and M. Ostwald (2008). Carbon Inventory Methods Handbook for Greenhouse Gas Inventory, Carbon Mitigation and Round wood Production Projects. *Springer*, Vol. 29.

Ravindranath, N.H. and M. Ostwald (2008). Carbon Inventory Methods Handbook for Greenhouse Gas Inventory. Carbon Mitigation and Round wood Production Projects. *Springer,* Vol. 29.

Ravindranath, N.H., B.S. Somashekhar and M. Gadgil (1997). Carbon flow in Indian forests, submitted to the Ministry of Environment and Forest.

Ravindranath, N.H., B.S. Somashekhar, , M. Gadgil (1997). Carbon flow in Indian forests, submitted to the Ministry of Environment and Forest.