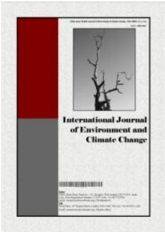

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Assessment of Biomass and Carbon Stocks in Mango (*Mangifera indica* L.) Orchards of Ratnagiri District of Maharashtra State, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A study was undertaken on mango orchards ranging in age from 10 to 50 years old, with the goal of determining the biomass and carbon stock. Carbon sequestration by green plants is an effective method of reducing atmospheric CO_2. At the moment, carbon sequestration by horticulture crops is an effective method of reducing atmospheric CO_2. In the current work, a non-destructive in-situ biomass estimation approach was utilised to measure the biomass of a tree. The above ground biomass (AGB), below ground biomass (BGB), and carbon sequestration capacity of Mango (*Mangifera indica L.*) orchards in Ratnagiri district of Konkan area, Maharashtra, are investigated in this study. In Ratnagiri district the average carbon stock rate was found to be 95.89 t/ha. In present study, allometric equations used to estimate AGB and BGB of *Mangifera indica L.* The potential of

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mango to sequester carbon depends on the age of the mango tree and the diameter of the trees. In the present study, above-ground biomass indicates that as mango tree diameter increases, the value of above-ground biomass also increases. Hence, the study showed that the diameter class for AGB as a function of diameter at breast height (DBH) has demonstrated a strong relation. This indicates the important role of large-diameter trees in carbon capture and storage.

Keywords: Biomass carbon; carbon sequestration; GBH; total biomass; carbon stock.

1. INTRODUCTION

In recent decades, climate change and biodiversity conservation are two major issues which requires huge attention to scientific community and policy makers. Increasing atmospheric CO_2 level in the atmosphere as a result of anthropogenic activities such as global warming, as changes in frequency or severity of extreme events as well as more precipitation, burning of fossil fuels, deforestation, etc. Global warming is one of the problems of new millennium. Carbon emissions are one of the primary contributors to global warming. Global climate change and global warming have many more adverse impacts on humans and natural systems. Between 1750 and 2011 year, cumulative anthropogenic CO_2 emissions to the atmosphere were 2040 ± 310 Gt CO_2, with over half of the anthropogenic emissions occurring in the last 40 years (IPCC) [1].

Carbon is mostly found in all living organisms primarily as plant biomass, soil organic matter, etc. The 50 per cent of tree standing biomass is carbon, thus trees are key sinks for atmospheric carbon, i.e. carbon dioxide (Ravindranath *et al*.) [2]. Carbon sequestration is a concept of storing carbon in the oceans, soils, vegetation and geologic formations for long periods of time (Dharmesh *et al*.) [3]. Carbon sequestration in expanding forests is proven to be a cost-effective method for mitigating global warming and climate change.

Reforestation and afforestation have the greatest potential for sequestering carbon in soil and constitutes carbon sink primary in above and below ground biomass (Resh *et al*.) [4]. Naik et al. [5] investigated biomass production and carbon stock estimation in mango orchards in the hot and humid eastern area of India. In 2-10 year old mango orchards, total biomass ranged from 0.53 to 10.5 Mg/ha, with a mean addition of 0.26 to 1.05 Mg/ha/yr. Carbon sequestration through tree-based systems will be viewed as an appealing commercial potential for carbon trading. Mango (*Mangifera indica L.),* sometimes known as the "King of Fruits," is a member of the *Anacardiaceae* family and is widely grown in India. About 18.431 MT of total production of Mango in India with approximately 2.516 million ha area and productivity of 7.3 Mt/ha. India contributes about 64 % of the world's Mango production. In Maharashtra, about 4.82 lakh ha area occupying Mango with annual production of 6.33 MT with productivity of 1.3 MT/ha. In Konkan, 1.10 lakh ha productive area was under Mango cultivation with annual production of 2.6 lakh MT. Hence, in Konkan Mango productivity is about 2.5 to 3.0 MT/ha, which is about three times less than the average productivity of the country. Plant biomass is important in terrestrial ecosystem for estimating the carbon stock. Estimating the quantity of carbon dioxide sequestered from the atmosphere requires estimating the biomass of individual trees or orchards. Despite the fact that biomass has long been of primary relevance and interest in forestry, research on this method in horticulture plants is limited. As a result, this study sought to estimate the biomass and carbon stock of mango orchards in Ratnagiri district of the Konkan region of Maharashtra.

