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Research Article

Carbon sequestration potential, physicochemical and microbiological properties of selected trees *Mangifera indica L.*, *Manilkara zapota L.*, *Cocos nucifera L.* and *Tectona grandis L.*

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Abstract

The present study focussed on the estimation of carbon sequestration potential, physicochemical and microbiological properties in selected types of trees such as *Mangifera indica L.* (Mango), *Manilkara zapota L.* (Sapotta), *Cocos nucifera L.* (Coconut) and *Tectona grandis L.* (Teak) maintained under different years viz., 5, 10, 15 and 20 years. Based on the study the highest total organic carbon was recorded in soil cultivated with teak (0.69 to 1.11 %) followed by sapotta (0.36 to 1.07 %), mango (0.64 to 0.85 %) and coconut (0.57 to 0.81 %) in 0-20 cm depth of 20-year-old trees. Whereas standing biomass, standing carbon and equivalent CO_2 were recorded high in teak (17.93 to 365.87 t ha^{-1}) followed by coconut (9.14 to 285.68 t ha^{-1}), mango (1.85 to 80.74 t ha^{-1}) and sapotta (2.86 to 24.45 t ha^{-1}) in 20-year-old trees.

INTRODUCTION

Carbon is a major element found in all living organisms predominantly as plant biomass, soil organic matter and as the gas carbon dioxide (CO_2) in the atmosphere and dissolved in seawater. Carbon sequestration is a long-term storage of carbon in oceans, soils, vegetation (especially forests) and geologic formations (William, 1999; Dharmesh *et al.,* 2014).

Soil carbon is playing a key role in improving plant health, ability to transfer nutrients to plants, increasing water-holding capacity, maintaining biodiversity and reducing salinization of the soil (John, 2010; Scotti *et al*., 2015). As more photosynthesis occurs, more CO_2 is converted into biomass, reducing carbon in the atmosphere and sequestering it in plant tissue as above and below ground biomass (Gorte, 2009; IPCC, 2003; Chavan and Rasal, 2012a).

Reforestation and afforestation may have the greatest potential for sequestering carbon in soil and constitutes a major carbon sink as above and below ground biomass (Vitousek, 1991; Brown *et al*., 1992; Moffat, 1997; Bruce *et al*., 1999; Resh *et al*., 2002).

The standing biomass (as above ground and below ground biomass) of trees in India is estimated to be about 8,375 million tons reported for the year 1986, of which carbon storage would be 4,178 tons. The total carbon stored in forests, including soil is estimated to be 9,578 million tons (Ravindranath *et al.,* 1997; Devagiri *et al*., 2013). Several authors have reported that the total standing biomass of *Emblica officinalis Gaertn.* (63.31 Kg ha^{-1}), *Tamarindus indica L.* (67.32 Kg ha^{-1}), *Achras sapota L.* (23.65 Kg ha^{-1}), *Annona reticulata L.* (153 Kg ha^{-1}), *Annona squamosa L.* (135 Kg ha^{-1}), *Eucalyptus ssp*. (641.35 t ha^{-1}), *Mangifera indica L.*

(58.14 t ha^{-1}), *Albizia lebbek* L. (67.7 t ha^{-1}), *Delonix regia* (38.11 t ha^{-1}) and *Tectona grandis L* (147.5 t ha^{-1}) (Chaturvedi and Singh, 1982, 1987; Jana *et al*., 2009; Chavan and Rasal, 2011a, 2011b, 2012b, 2012c; Giri *et al*., 2014; Das and Mukherjee, 2015).

Suryavanshi, *et al*., (2014) reported the major carbon sequestrating species were *Moringa oleifera* (15.775tons/tree) followed by *Azardirachta indica (*12.272 tons/tree), *Delonix regia* (12.247 tons/tree), *Peltoforum pterocarpum* (9.576 tons/tree), *Acacia nilotica* (9.248 tons/tree) *Dalbergia sisso*o (7.207 tons/tree), *Butea monosperma* 3.553tons/tree), *Albizia lebbeck (*2.419 tons/tree). The *Eucalyptus citriodora has* lowest carbon sequestration potential (1.814 tons/tree) and the second lowest carbon sequestrating species was *Tectona grandis* having carbon content (1.915 tons/tree). The study was carried out in North Maharashtra University campus.

