

Original Research Article

Assessment of biomass and carbon stocks in mango (*Mangifera indica* L.) orchards of Ratnagiri district of Maharashtra state, India

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 CO₂. At the moment, carbon sequestration by horticulture crops is an effective method of reducing atmospheric CO₂. 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 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 CO₂ 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 CO₂ emissions to the atmosphere were 2040 ± 310 Gt CO₂, 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. MATERIAL 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 CO₂ 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 tree 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).

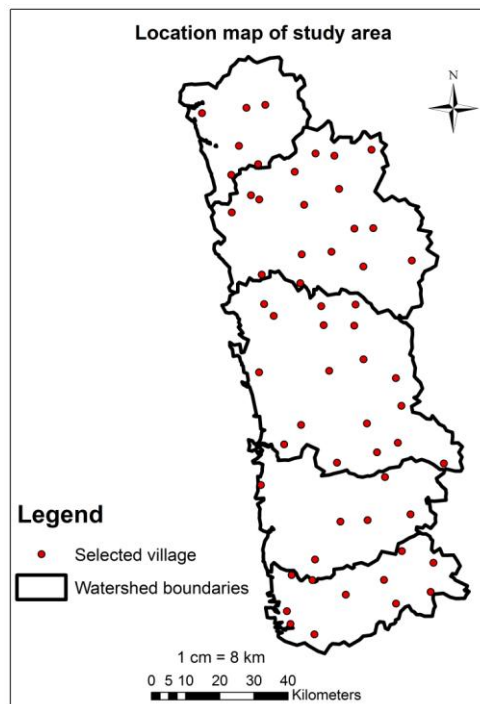


Fig. 1: Location map of study area

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 CO₂ sequestered by Mango orchards

To calculate CO₂ assimilation by vegetation, estimated carbon stocks would be transformed into CO₂ equivalents (biomass value × 3.667) (Guleria *et al.*) [10]. Amount of CO₂ 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].

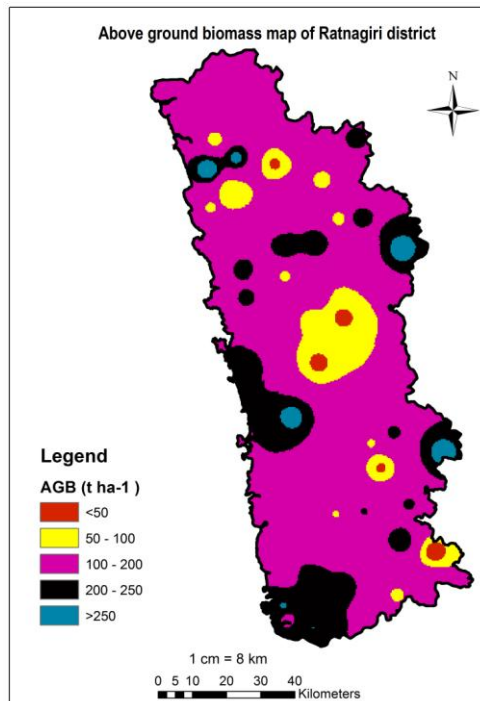


Fig.2: Above ground biomass map of Ratnagiri district

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	

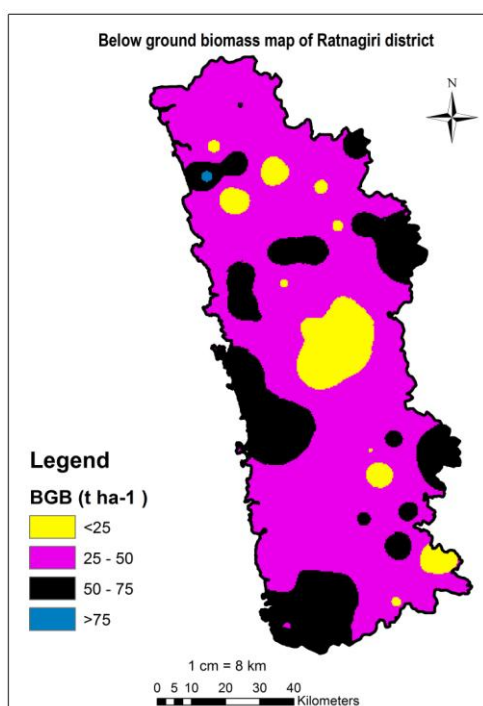


Fig.3: Below ground biomass map of Ratnagiri district

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].

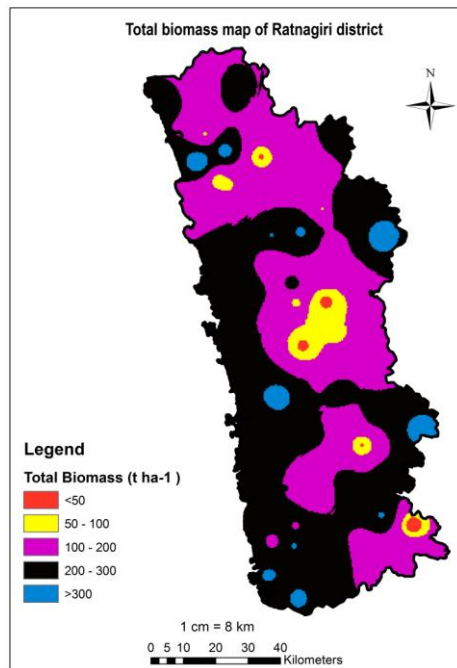


Fig. 4: Total biomass map of Ratnagiri district

3.5 Carbon stock and CO₂ 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 CO₂ 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 CO₂ sequestered were ranging from 19.99 to 734.81 t CO₂/ha with an average rate of 351.62 t CO₂/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].