2. MATERIALS AND METHODS

Konkan region, which occupies the entire west coast of Maharashtra having uneven terrain. The Ratnagiri district selected for the study which is a coastal area of Maharashtra state, located on India's western coast. The Ratnagiri district covers an area of 8,461 sq. km. It is divided into 5 watersheds which covered 8,459 sq. km. area with average annual rainfall of 3,591 mm.

2.1 Assessment of Carbon Sequestration from Ratnagiri District

Atmospheric enrichment of CO_2 can be managed by reducing anthropogenic emissions and by adopting proper management practices in agriculture and forestry ecosystems, which would enhance storing or sequestering carbon either into the plant or into the soil. Carbon sequestration by fruit trees are mostly determined by how old tree, diameter, and terrestrial area. Carbon storage increases in young tree species, but diminishes after full development as the stand ages (Jana et al.) [6]. Similarly, the amount of carbon sequestered continuously by a tree increases considerably over the time as well as age of tress till it matures. There are two major carbon pools. Those are biomass and soil carbon. In the present study, total carbon stock values were calculated using coefficient value for the conversion of biomass to carbon as carbon stock present in biomass.

2.2 Carbon Stock in Biomass

The entire amount of live and inert or dead organic matter above and below ground, represented in tonnes of dry matter per unit area, is called as biomass. In situ sampling methods, such as direct destructive biomass estimation and non-destructive indirect biomass estimation, remote sensing methods, or alternative models, can be used to measure stored carbon and tree biomass. The in situ non-destructive biomass approach was employed in this work to assess the biomass of mango orchards. Biomass estimation without harvesting a tree is reasonably straightforward and appropriate when utilising allometric or conversion factors (FAO) [7].

2.3 Estimation of above Ground Biomass using Regression Equations

Regression equations were used to estimate the above ground biomass from Mango orchards. Depending upon the diameter at breast height and considering climatic conditions, regression equations developed by FAO [7] was used to estimate above ground biomass including stem, stump, branches, bark, seed and foliage of individual Mango orchards in kg. The climatic zone of Ratnagiri district is humid zone. Humid region equation was applied. Regression equation used for estimation of above ground biomass is as follows,

$$Y = 42.69 - 12.800 \times D + 1.242 \times D^2$$

Where, Y denotes above ground biomass in kg, D denotes diameter at breast height in cm

For effective data collection, the entire study area was divided into grid by plotting a grid size of 10 km × 10 km for effective data collection. Therefore, total 58 villages were selected for data collection (Fig. 1).

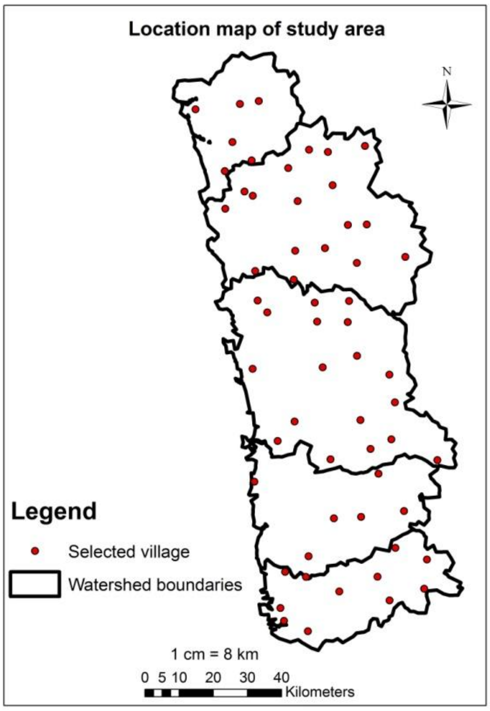

Fig. 1. Location map of study area

2.4 Below ground Biomass Estimation

The below ground biomass was determined by multiplying above ground biomass by 0.26, where 0.26 is the root to shoot ratio (Ravindranath and Ostwald) [8].