Estimates of carbon stocks and stock changes in tree biomass (above and belowground) are necessary for reporting to the United Nations Framework Convention on Climate Change (UNFCCC) and will be required for Kyoto Protocol reporting (Green *et al*, 2007; Chavan and Rasal, 2012a).

The tree crops cultivation and agro forestry system play a key role in the terrestrial carbon sequestration by efficiently converting the CO_2 into huge biomass besides improving the soil C pools. Hence, the present study aimed to estimate carbon stock in the soil and above and below ground biomass in different types of trees maintained under different years in south zone of Tamil Nadu.

MATERIALS AND METHODS

Study area

The study was conducted in 5 revenue villages such as Nallamanarkottai, Nallamanarkottai, Eriyodu, Paganatham, Thennampatty and Perumpulli of Vedasandur taluk in southern agro climatic zone of Tamil Nadu. The study was carried out during January 2015.

Bio-physical and socio-economic status of study area

The base line survey was conducted to collect information about biophysical and socio economic status through questionnaire method of selected orchards and agro-forests in southern and hilly zone of Tamil Nadu. The biophysical status such as latitude, longitude, temperature, rainfall, soil fertility managements and agronomical practices were periodically documented. The socio economic status such as total cultivable area, natural resources and economical wealth of the study area were also documented.

Estimation of Total Organic carbon (TOC%) using total organic carbon analyzer

The collected soil samples were shade dried and sieved using 200 mm sieves. The processed soil samples were stored in polythene bags. The total organic carbon was analyzed using Total Organic Carbon (TOC) analyzer with Solid Sample Module (SSM) - (*Make-SHIMADZU-Model TOC-L and SSM-5000A* Model number). The working principle of this equipment is combustion method. There are two separate sample inputs and sensors available with this equipment for detection of Total Carbon and Inorganic Carbon. The total carbon value was measured under 900 ºC and inorganic carbon under 200 ºC. Forty milligram of processed soil sample was weighed in two ceramic boats and loaded in the machine one after other and determined total carbon and in-organic carbon determination.

The total organic carbon = Total carbon – In-organic carbon

Estimation of Soil Carbon Stock in orchard trees

The quantity of carbon stock in 30 cm depth was calculated by following the method described by Batjes (1996). It involved multiplying bulk density (Mg m^{-3}) of each layer, and thickness of each horizon (cm) with the Soil organic carbon (%) in that layer.

Total C stock (Mg ha^{-1}) = SOC (%) x Bulk density (Mg m^{-3}) x depth (cm).

Biophysical measurements

The biophysical measurements such as height and diameter at breast height (DBH) were measured for each sample tree. The stratified random sampling was deployed and selected. A quadrant of 25 x 25 m was selected and the different orchards present in it are estimated for Height and Girth at Brest Height (GBH) at above ground were recorded.

Estimation of above ground biomass and derivation of above ground carbon

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 (Brown, 1997; Ravindranath and Ostwald, 2008; Chavan and Rasal, 2012a). The volume was calculated based on diameter and height. The wood density value for all the tree species taken for this study was obtained from global wood density database (http://hdl.handle.net/10255/dryad.235).

The biomass of all tree samples were calculated for total area for tons per hectare (t ha^{-1}).

AGB = Biovolume X Wood density

The above ground carbon (AGC) is the 50% of dry weight of above ground biomass (IPCC, 1996; Chavan and Rasal, 2012a).

AGC = AGB/2

Estimation of Belowground biomass and derivation of below ground carbon

The Below Ground Biomass (BGB) includes all biomass includes live roots excluding fine roots having <2mm diameter (Chavan and Rasal, 2012a). 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; Chavan and Rasal, 2012a). The equations are given below.

