Journal of Environment and Earth Science www.iiste.org
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol 2, No.1, 2012

Total Sequestered Carbon Stock of *Mangifera indica*

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Abstract:

Carbon sequestration by green plants is a suitable way to reduce atmospheric CO_2. In the present investigation aboveground and belowground carbon sequestration potential of *Mangifera indica* from nine sectors of Aurangabad city was measured. The total standing aboveground biomass and belowground biomass of *Mangifera indica* are 82.83tha^{-1} and 21.54tha^{-1} respectively, while total standing biomass of *Mangifera indica* in 2847 hectares of Aurangabad is 104.41tha^{-1}. The sequestered carbon stalk in aboveground and belowground standing biomass of *Mangifera indica* are 44.73 tha^{-1} and 11.63 tha^{-1} respectively while, total sequestered carbon of *Mangifera indica* in 2847 hectares area is 56.36 tha^{-1}. The newly developed allometric equations for *Mangifera indica* on the diameter class basis for AGB as a function for DBH and height have shown high correlations.

Key words: Aboveground carbon, Allometric equation, belowground carbon, CDM, carbon sequestration potential, climate change, carbon stock, Total Biomass.

1. Introduction

Global emission of carbon dioxide has increased by 18% and is damaging the environment by reaching to the highest level after 1750. Its level increased per year by 1.5ppb in year 1990-2000, by 2ppb in 2001-2009 and by 2.3ppb in 2009-2010 which is highest in recent decades. It is contributing to global warming and climate change as discussed in earth summit held in 1992 at Rio De-Janerio, Quoto protocol signed in 1997 at Japan, Copenhagen conference in 2009 held at Denmark, Kankun conference in 2010 held at Maxico and Darban conference held in 2011 in South Africa (D.M., 2011). Many efforts are being made to reduce atmospheric carbon dioxide. The Kyoto Protocol, prepared by the United Nations in the Framework of Convention on Climate Change stipulates Clean Development Mechanisms (CDM) and its Joint Implementation whereby storage of carbon in various terrestrial sinks may be acceptable for insertion in national greenhouse gas inventories of each nation. Reducing greenhouse gas emissions including carbon dioxide can be achieved by controlling emissions and avoiding unadvisable land use changes. Carbon sequestration in growing forests is known to be a cost-effective option for mitigation of global warming and global climatic change. Sequestration can be defined as the net removal of carbon dioxide from the atmosphere into long lived carbon pools. 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; Almgir and Al-Amin, 2007).

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 of biomass 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 objective of this paper is to estimate sequestered carbon of *Mangifera indica* from Aurangabad.

1.1 Plant study

The scientific name of mango tree is *Mangifera indica* L. It belongs to Anacardiaceae family. The canopy of *Mangifera indica* is evergreen and fast growing tree. Mango is a common garden tree throughout the tropics. Most of the fruit trees belonging to this family that are commonly known as mango trees and belong to the species *Mangifera indica*. The wild *Mangifera* species are generally edible but have lower quality fruits. The mango tree have adapted throughout the tropics and subtropics. Much of the spread and naturalization has come about in conjunction with the spread of human populations. Mango tree is an evergreen tree changeable in height from 5 to 40m in with a short straight bole reaching a diameter to 100cm. The total tree biomass is composed of following components (Bally, 2006; Chavan and Rasal, 2011).

1. **Bark & Branches:** The bark of mango tree is somewhat rough, fissured and dark brown to grey. Its twigs are rounded, stout, and glabrous with prominent leaf scars. Its shoots are reddish-green and smooth, turning light brown shoots.

2. **Leaves:** The leaves of mango tree are simple, alternate, petiolate and at 2-10 cm and distinctly thickened at the lower end and smell of turpentine when these are crushed. They are glabrous in appearance and shaped like front. They extend from 15-30 cm in length and 4-6 cm in width. They are reddish-brown when young and turn a shiny dark green with age.
3. **Flowers:** The flowers are in bunches, 5-7mm across and may be male or hermaphrodite. They consist of 5 green triangular sepals, 5 clawed with curved petals, Flowers appear in the period of December to May and fruits in April to August.