2.5 Total Biomass Estimation

The sum of above and below ground biomass is the total biomass of Mango orchards.

2.6 Carbon Stock Estimation of Mango Orchards

Carbon was assumed to be 50% of the biomass of any plant species (Vieilledent et al.) [9]. As a result, the coefficient value of 0.5 for biomass to carbon conversion was used (Ravindranath et al.) [2].
Biomass to carbon stock = 0.5 x total biomass of Mango orchards

2.7 Amount of CO_2 Sequestered by Mango Orchards

To calculate CO_2 assimilation by vegetation, estimated carbon stocks would be transformed into CO_2 equivalents (biomass value × 3.667) (Guleria *et al*.) [10]. Amount of CO_2 sequestered by each selected village was calculated from carbon stock values of Mango orchards.

2.8 Generation of Maps

The estimated values of above and below ground biomass, carbon stock and carbon sequestered of selected village in Ratnagiri district for Mango orchards were assigned in attribute table in ArcGIS software available with Dr. Balasaheb Sawant Konakn Krishi Vidyapeeh, Dapoli to generate respective maps of Ratnagiri district of Konkan region, Maharashtra.

3. RESULTS AND DISCUSSION

For assessing the contribution of horticulture crop lands to global carbon cycle, tree above and below ground biomass and carbon stock of mango orchards are important in Ratnagiri district. Horticultural crop area of Ratnagiri district were 1,50,057 ha, out which Mango crop area about 60,105 ha.

3.1 Carbon Stock in Mango Crop

The girth of mango orchards was measured at a breast height of 1.3 m from the ground surface in order to estimate the mango tree biomass and carbon stock. 30 Mango orchards girth were measured at each selected village. The different sizes of girth at breast height (GBH) and their mean were calculated for each selected village. Watershed wise mean values of GBH were shown in Table 1. From the Table 1, it seen those average girths at breast height were ranging from 40.86 to 174.84 cm with mean of 124.29 cm (standard error of 2.78) of mango orchards in Ratnagiri district.

3.2 Estimation of above Ground Biomass of Mango Orchards

The potential of Mango orchard to sequester carbon depends on the age and diameter of Mango orchard. Values of above ground biomass in Ratnagiri district were ranges from 8.64 to 318.07 t/ha with average of 148.22 t/ha (standard error of 8.08) (Table 2 and Fig. 2). Values of above ground biomass indicate that as Mango tree diameter increases the value of above ground biomass is also increases. Above ground biomass accumulated in each tree was 80 % of the total biomass of the tree. These values corresponded to various studies that provided the percentages of above ground biomass, such as 70 – 80 per cent (Brahma et al.) [11].

Table 1. Watershed wise girth at breast height (GBH) of Mango orchards in Ratnagiri district

Sr. No.	Watershed	Girth at breast height (cm)	Average GBH (cm)
1	Watershed 1 (940494 ha)	93.52 – 174.84	135.98
2	Watershed 2 (233174 ha)	68.28 – 165.13	119.89
3	Watershed 3 (261259 ha)	58.23 – 165.58	123.12
4	Watershed 4 (147355 ha)	70.30 – 143.40	119.72
5	Watershed 5 (109996 ha)	40.86 – 158.13	129.16
		Average	**124.29**

3.3 Estimation of below Ground Biomass of Mango Orchard

Values of below ground biomass in Ratnagiri district were ranges from 2.25 to 82.70 t/ha with average of 38.54 t/ha (standard error of 2.10) (Table 2 and Fig. 3). Below ground biomass accumulated in each tree was 20 % of the total biomass of the tree. Similar percentage of below ground biomass i.e. 19 % was found in moist central African forest (Ekoungoulou *et al.*) [12].