BGB = AGB X 0.26

The below ground carbon (BGC) is the 50% of dry weight of below ground biomass (IPCC, 1996; Chavan and Rasal, 2012a).

BGC = BGB/2

The total standing biomass (TSB) is obtained from the sum of AGC and BGC which is multiplied with 3.67 (44/12, where Molecular weight of CO_2 = 44 and Atomic weight of carbon = 12) for equivalent CO_2 t ha^{-1}

Collection of soil samples and estimation of physico chemical properties and microbiological properties:

The soil samples were collected at 3 different depths *ie*, 0-20, 20-40 and 40-60 cm of the soil by following the method described by Muthuvel and Udayasoorian, 1999. The soil samples were collected in a clean polythene bag, properly sealed, brought to the laboratory and stored at 25°C until further analysis. The soil samples were shade dried then powdered with wooden mallets and pass through 2 mm sieve. The collected soil samples were utilized for physicochemical and microbiological analysis by following standard methods. The physicochemical properties such as available Nitrogen was estimated by alkali permanganate method (Subbiah and Asija, 1956). The available Phosphorous was analyzed by following colorimetric method (Olsen *et al*., 1954). Available Potassium by neutral ammonium acetate method (Jackson, 1956), Calcium (Ca), Magnesium (Mg), Iron (Fe), Manganese (Mn), Zinc (Zn) and Copper (Cu) by following DTPA extract method (Lindsay and Norwell, 1978). Total Bacteria and Fungi in soil were enumerated by following serial dilution plate count technique (Waksman, 1952).

RESULTS AND DISCUSSION

Study area

The Vedasandur taluk is located in dindigul district of south zone, Tamil Nadu and the location of study area given in figure 1. The tree species such as mango, sapotta, coconut and teak maintained under different years viz.5, 10,15 and 20 years were selected for this study since these are predominantly growing in the concerned taluk. There are 1000 teak ha^{-1}, 220 mango ha^{-1}, 156 sapotta $ha^{-1}$and 250 coconut ha^{-1} can be planted in study area.

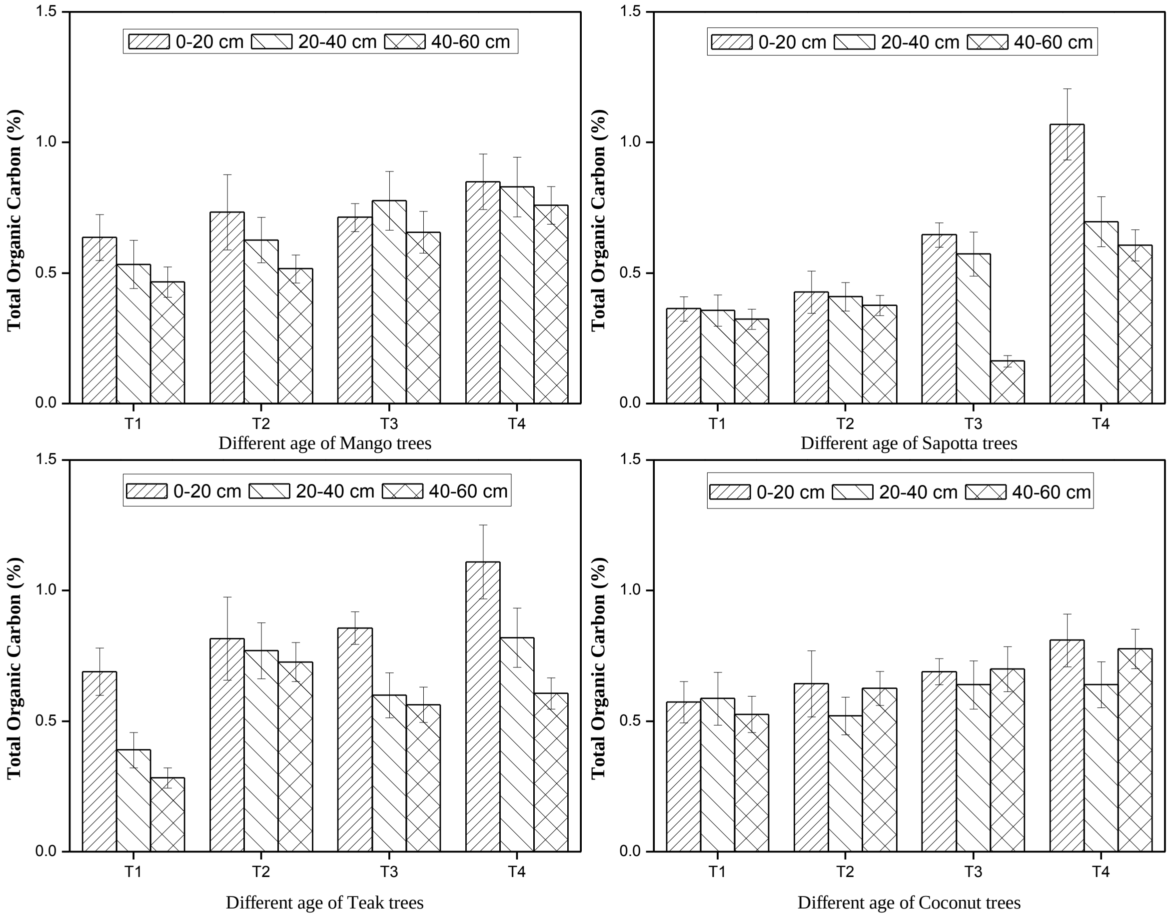
Bio-physical and socio-economic status of study area