4. **Fruits:** The mango fruits are botanically considered to be edible drupes. They are initially with green peels and turn various shades of red, yellow and green colors after growth and when ripe. The fruits of commercially cultivated species are larger in size and more in weights. The pulp surrounds a stony hard coat that contains a seed in each fruits.

The mango fruit is an important source of sustenance for birds, bats, insects, and mammals. Although grown widely, mangos prefer a warm, frost-free climate with a well-defined winter dry season. Rain and high humidity during flowering stage and fruit development stage reduces fruit yields. The tree generally flowers in mid to late winter, with fruits maturing in the early to mid-summer months. Mango trees are usually between 3 and 10 m (10–33 ft.) tall but can reach up to 30 m (100 ft.) in some natural forest situations. The canopy is evergreen with a generally spreading habit. The heavy canopy of the mango is a good shelter and shade for both animals and humans. Mangos are well adapted to cultivation in various soils and have been grown commercially for centuries. Today, mangos are well recognized and eaten throughout the world. They are regarded as one of the most popular and esteemed tropical fruits (Bally, 2006).

***1.2 Distribution*:** The genus *Mangifera* originates in tropical Asia. The large numbers of species are found in Borneo, Java, Sumatra, and the Malay Peninsula. The most-cultivated *Mangifera* species, *M. indica* (mango), has its origins in India and Myanmar (Bally, 2006).

India ranks first among world's mango producing countries. It accounts for about 50% of the world's mango production. India's shared around 12 million tons as against world's production of 23 million tons as figured in 2002-03. An increasing trend has been observed in world mango production averaging 22 million metric tons per year. In India the major mango producing States are Andhra Pradesh, Bihar, Gujarat, Karnataka, Maharashtra, Orissa, Tamil Nadu, Uttar Pradesh and West Bengal. Other States where mangoes are grown include Madhya Pradesh, Kerala, Haryana, Punjab etc. Source: Database of National Horticulture Board, Ministry of Agriculture, Govt. of India. Worldwide production is mostly concentrated in Asia, accounting for 75%. It is followed by South and Northern America with about 10% share. The other major mango producing countries include China, Thailand, Mexico, Pakistan, Philippines, Indonesia, Brazil, Nigeria and Egypt (ESD, 2009).

1.3 Economic Importance: The fruits of mango are is incredibly popular with the ample due to their wide range of adaptability, high nutritive value, richness in variety, delicious taste and excellent flavor. Mango fruit is rich source of vitamin A and C. Good mango varieties contain 20% of total soluble sugars. The acid content of ripe desert fruit varies from 0.2 to 0.5 % and protein content is about 1 %. The wood is relatively soft and used as timber and dried twigs are used for religious purposes. The mango fruit kernel is most important part and contains about 8-10% good quality fat useful for saponification. Its starch is used in confectionery industries. Mango has medicinal uses too. The ripe fruit is high in calories with diuretic and laxative properties. It helps to increase digestive capacity (Bally, 2006; ESD, 2009).

2. Experimental Methodology

2.1 Study area:

The study is located in the state of Maharashtra, in India. Aurangabad is located at the latitude 19^0 53'47"N and longitude 75^0 23'54" E. The average day temperature ranges from 27.7^0C to 38.0^0 C while it falls from 26.9^0C to 20.0^0C during night. The average annual rainfall in Aurangabad city and adjoining area is 725.8 mm (28.57"). Relative humidity is extremely low in this region for major part of the year which ranges between 35 to 50%, while it is highest (85%) during monsoon. The total land portion under forest cover is about 557 km^2 which is only 7.6% area of total land area in Aurangabad (SFR, 2009). The total 28.47 sq.km area of Aurangabad city is selected for the carbon sequestration study.

The total 2847 hectares of study area from Aurangabad was selected for the carbon sequestration study. The fig.1 shows the 9 sectors from Aurangabad as sampling locations for *Mangifera indica* trees studied. The samples were collected from a representative tree of each species from each sampling plot from the study region.