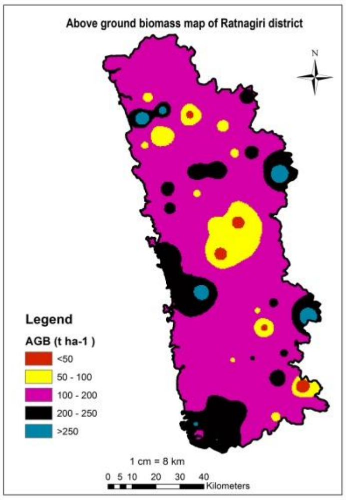

Fig.2. Above ground biomass map of Ratnagiri district

Table 2. Watershed wise values of AGB, BGB and total biomass Mango from Ratnagiri district

Watershed	Range of AGB (t/ha)	Average AGB (t/ha)	Range of BGB (t/ha)	Average BGB (t/ha)	Range of total biomass (t/ha)
Watershed 1	76.32 – 318.07	191.81	19.84 – 82.70	49.87	96.16 – 400.77
Watershed 2	35.16 – 280.44	146.77	9.14 – 72.92	38.16	44.31 – 353.36
Watershed 3	23.24 – 282.14	157.05	6.04 – 73.36	40.83	29.29 – 355.49
Watershed 4	37.87 – 204.85	144.40	9.85 – 53.26	37.55	47.71 – 258.11
Watershed 5	8.64 – 254.79	175.56	2.25 – 66.25	45.65	10.89 – 321.04
	Average	**148.22**		**38.54**	

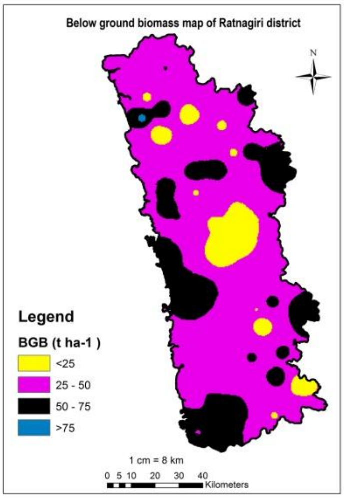

Fig. 3. Below ground biomass map of Ratnagiri district

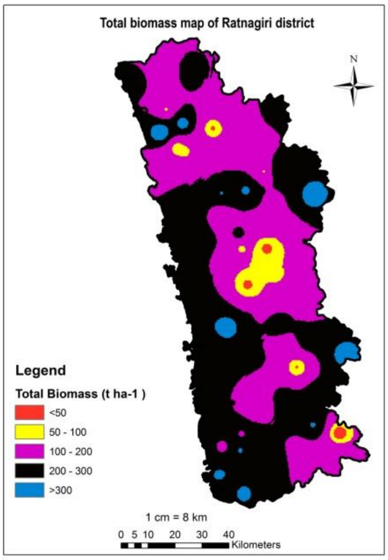

Fig. 4. Total biomass map of Ratnagiri district

Table 3. Watershed wise carbon stock and carbon sequestration for Ratnagiri district

Watershed	Carbon stock range (t C/ha)	Average carbon stock (t C/ha)	Carbon sequestration range (t CO_2/ha)	Average carbon sequestered rate (t CO_2/ha)
Watershed 1	48.08– 200.38	114.51	176.31 – 734.81	419.91
Watershed 2	22.15 – 176.68	85.97	81.24 – 647.89	315.25
Watershed 3	14.64 – 177.75	91.37	53.70 – 651.79	335.05
Watershed 4	23.86 – 129.06	85.68	87.48– 473.24	314.19
Watershed 5	10.89 – 160.52	101.91	5.45 – 588.63	373.71
	Average	**95.89**		**351.62**