The Vedasandur taluk is located at 10.53°N latitude and 77.95°E longitude recorded with an average annual temperature of 28.2 °C and the average rainfall was 630 mm. The farmers in these areas doing agriculture practices along with other activities such as dairy farming, poultry predominantly. They are using farm yard manure (12.5 t ha^{-1}) and poultry manure (5 t ha^{-1}) as their farm inputs. This taluk is a rainfed area, depending on the rainfall for agriculture practice, they cultivate rainfed crops such as millets and pulses as intercrop in tree crop field during September month.

Study on carbon sequestration potential of different types of trees

Different ages (5,10,15 and 20) of different types of trees such as mango, sapotta, coconut and teak in Vedasandur taluk under south zone of Tamil Nadu were selected for the study. The total organic carbon level was studied in all the type of trees selected for this study where carbon level was gradually increasing from 5 to 20 years old (Graph 1). The organic carbon content at 0-20 cm depth was higher in Teak plantations (0.69 to 1.11 %) in all the age of plantations viz. 5 to 20 years followed by mango (0.64 to 0.85 %), sapotta (0.36 to 1.07 %) and coconut (0.57 to 0.81 %). The equivalent CO_2 (eCO_2) and carbon stock was derived from the bulk density and organic carbon of the soil at 30 cm depth. The equivalent CO_2 (131.54 t ha^{-1}) was also found high in teak trees soil samples compared to the other tree soil samples (Table 1). With respect to different depths of soil (0-20, 20-40, 40-60 cm) the surface soil (0-20 cm) was recorded high organic carbon content (%) than the sub-surface profile in all orchards and agroforest.