2.2 Biophysical measurements:

The height and diameter at breast height (DBH) are two main biophysical measurements which measured for each tree sample. The mango tree height measured by Theodolite instrument follower the procedure given elsewhere (Chavan and Rasal, 2010; Chavan and Rasal, 2012). The tree diameter was measured at breast height (DBH) by using diameter measure tape.

2.3 Estimation of Aboveground biomass:

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. The wood density value for the *Mangifera indica* species obtained from web (www.worldagroforestry.org).

AGB (g) = Volume of biomass (cm3) X wood density (g/cm3)

The biomass of all samples *Mangifera indica* trees in the all the sample plots (t) was calculated and extrapolating it for total area (tha^{-1}).

2.4 Estimation of Belowground biomass:

The Below Ground Biomass (BGB) includes all biomass includes all biomass of live roots excluding fine roots having <2mm diameter (Chavan and Rasal, 2011). Biomass estimation equations for tree roots are relatively uncommon in the literature. 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 X above-ground biomass (tha^{-1})

3. Result and Discussion

3.1 Biomass estimation

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 study conducted by Chavan and Rasal (2011) in University campus of Aurangabad found that carbon content of dry biomass was 54% for *Mangifera indica*. 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 (Losi et al., 2003; Jana et al., 2009) as the content of carbon in woody biomass in any component of forest on average is around 50% of dry matter (Paladinic et al., 2009).

The standing biomass stalks in *Mangifera indica* trees in Aurangabad are shown in Table 1. It was observed that sector no. 4 contain highest *Mangifera indica* in aboveground biomass, belowground biomass and total standing biomass (32.31 tha^{-1}, 8.40 tha^{-1} and 40.71 tha^{-1}) followed in sector no. 8 (8.27 tha^{-1}, 2.15 tha^{-1} and 10.42 tha^{-1}), sector no. 6 (7.61 tha^{-1}, 1.9 tha^{-1} and 9.59 tha^{-1}), sector no. 9 (7.45 tha^{-1}, 1.94 tha^{-1} and 9.39 tha^{-1}), sector no. 5 (6.82 tha^{-1},1.79 tha^{-1} and 8.61 tha^{-1}), sector no. 7 (6.79 tha^{-1}, 1.77 tha^{-1} and 8.56 tha^{-1}), sector no. 2 (5.57 tha^{-1}, 1.45 tha^{1} and 7.02 tha^{-1}), sector no. 3 (5.39 tha^{-1}, 1.40 tha^{-1} and 6.79 tha^{-1}) and lowest at sector no.1 (2.61 tha^{-1}, 0.68 tha^{-1} and 3.29 tha^{-1}). The total standing aboveground biomass and belowground biomass of *Mangifera indica* were 82.83 tha^{-1} and 21.54 tha^{-1} respectively while, total standing biomass of *Mangifera indica* in 2847 hectares area were 104.41 tha^{-1}.

3.2 Carbon stock estimation

The sequestered carbon stalks in *Mangifera indica* trees in Aurangabad are shown in Table 2 and Fig. 2&3. It was observed that sector no. 4 contain highest *Mangifera indica* carbon stalk in aboveground, belowground and total carbon sequestered (17.44 tha^{-1}, 4.53 tha^{-1} and 21.97 tha^{-1}) followed in sector no. 8 (4.46 tha^{-1}, 1.16 tha^{-1} and 5.62 tha^{-1}), sector no. 6 (4.11 tha^{-1}, 1.07 $tha^{-1}$and 5.18 tha^{-1}), sector no. 9 (4.02 tha^{-1}, 1.04 $tha^{-1}$and 5.06 tha^{-1}), sector no. 5 (3.65 tha^{-1}, 0.97 tha^{-1} and 4.62 tha^{-1}), sector no. 7 (3.67 tha^{-1}, 0.95$tha^{-1}$and 4.62 tha^{-1}), sector no. 2 (3.01 tha^{-1}, 0.78 tha^{-1} and 3.79 tha^{-1}), sector no. 3 (2.91 tha^{-1}, 0.75 tha^{-1} and 3.66 tha^{-1}) and lowest at sector no. 1 (1.41 tha^{-1}, 0.36 tha^{-1} and 1.77 tha^{-1}). The sequestered carbon stalk in aboveground and belowground standing biomass of *Mangifera indica* were 44.73 tha^{-1} and 11.63 tha^{-1} respectively while, total sequestered carbon of *Mangifera indica* in 2847 hectares area were 56.36 tha^{-1} (Table 2). Hairiah, (2009) referred as 1t of Carbon is equal to 3.67tCO_2. The atmospheric CO_2 captured by *Mangifera indica* from the Aurangabad city were 206.84 tCO_2 ha^{-1}.