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

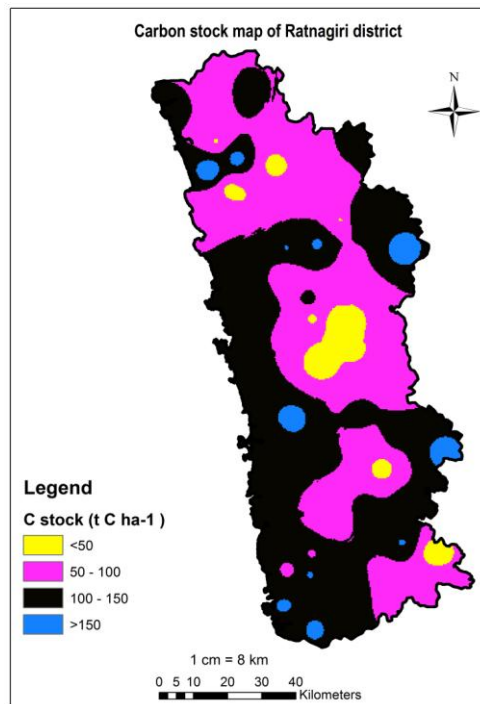


Fig. 5: Carbon stock map of Ratnagiri district

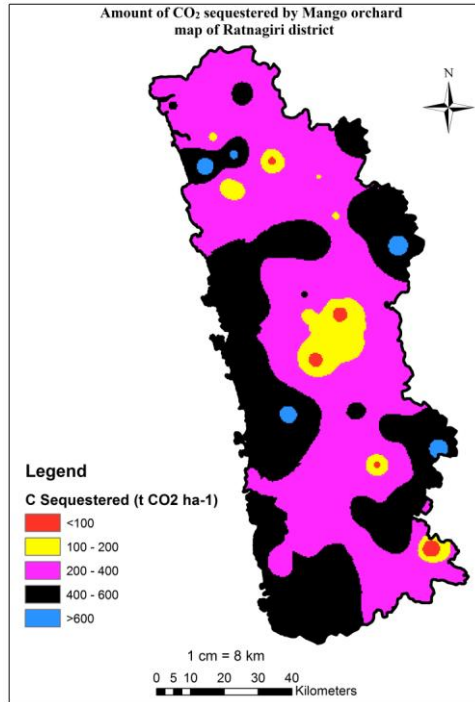


Fig. 6: Amount of CO₂ sequestered by Mango orchard map of Ratnagiri district

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 CO₂ 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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6. REFERENCES

1. IPCC. Climate Change: Synthesis Report. Contribution of working groups i, ii and iii to the fifth assessment report of the intergovernmental panel on climate change [Core writing team, R. K. Pachauri and L. A. Meyer (eds.). 2014. IPCC, Geneva, Switzerland, 151.

2. Ravindranath NH, Somashekhar BS, Gadgil M. Carbon flow in Indian forests. *Climate change*. 1997; 35: 297-320.
3. Dharmesh GJ, Vishant RM, Yogesh BP, Himanshu AP. Carbon stock estimation major tree species in Attarsumba range, Gandhinagar forest division, India. *Annals of Biological Research*. 2014; 5: 46-49.
4. Resh SC, Binkley D, Parrotta JA. Greater soil carbon sequestration under Nitrogen-fixing trees compared with *Eucalyptus* species. *Ecosystems*. 2002; 5: 217-231.
5. Naik SK, Sarkar PK, Das B, Singh AK, Bhatt BP. Biomass production and carbon stock estimate in mango orchards of hot and humid climate in eastern region, India. *Carbon management*. 2019; 10: 1-11.
6. Jana B.K, Biswas S, Majumder M, Roy PK, Mazumdar A. Carbon sequestration rate and above ground biomass carbon potential of four young species. *Journal of Ecology and Natural Environment*. 2009; 1: 015-024.
7. FAO. Estimating biomass and biomass change of tropical forests: a primer, by S. Brown. FAO Forestry Paper No. 134, Rome. 1997.
8. Ravindranath NH, Ostwald M. Carbon inventory methods handbook for greenhouse gas inventory, carbon mitigation and round wood production projects. *Advances in Global Change Research*, Springer-Verlag, Berlin, 2008; 121-154.
9. Vieilledent G, Vaudry R, Andriamanohisoa SF, Rakotonarivo SH, Randrianasolo Z, Razafindrabe HN, Rakotoarivony CB, Ebeling J, and Rasamoelina M. A universal approach to estimate biomass and carbon stock in tropical forests using generic allometric models. *Ecological Applications*. 2012; 22: 572–583.
10. Guleria V, Vashisht A, Gupta A, Salven T, Thakur C, Kumar P. Carbon stocks and soil properties under nitrogen-fixing trees on degraded site in subtropical Himalayan region. *Indian Journal of Soil Conservation*. 2014; 42: 293-297.
11. Brahmaa B, Natha AJ, Deba C, Sileshi GW, Sahoo UK, Das AK. A critical review of forest biomass estimation equations in India. *Trees, Forests and People*, 2021; 5: 1-16.

12. Ekoungoulou R, Xiaodong Liu SA, Loumeto JJ, Folega F. Carbon stock estimation in secondary forest and gallery forest of Congo using allometric equations. International journal of scientific & technology research. 2014; 3: 465-474.
13. Kumar M. Carbon Sequestration in a Agroforestry system at Kurukshetra in Northern India. International Journal of Theoretical and Applied Sciences, 2017; 9(1): 43 – 46.
14. Ganeshamurthy AN, Ravindra V, Rupa TR and Bhat PM. Carbon sequestration potential of mango orchards in tropical hot and humid climate of Konkan region of India. Curr. Sci., 2019; 116(8): 1417–1423.

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