Graph1: The total organic carbon of Mango, Sapotta, Teak and Coconut tree samples



Note: T1, T2, T3 and T4 – 5, 10, 15 and 20-year age of trees

Estimation of standing biomass as above and below ground biomass in different types of trees maintained under different years

The standing biomass of different types and age of trees such as mango, sapotta, teak and coconut were estimated by measuring the height and girth of the tree. The total standing biomass in 5 to 20 years old mango orchards recorded as 1.85 to 80.74 t ha^{-1}. The biomass recorded 17.93 to 365.87 t ha^{-1} for teak plantation and 2.86 to 24.45 t ha^{-1} of sapotta orchards respectively and 9.14 to 285.68 t ha^{-1} in coconut trees. In case of total standing carbon, 0.93 to 40.37 tC ha^{-1} in mango from 5 to 20 year orchards, 8.97 to 182.93 tC ha^{-1} in teak plantation, 1.43 to 12.22 tC ha^{-1} in sapotta orchards and 4.57 to 142.84 tC ha^{-1} in coconut trees were recorded. The highest total standing biomass was recorded in teak followed by coconut, mango and sapotta. The equivalent CO_2 was derived from total standing carbon where the mango orchards recorded 3.4 to 148.16 t ha^{-1} from 5 to 20 years, teak plantations, sapotta and coconut trees recorded 32.91 to 671.36 t ha^{-1}, 5.25 to 44.8 t ha^{-1} and 16.78 to 524.22 t ha^{-1} respectively. The significant differences in total standing biomass, carbon and equivalent CO_2 was recorded in 20-year-old compared with 5, 10, 15 years of orchards (Table 2).

Physico chemical properties of different types of trees (data not given)

Primary nutrients in different types of trees

Available nitrogen

The nitrogen content is significantly increasing in different types of trees. The available nitrogen content ranging from 80 to 103 (mg kg^{-1}) in mango, 91 to 105 (mg kg^{-1}) in sapotta, 82 to 126 (mg kg^{-1}) in teak and 85 to 117 (mg kg^{-1}) in coconut of 5 to 20-year-old tree planted soil samples. The highest nitrogen content was recorded in soils with teak plantation which was evidenced as highest carbon storage in soil and standing biomass. The increase in nitrogen content in the soil is due to the high litter fall and its decomposition. There are no significant differences in the nitrogen content was observed with respect to the depths.

Available phosphorous

The available phosphorous content was decreased in 20 years of all the trees compared to 5, 10 and 15 years. This is due to the intake of phosphorous by trees during their growing period. The highest phosphorous was recorded in 15 years of coconut trees 12.5 (mg kg^{-1}) and the lowest was recorded in 3.5 (mg kg^{-1}) in 20 years of sapotta. The significant differences were not found in different depths.

Available potassium

The available potassium was increased in different years viz 5,10,15 and 20 years old but no significance was observed in different depths in all the trees. The highest potassium was observed in 20 years of sapotta 235.75 (mg kg^{-1}) and the lowest was recorded in 5 years of mango 88.3 (mg kg^{-1}).

Secondary nutrients in different types of trees

The increasing trend of calcium was observed in all the trees as the age of trees increased and significant differences were observed in different depths. Whereas the magnesium was recorded as on par with each other in all the years and types of trees. The incredibly highest magnesium was recorded in coconut tree samples compared to the other samples.

Micronutrients in soils of different types of trees

The micronutrients such as iron, manganese, zinc and copper were estimated for all the tree samples. The manganese was increased as the age of trees increased. There were no significant differences found in remaining micronutrients such as iron, zinc and copper. But the iron was found very high in 5 and 10 years of sapotta. This may be due to the differential preference of element by different tree species.

Table 1: Influence of different types of orchard soil on carbon stock and equivalent CO_2