The total of aboveground biomass and belowground biomass together as sequestered carbon stalk per hectare as estimated from university campus of Aurangabad for *Mangifera indica* it was 30.6 Kg C ha^{-1} (Chavan and Rasal, 2011). The total aboveground biomass carbon stock per hectare as estimated for *Shorea robusta*, *Albizzia lebbek*, *Tectona grandis* and *Artocarpus integrifolia* were 5.22, 6.26, 7.97 and 7.28 t C ha-1, respectively in selected forest stands (Jana, 2009). The average standing stock of organic carbon in *Mangifera indica* is higher than organic carbon content in selected well grown trees of Dr. B. A. M. University campus which was 1.65 t/tree (Chavan and Rasal, 2010).

The Aboveground and Belowground carbon Total carbon stalk of a tree has been evaluated by sum of Aboveground and belowground carbon stalk of *Mangifera indica* in (tha^{-1}). From the Fig. 4 it is revealed that the total carbon stalk (tha^{-1}) at *Mangifera indica* from 9sectors of Aurangabad the highest carbon content in sector 4th it was 39% followed by sector 8 (10%), sector 6 & 9 (9% each), sector 5&7 (8% each), sector 2 & 3 (7% each) and lowest at sector 1 (3%).

3.3 Statistical Analysis

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).

Allometric equations describe the relation between biomass Vs diameter and height of tree. To test the effect height and diameter on aboveground biomass of the tree the model is used $Y = a + b (D) + c (H)$. Where, Y is aboveground biomass (gm), D is diameter at breast height (cm), H is total height of tree (m), a is the intercept and b, C = regression coefficients. For *Mangifera indica* the biomass equations developed on the basis of diameter class < 25cm, >25 to <65 cm diameter and >65cm (Table 3).

The allometric equations were developed for aboveground biomass with height and diameter of *Mangifera indica* tree on the diameter class viz. diameter below 25cm, diameter above 25cm to 65cm and diameter above 65cm (Table 4). From the developed allometric equations for total above ground biomass (AGB) of *Mangifera indica* as a function of Diameter at Breast Height and Height showed high correlation was for equation for <25cm (95.8%), equation >25cm to <65cm (93.8%) and >65cm it was 98.6cm and high significant P>0.00 value.

Fig.1: Allometric relationship between aboveground biomass (Kg) with Height (m) and Diameter (m) and DBH <25cm for *Mangifera indica* tree. The developed allometric equation is B = - 2.43 + 0.154 D + 0.193

H, where B is above-ground biomass (Kg) with D (cm) is diameter at breast height (1.3m) and H is (ft) total height.

