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RESEARCH ARTICLE

Age-dependent variations in carbon sequestration in mango orchards on alfisols in tropical climates

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Abstract

Understanding carbon fluxes from land-use transitions is vital for climate change mitigation, as activities like deforestation and urban expansion alter carbon storage and emissions. These alterations impact the carbon cycle, affecting the balance between carbon dioxide (CO_2) absorption and its emission into the atmosphere. A through understanding of land use and land-use change dynamics in a specific region is essential for this analysis. Notably, the growing cultivation of fruit crops on agricultural land greatly enhances carbon sequestration potential. This study found that carbon sequestration in mango orchards increased with age of the trees. On average, 115.57 t C/ha was sequestered in Dhenkanal and 130.48 t C/ha in Rayagada. In these orchards, above-ground carbon constituted 24.45% in Dhenkanal and 27.69% in Rayagada of the total carbon sequestered per hectare, using the recommended 8 m x 8 m tree spacing. Collecting fundamental data on the carbon content of various land-use and land-use change categories at the regional level is crucial for effective climate change mitigation. This study provides novel insights into carbon stocks in mango orchards relative to tree age, enhancing our understanding of the carbon cycle within mango cultivated systems. Subsequent research should encompass mango orchards from many regions around the country, employing higher sample sizes to more accurately measure carbon sequestration in farmed mango orchards countrywide.

Keywords

carbon sequestration; litter biomass; mango; root biomass; soil carbon stock; tree biomass

Introduction

Public and political concerns are growing over the impact of human activities, mainly deforestation and increased fossil fuel consumption, on climate change and biodiversity loss (1). One of the most alarming issues of the new millennium resulting from human activity is global warming, primarily by greenhouse gases. Deforestation plays a significant role in the accumulation of greenhouse gases (GHGs) in the atmosphere (2-4). A key strategy to mitigate rising GHG concentrations and the subsequent climate change is to enhance plants' carbon sequestration and storage capabilities. Trees act as substantial carbon reservoirs and potential carbon sinks. Forests sequester approximately 40 percent of the global carbon on land (5). Forest carbon content is 20-50 times higher than in cleared lands, with variations depending on land use and ecosystem type (6).

In India and other tropical countries, forest and fruit orchard carbon sinks are believed to offset significant carbon emissions from fossil fuel combustion. Fluctuations in forest carbon have a substantial impact on the global carbon budget. Indian forests sequester approximately 5.3 to 6.7 percent of global carbon emission based on estimates of soil carbon densities in various forest types (7,8). However, rapid industrialization and population growth led to decreased forested areas, whereas the area dedicated to perennial fruit orchards is expanding (9).

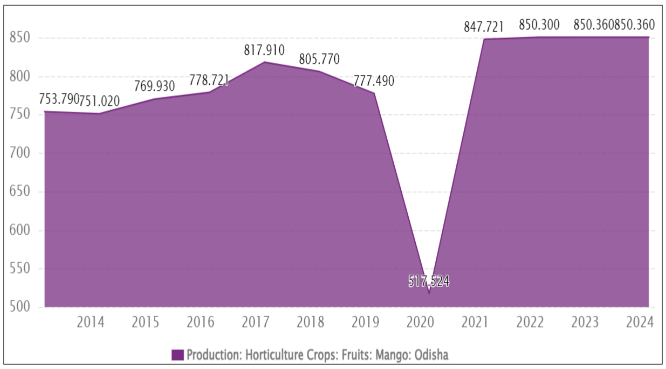
In their early stages, orchards and forests sequester comparable amounts of carbon. However, comparing the two can be misleading, as human activities largely influence orchard management, while forest management in Asian countries often focuses on silviculture with less reliance on external inputs. Although orchards have considerable carbon sequestration capability, this is on a smaller scale due to the indirect carbon emissions associated with orchard management practices. Assessing the carbon sequestration capability of fruit orchards in India is vital for strategic planning, mitigating GHG emissions, and engaging in carbon offset trading initiatives.