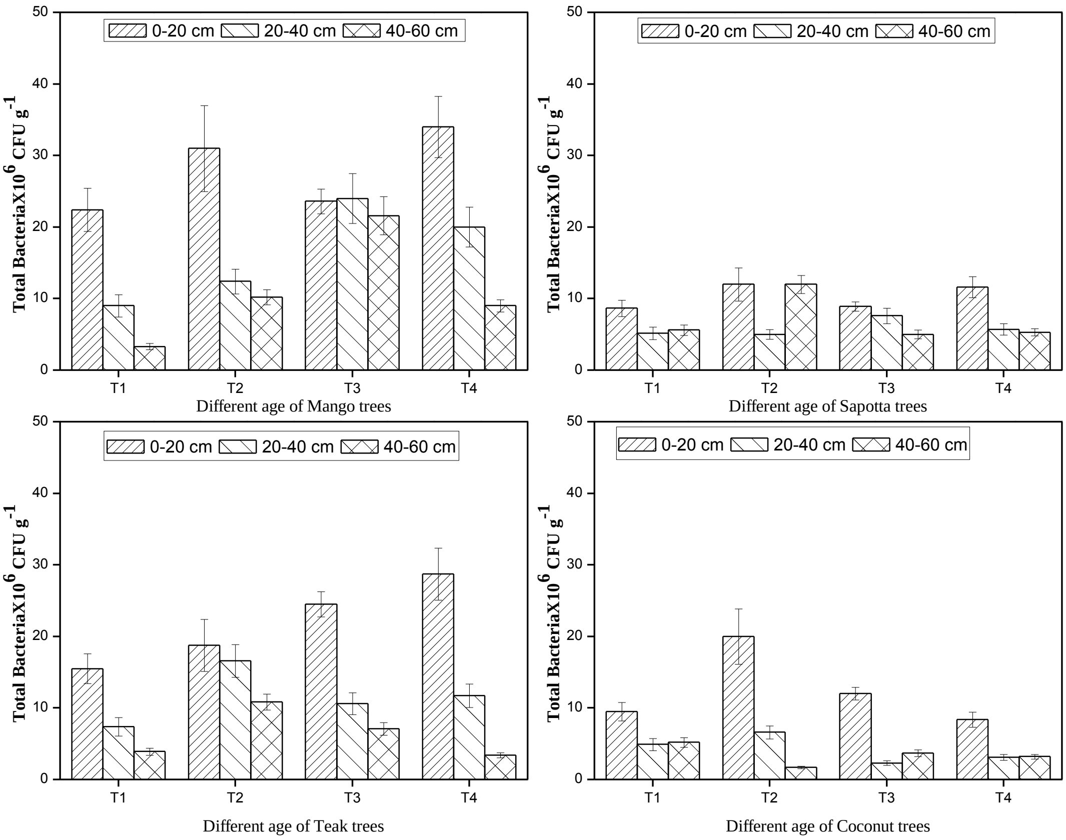
Mango	**Age of trees**	**Bulk Density ($g\ cm^{-3}$)**	**OC (%)**	**Carbon stock ($t\ ha^{-1}$)**	**eCO2 ($t\ ha^{-1}$)**
	5	1.33	0.64	25.60	93.95
	10	1.00	0.73	21.90	80.37
	15	1.18	0.71	25.06	91.97
	20	1.11	0.85	28.33	103.98
Sapotta	**Age of trees**	**Bulk Density ($g\ cm^{-3}$)**	**OC (%)**	**Carbon stock ($t\ ha^{-1}$)**	**eCO2 ($t\ ha^{-1}$)**
	5	1.33	0.36	14.40	52.85
	10	1.33	0.43	17.20	63.12
	15	1.14	0.64	21.96	80.60
	20	1.03	1.07	33.12	121.55
Teak	**Age of trees**	**Bulk Density ($g\ cm^{-3}$)**	**OC (%)**	**Carbon stock ($t\ ha^{-1}$)**	**eCO2 ($t\ ha^{-1}$)**
	5	1.11	0.69	23.00	84.41
	10	1.11	0.82	27.33	100.31
	15	1.14	0.86	29.51	108.30
	20	1.08	1.11	35.84	131.54
Coconut	**Age of trees**	**Bulk Density ($g\ cm^{-3}$)**	**OC (%)**	**Carbon stock ($t\ ha^{-1}$)**	**eCO2 ($t\ ha^{-1}$)**
	5	1.05	0.57	18.00	66.06
	10	1.05	0.64	20.21	74.17
	15	1.05	0.69	21.79	79.97
	20	1.11	0.81	27.00	99.09