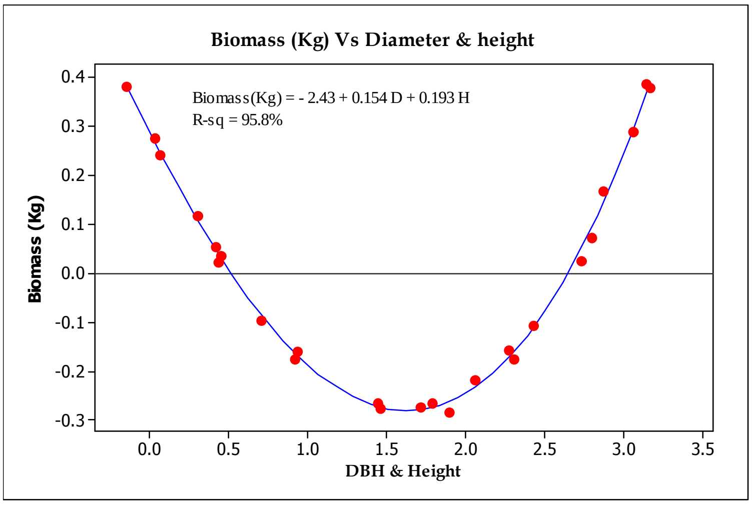


Fig.2: Allometric relationship between aboveground biomass (Kg) with Height (m) and Diameter (m) with DBH >25cm to <65cm for *Mangifera indica* tree. The developed allometric equation is B = - 26.6 + 0.614 D + 1.39 H, where B is above-ground biomass (Kg) with D (cm) is diameter at breast height (1.3m) and H is (ft) total height.

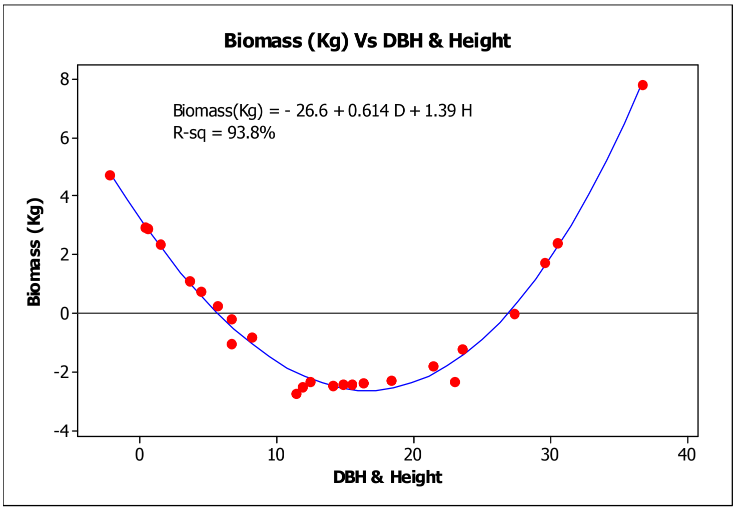
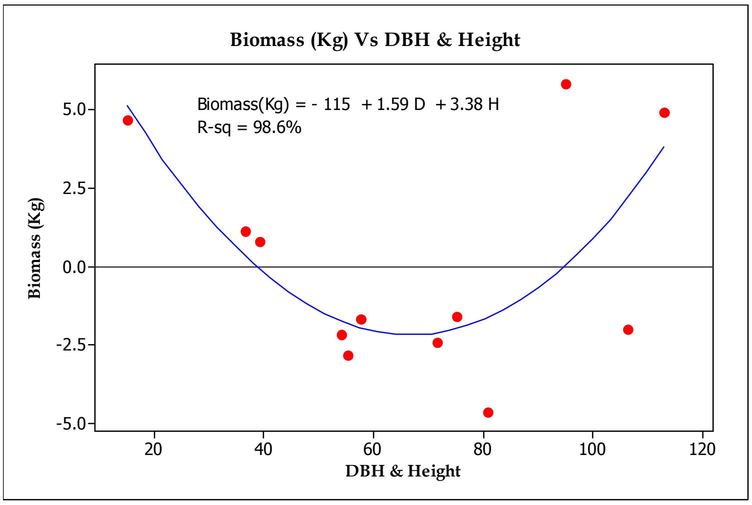


Fig.2: Allometric relationship between aboveground biomass (Kg) with Height (m) and Diameter (m) with DBH >65cm for *Mangifera indica* tree. The developed allometric equation is B = - 26.6 + 0.614 D + 1.39 H, where B is above-ground biomass (Kg) with D (cm) is diameter at breast height (1.3m) and H is (ft) total height.