Mango is the predominant fruit crop extensively cultivated across India and thrives in a seasonally moist tropical climate characterized by distinct dry and wet seasons. The seasonality of Photosynthetically Active Radiation (PAR) is significantly higher in the late wet season compared to the dry season. Tropical fruit trees in seasonally moist regions have developed strategies to optimize carbon uptake in response to significant seasonal light and water availability variations. One such adaptation is the development of deep root systems, often extending beyond 1.0 meters in depth. These deep roots allow trees to access water stored in deeper soil layers during the dry season, helping them survive water scarcity.

India has two distinct mango populations: wild polyembryonic and cultivated grafted mangoes. Although exact estimates of the area covered by wild polyembryonic mangoes are not readily available, they are believed to be substantial, as India is the origin of mangoes. Cultivated mangoes occupy approximately 2.3 million hectares and offer considerable potential for carbon sequestration (9). This area is projected to grow due to the increasing emphasis on horticulture in government policies.

In 2024, Odisha recorded mango production at 850.36 thousand tonnes, remaining consistent with the figures from 2020. This data, updated annually, has averaged 778.721 thousand tons from March 2012 to 2024 (Fig. 1). The highest recorded production was 850.36 thousand tons in 2024, while the lowest was 517.524 thousand tons in 2020 (10).

There is limited information on the effect of tree age on



X - axis: years and Y- axis: production (in thousand tons)

Fig. 1. Trends in mango production in Odisha in the past decade (DAFW, 2024).

carbon sequestration in mango orchards established with grafted or layered seedlings, primarily due to the lack of non-destructive methods for estimating tree biomass. Scientists have developed allometric equations for estimating biomass in grafted mango trees (11). This paper estimates carbon sequestration in mango trees across various age groups in the primary mango-producing districts of Odisha, namely Dhenkanal and Rayagada, utilizing similar methodologies.

Materials and Methods

This study was conducted on farmers' fields in the Dhenkanal and Rayagada districts in Odisha, Eastern India. The orchard site is situated at an elevation of approximately 971 meters above sea level, spanning latitudes between 26°N and 94°20'E and longitudes 85°22'E and 86°52'E. The region experiences four seasons: a dry season with clear, bright weather from December to February, summer from March to May, the southwest monsoon from June to September and the northeast or retreating southwest monsoon from October to November. Climatologically, the area is classified as having a "sub-humid tropical monsoon climate with four seasons." Key attributes of this climate include a mild temperature range, with the highest average maximum temperature reaching 40° C in May and June and the lowest average minimum temperature dropping to 7°C in January. There are two separate rainy seasons: the southwest and northeast monsoons, which follow one another with contrasting wind patterns from June to September and from October to November. The study was conducted at the beginning of the southwest monsoon, following the harvest of the fruits.

Selection of orchard

For this study, mango orchards of different age groups, 5-10 years, 10-15 years and over 15 years of the Chausawas variety, were selected from farmers' fields in Alfisol. The orchards were planted with a density of 156 trees per hectare, spaced at 8 m x 8 m. Fertilizers were applied according to recommended guidelines. Established practices provided by the Indian Institute of Horticultural Research (IIHR) in Bengaluru were followed for effective orchard management, including pest and disease control strategies.

Estimation of tree biomass

The allometric equation, mainly designed for orchard mango trees, was employed to estimate both above-ground biomass (AGB) and below-ground biomass (BGB) of mango trees (11). This equation was derived from the destructive sampling of 184 mango trees. The primary allometric parameters evaluated included the number of primary and secondary branches, the circumference of both types of branches, tree height, tree volume, basal diameter and diameter below the graft union. The stem diameter beneath the graft union was measured using a diameter tape, while the tree height and crown diameter were measured with a Spiegel Relaskop. Various statistical models, including the ML and power models, were assessed for estimating tree biomass, with the power model being selected due to its optimal fit. The power model used for estimating AGB is as follows:

$$AGB = 2.886 \times X^{1.039} \qquad \text{Eqn.1}$$

For BGB estimation, a ratio of 1:0.29 was applied as recommended (11).