Note: eCO_2 – Equivalent CO_2

Microbial properties and humus content in different orchards and agroforests soil

The bacterial and fungal colonies were recorded high in mango (22.4 to 34 X10^6 CFU g^{-1}) (5 to 16.2 X10^4 CFU g^{-1}) orchard soil followed by teak (15.5 to 28.73 X10^6 CFU g^{-1}) (3.5 to 15.18 X10^4 CFU g^{-1}), sapotta (8.65 to 11.6 X10^6 CFU g^{-1}) (8.5 to 11 X10^4 CFU g^{-1}) and coconut (9.5 to 20 X10^6 CFU g^{-1}) (6 to 9 X10^4 CFU g^{-1}) orchards (graph 2a, 2b). The highest humus content was recorded in mango orchard at 0-20 cm depth for 5 to 20 years (15.97 to 30.87 kg acre^{-1}) followed by teak (9.1 to 26.74 kg acre^{-1}), sapotta (10.2 to 18.41 kg acre^{-1}) and coconut orchards (10.38 and 11.94 kg acre^{-1}) (graph 2c). Therefore, the microbial colonies and Humus content were recorded high in mango and teak compared to sapotta and coconut orchards. Among different depths of all the tree types, the microbial colonies and humus content were recorded high at 0 – 20 cm than the sub-surface depths in all the years.

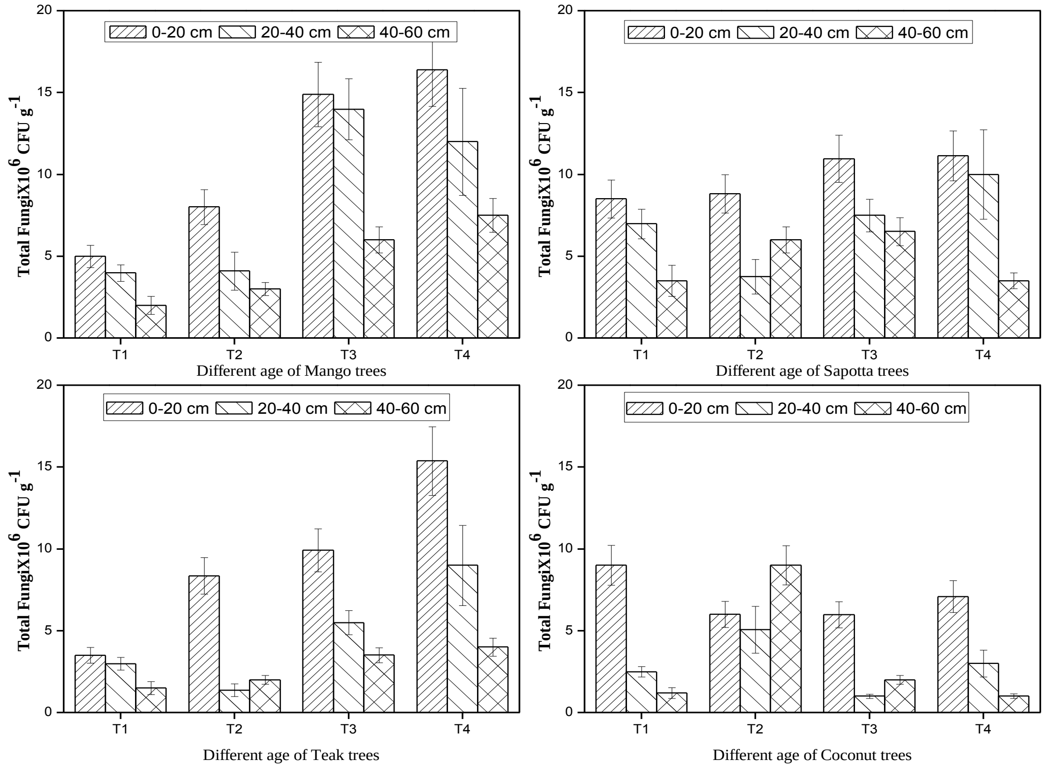
Graph 2: Microbiological and biochemical properties of different types of trees
Graph 2a: Enumeration of total bacteria