Site specific equations must be considered for accurate estimation of above-ground biomass in logged-over tropical rainforests, although several authors have stated that for tropical forests, local species-species allometric relationships must be employed (Alves et al., 1997; Chave et al., 2004; 2005; Brown 1997; Schroeder, 1997). The studies in both primary and secondary forests in Southeast Asia reported the importance of site-specific equations for accurate biomass estimation based on application and/or comparison of the proposed pan-tropic general models (Brown 1997 and Chave et al., 2005) and observed biomass data biomass data sets for each forest type (Bauki et al., 2009; Kenzo et al., 2009). The above studied species specific equations useful for accurate estimation of above-ground biomass in *Mangifera indica*.

4 Conclusions:

Total standing biomass of *Mangifera indica* in 2847 hectares of Aurangabad are 104.41tha^{-1}. The sequestered carbon stalk in aboveground and belowground standing biomass of *Mangifera indica* are 44.73 tha^{-1} and 11.63 tha^{-1} respectively while, total sequestered carbon of *Mangifera indica* in 2847 hectares area are 56.36 tha^{-1}. The atmospheric CO_2 captured by *Mangifera indica* from the Aurangabad city are 206.84 tCO_2 ha^{-1}. The allometric regression equations indicate high correlation and accurate relationship between aboveground biomass as a function of both variables DBH and height in the *Mangifera indica* in the study area.

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Tables:

Table 1: The sector wise aboveground biomass and belowground biomass of *Mangifera indica* in Aurangabad

Sectors	No. of tree	Aboveground biomass tha^{-1}	Belowground biomass tha^{-1}	Total Standing Biomass tha^{-1}
1	191	2.61	0.68	3.29
2	407	5.57	1.45	7.02
3	394	5.39	1.40	6.79
4	2359	32.31	8.40	40.71
5	497	6.82	1.79	8.61
6	556	7.61	1.98	9.59
7	496	6.79	1.77	8.56
8	604	8.27	2.15	10.42
9	544	7.45	1.94	9.39
Total	6048	82.83	21.54	104.41

Table 2: The sector wise aboveground and belowground carbon of *Mangifera indica* in Aurangabad.

Sectors	No. of tree	Aboveground carbon tha^{-1}	Belowground carbon tha^{-1}	Total Carbon sequestered tha^{-1}
1	191	1.41	0.36	1.77
2	407	3.01	0.78	3.79
3	394	2.91	0.75	3.66
4	2359	17.44	4.53	21.97
5	497	3.65	0.97	4.62
6	556	4.11	1.07	5.18
7	496	3.67	0.95	4.62
8	604	4.46	1.16	5.62
9	544	4.02	1.04	5.06
Total	**6048**	**44.73**	**11.63**	**56.36**

Table 3: The regression coefficient (a, b and c) for estimate aboveground biomass of *Mangifera indica*

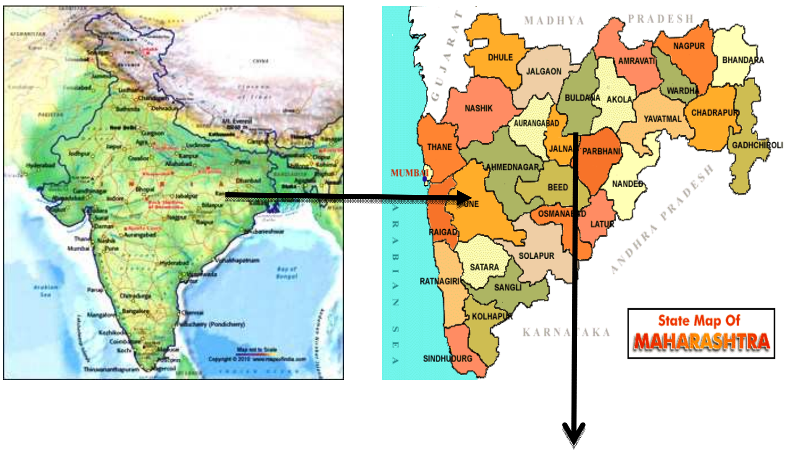
Diameter class	a	b	c
< 25cm	-2.43	0.154	0.193
>25 to <65 cm	-26.6	0.614	1.39
>65 cm	-115	1.59	3.38