Tree Sampling : Fully developed leaves were collected from 18 randomly selected trees in each orchard across all age groups to estimate their carbon content. These samples were pooled, thoroughly washed and then dried in a hot air oven at 65°C until they reached a constant weight. Once dried, the samples were finely ground for subsequent carbon analysis. In addition, twig samples representing tertiary and smaller branches were selected and prepared for carbon estimation. Finally, bark and wood samples were extracted from the chosen trees using a tree drill and processed for carbon assessment.

Carbon Estimation

Mango Tree Samples : The carbon content of the mango tree samples was measured using a CHNS analyzer (Elementar) and reported as a percentage of carbon within the samples.

Weeds and Litter : The biomass of litter and weeds collected from the orchards was processed and evaluated for carbon content using a CHNS analyzer (Elementar), with the results expressed as a percentage of carbon in the samples.

Soil Samples : Representative soil pedon samples were collected from depths of 0-15, 15-30, 30-60 and 60-100 cm in the orchards of the two districts. and the total carbon stocks were estimated.

Ten soil samples were randomly gathered at each depth and combined to create a composite soil sample at each site. The soil samples were thoroughly mixed and transported in plastic bags to the laboratory, where they were air-dried, passed through a 2-mm sieve, and stored for subsequent analysis. Soil bulk density was measured using the core sampling method with a volumetric cylinder. This measurement was expressed as the ratio of the oven-dry weight of the soil (dried at 105°C for 24 hours) to its total volume, providing the soil bulk density value. The air-dried soil samples were sieved again with a 2-mm mesh. Total soil organic matter was assessed using the wet acid digestion Walkley-Black method (12).

The calculation of soil organic carbon stock involved using the concentration of total soil organic carbon (TOC) along with the soil bulk density for each layer (13), employing the following equation:

$$C\ Stock = (TOC \times Ds \times e)/10 \qquad \text{Eqn.2}$$

Where TOC is the total organic carbon at a given soil depth, Ds is the soil bulk density at a given soil depth and e is the thickness of the layer.

Results

Soil Properties : The soil in Odisha's Dhenkanal and Rayagada districts typically reflects a tropical hot and sub-humid climate. The orchard soil is classified as Udic Haplustalf, which is well-suited for mango cultivation, especially in Alfisols. These soils exhibit acidity due to base leaching caused by heavy rainfall during the six-month monsoon period. The electrical conductivity is low, recorded at less than 0.528 dS/m, and the organic matter content is also low at 0.41%. Available nitrogen and phosphorus levels are low, while potassium levels are medium. In acidic soils, phosphorus fixation is high, which accounts for the low availability of phosphorus. Despite these fertility constraints, mango trees thrive in these soils.

Allometric Parameters and Carbon Capture by Mango Trees of Different Age Groups : The number of primary branches in mango trees ranged from 2.66 to 3.33 in Dhenkanal and 3.00 to 4.00 in Rayagada, with an average of 3.33 (Table 1). The diameter of the primary branches varied from 16.48 to 49.07 cm in Dhenkanal and from 17.00 to 49.77 cm in Rayagada. The above-ground biomass (AGB) of mango trees ranged from 146.61 kg/tree for 5-10-year-old trees to 575.27 kg/tree for trees over 15 years old in Dhenkanal, while Rayagada recorded higher values ranging from 171.57 kg/tree to 706.29 kg/tree (Table 1).

The below-ground biomass (BGB) exhibited a similar trend. The total carbon sequestered by trees ranged from 97.58 kg/tree to 401.79 kg/tree in Dhenkanal and from 116.83 kg/tree to 501.27 kg/tree in Rayagada, with an overall mean of 276.18 kg/tree (Table 1).

Carbon Sequestration in Weed and Litter Biomass : Weed biomass in the orchards was measured at 1380 kg/ha in Dhenkanal and 1685 kg/ha in Rayagada for 5-10-year-old orchards. This biomass decreased to 535 kg/ha in Dhenkanal and 650 kg/ha in Rayagada for orchards older than 15 years (Table 2). The decline in weed biomass in older orchards is attributed to increased shading and nutrient competition. Litter biomass was higher, ranging from 735 kg/ha to 1008 kg/ha in Dhenkanal and from 874 kg/ha to 1050 kg/ha in Rayagada (Table 2). The mean carbon content in weeds and litter was found to be 47.62% and 45.82%, respectively.