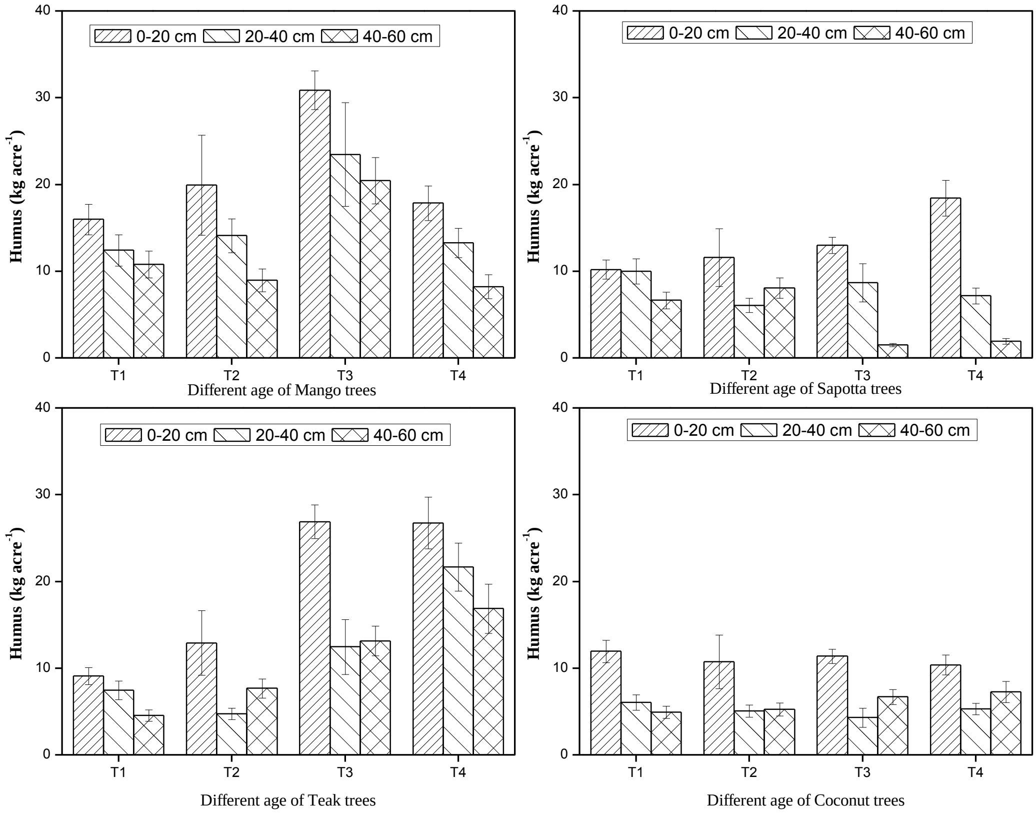
Note: T1 – 5 year, T2 – 10 year, T3 – 15 year, T4 – 20 year

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 sapotta, mango and coconut. Whereas standing biomass, standing carbon and equivalent CO_2 was recorded high in teak followed by coconut, mango and sapotta. 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 sapotta. 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, sapotta

Graph 2b: Enumeration of total fungi



Graph 2c: Estimation of Humus



Note:

T1 – 5 year, T2 – 10 year, T3 – 15 year, T4 – 20 year and coconut will be 0.37, 0.36, 0.154 and 1.14 tons per tree respectively in 20 years. The values of each tree is lying in the same line except sapotta and coconut, because it is depends on the tree height, wood density and land management practices. The significant differences were observed in different years of orchards but there was no significance in carbon sink in the soil and standing biomass. From this study it was observed that the teak plantations contribute more carbon sink in soil as well as holding the CO_2 in tree biomass as it can be planted more number of trees per hectare.

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