(a = intercept, b & C = regression coefficient, R= regression coefficient)

Table 4: Allometry equations based on the regression coefficient to estimate aboveground biomass of *Mangifera indica*

Diameter class	Biomass equations	R^2
< 25cm	Biomass(Kg) = - 2.43 + 0.154 D + 0.193 H	95.8 %
>25 to <65 cm	Biomass(Kg) = - 26.6 + 0.614 D + 1.39 H	93.8 %
>65 cm	Biomass(Kg) = - 115 + 1.59 D + 3.38 H	98.6 %

Figures:



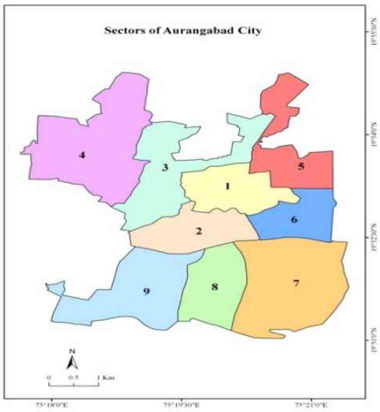


Figure 1: Location of study sites in Aurangabad city.

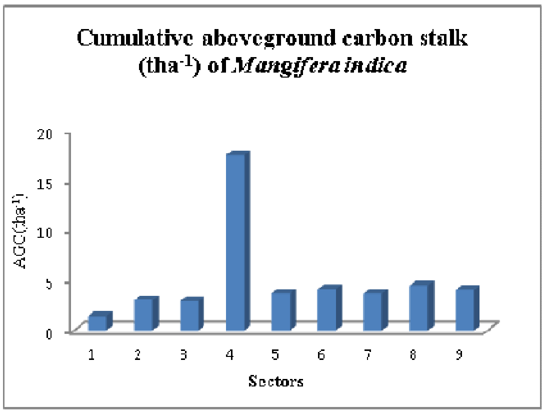


Fig.2: Aboveground carbon (tha^{-1}) of
Mangifera
Mangifera indica from 9 sectors of Aurangabad.

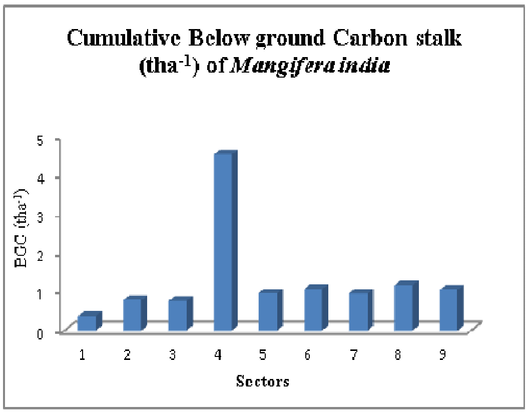


Fig.3: Belowground carbon (tha^{-1}) of
indica from 9 sectors of Aurangabad.

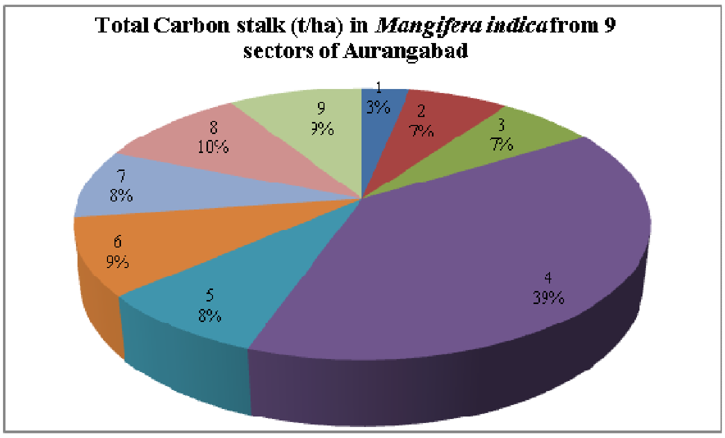


Fig.4: Total carbon stalk (tha^{-1}) of *Mangifera indica* from 9 sectors of Aurangabad