In this study, the carbon biomass from weed and litter accounted for 1.04% to 0.51% of the total carbon sequestered in 5-10-year-old orchards and over 15-year-old orchards in Dhenkanal. Rayagada's values ranged from 1.18% to 0.5% (Table 3).

Soil Carbon Stocks : Soil organic carbon (SOC) in the experimental orchards averaged 77,000 kg/ha in Dhenkanal and 81,000 kg/ha in Rayagada (Table 2). These levels are comparable to those reported in other studies on mango orchards and Indian forest soils. The SOC contributed a significant portion of the total carbon sequestered in these orchards.

Table 1. Allometric parameters and tree C sequestration from mango orchards of different age groups

Location/Tree age group	No of Primary Branches*	Mean Girth of primary branches (cm)*	Average Value x No. of Primary Branches	AGB Kg/tree	AGB C Kg/tree	BGB Kg/tree	BGB C Kg/tree	Total C Kg/tree
Dhenkanal								
5-10 years	2.66	16.48	43.84	146.61	75.34	42.52	22.24	97.58
10-15 years	3.33	28.77	95.80	330.33	174.81	95.80	50.93	225.74
>15 Years	3.33	49.07	163.40	575.27	308.69	166.83	93.11	401.80
	3.11	31.44	101.01	350.73	186.28	101.71	55.42	241.71
Rayagada								
5-10 years	3.00	17.00	51.00	171.58	90.16	49.76	26.67	116.83
10-15 years	3.66	35.54	130.08	453.89	243.15	131.63	70.74	313.88
>15 Years	4.00	49.77	199.08	706.29	386.06	204.83	115.21	501.28
Mean	3.55	34.10	126.72	443.92	239.79	128.74	70.87	310.66
Overall Mean	3.33	32.77	113.87	397.33	213.04	115.23	63.15	276.19

AGB, above ground biomass; BGB, below ground biomass.

Table 2. Soil C stock, litter and weed biomass C in the mango orchard

Source	Dhenkanal				Rayagada			
	5-10 years	10-15 years	>15 Years	Mean	5-10 years	10-15 years	>15 Years	Mean
Soil C t/ha	77.00	77.00	77.00	77.00	81.00	81.00	81.00	81.00
Weed biomass, kg/ha	1380.00	1012.00	535.00	975.67	1685.00	1244.00	650.00	1193.00
Weed C, kg/ha	641.70	480.70	259.48	460.63	793.64	595.88	313.3	567.60
Litter biomass, kg/ha	735.00	862.00	1008.00	868.33	874.00	955.00	1050.00	959.67
Litter C, kg/ha	331.49	394.80	464.69	396.99	396.80	441.21	486.15	441.39
Total C content (weed+litter), kg/ha	973.19	875.50	724.16	857.62	1190.43	1037.09	799.45	1008.99
Total C other than tree biomass, t/ha	77.97	77.88	77.72	77.86	82.19	82.04	81.80	82.01

Total Carbon Sequestration by Mango Orchards : The experimental mango orchard was established with a spacing of 8 m x 8 m, accommodating 156 trees per hectare (Table 3). The mango orchard's total carbon sequestered per hectare increased with tree age. For 5-10 years old orchards, the total carbon sequestered was 93.20 tonnes/ha in Dhenkanal and 100.41 tonnes/ha in Rayagada. For orchards older than 15 years, this increased to 140.40 tonnes/ha in Dhenkanal and 160 tonnes/ha in Rayagada. The mean carbon sequestered by mango trees in the experimental orchards was 115.57 tonnes/ha in Dhenkanal and 130.48 tonnes/ha in Rayagada.

Soil carbon constituted a higher proportion of the total carbon, accounting for 68.52% in Dhenkanal and 64.37% in Rayagada, while tree carbon accounted for 31.48% in Dhenkanal and 35.63% in Rayagada. The proportion of soil carbon decreased from 82.62% in 5-10-year-old orchards to 54.84% in orchards older than 15 years in Dhenkanal and from 80.67% to 50.63% in Rayagada (Table 3).