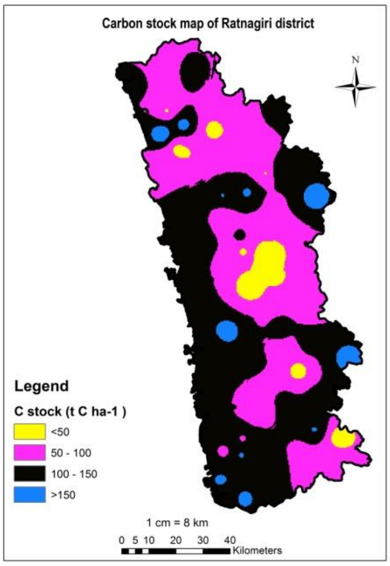

Fig. 5. Carbon stock map of Ratnagiri district

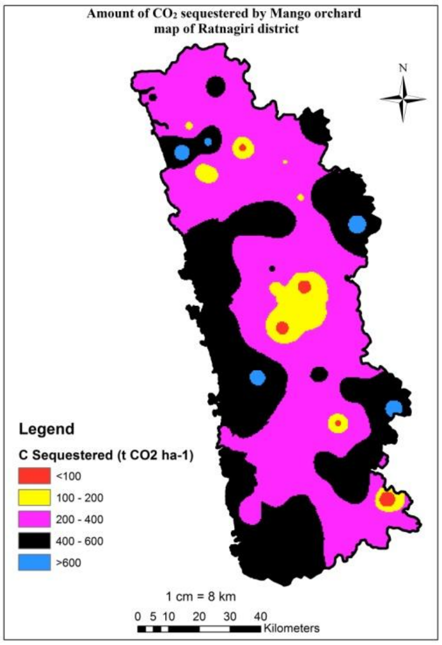

Fig. 6. Amount of CO_2 sequestered by Mango orchard map of Ratnagiri district

3.4 Total Biomass of Mango Orchard

Total biomass is the sum of above and below ground biomass of Mango. Total biomass values of Mango were ranging from 10.89 to 400.77 t/ha in Ratnagiri district (Fig. 4). The diameter increases the value of biomass is also increases. Thus, it shows that the total biomass increased with increasing diameter and ages of mango plants (Naik *et al*.) [5]. Similar study shows that above ground biomass in mango crop was 263.30 t/ha and below ground biomass was 79.23 t/ha (Kumar) [13].

3.5 Carbon Stock and CO_2 Sequestration of Mango Orchard

Carbon stock values for Mango orchards in Ratnagiri district were ranging from 10.89 to 200.38 t C/ha with average carbon stock of 95.89 t C/ha (standard error of 4.92) (Table 3 and Fig. 5). Amount of CO_2 sequestrated map was shown in Fig. 6. From Table 3, it is seen that, carbon stock values were also increased with increase in diameter of tree. The amount of CO_2 sequestered were ranging from 19.99 to 734.81 t CO_2/ha with an average rate of 351.62 t CO_2/ha (standard error of 18.06). Carbon stock rate ranges from 46.21 t C/ha to 93.47 t C/ha with average rate of 73.58 t C/ha from mango orchards in India (Ganeshamurthy *et al*.) [14].

4. CONCLUSION

The average carbon stock rate was found as 95.89 t C/ha from Mango orchards of Ratnagiri district. It shows that, carbon stock values were increased with increase in diameter of tree. Mango crop area about 60,105 ha in Ratnagiri district. Thus, total carbon stock and amount of CO_2 sequestered of Mango orchards from Ratnagiri district were found to be 5.76 M tonnes and 21.13 M tonnes respectively. Thus, it is also found that the horticultural crops having great potential to improving carbon sequestration.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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