Discussion

The results show that mango trees are well-adapted to Odisha's tropical hot and sub-humid climate, even in conditions of low soil fertility (14). The acidic soils and low phosphorus availability, typical of Alfisols in high-rainfall regions, do not hinder mango growth due to the species' tolerance for such conditions. However, the low levels of organic matter and nutrients highlight the importance of enhancing soil fertility management in mango orchards to maximize productivity (15).

The observed increase in allometric parameters, such as branch diameter and biomass, with tree age aligns with previous research, confirming that tree strength and carbon storage capacity increase over time. The higher carbon sequestration in Rayagada compared to Dhenkanal can be attributed to slight differences in climatic and edaphic conditions, which affect tree growth and biomass accumulation. A comparison with polyembryonic wild mango trees highlights the influence of orchard management practices, like pruning and high-density planting, which limit the overall size of grafted mango trees but enhance their suitability for commercial cultivation (16, 17).

Scientists have reported that a ten-year-old mango tree can sequester 58 kg of carbon, while a fifteen-year-old mango tree can sequester about 115 kg per tree (18). Our results indicate higher values, likely due to the robust tree growth in the sub-humid tropical monsoonal climate and fertile soils of Dhenkanal and Rayagada. However, these values remain significantly lower than those recorded for polyembryonic wild mango trees. The disparity arises from grafted mangoes being more compact, cultivated at higher densities, and regularly pruned to sustain a manageable, reduced height for efficient cultivation and harvesting (17). Additionally, it was reported that sapota trees sequestered 16.72 kg of carbon per plant. However, the tree age was not specified, highlighting the potential of fruit crops, such as apple, mango, guava, sapota, citrus and grape, to sequester carbon and boost biological yield (19, 20). Despite the higher values observed in our study, the robust tree growth in the sub-humid tropical climate supports these findings when compared to subtropical regions of India and the lateritic tropical belts along the western coast, where mango is extensively cultivated (11, 21).

Table 3. C pool compartment in mango orchard (8 m x 8 m=156 trees)

Source	Carbon quantity				C (%)			
				Dhenkanal				
Age group	5-10 years	10-15 years	>15 Years	Mean	5-10 years	10-15 years	>15 Years	Mean
AGB tree C (t/ha)	11.75	27.27	48.16	29.06	12.61	24.11	34.30	23.67
Litter C (t/ha)	0.33	0.39	0.46	0.40	0.36	0.35	0.33	0.34
Weed C (t/ha)	0.64	0.48`	0.26	0.46	0.69	0.42	0.18	0.43
Weed+litter C (t/ha)	0.97	0.87	0.72	0.86	1.04	0.77	1.51	0.78
Total above-ground C (t/ha)	12.73	28.14	48.88	29.91	13.65	24.89	34.81	24.45
Root C (t/ha)	3.47	7.94	14.52	8.65	3.72	7.02	10.34	7.03
Total tree C (t/ha)	16.20	36.09	63.40	38.57	17.38	31.91	45.16	31.48
Soil C (t/ha)	77	77	77	77	82.62	68.09	54.84	68.52
Total below-ground C (t/ha)	80.47	84.94	91.52	85.65	86.35	75.11	65.19	75.55
Total C sequestered in orchard (t/ha)	93.20	113.09	140.40	115.57	-	-	-	-
				Rayagada				
Age group	5-10 years	10-15 years	>15 Years	Mean	5-10 years	10-15 years	>15 Years	Mean
AGB tree C (t/ha)	14.07	37.93	60.23	37.41	14.01	28.95	37.64	26.87
Litter C (t/ha)	0.40	0.44	0.49	0.44	0.39	0.34	0.30	0.34
Weed C (t/ha)	0.79	0.60	0.31	0.57	0.79	0.45	0.20	0.48
Weed+litter C (t/ha)	1.19	1.04	0.80	1.01	1.18	0.79	0.50	0.82
Total above-ground C (t/ha)	15.25	38.97	61.02	38.42	15.19	29.75	38.14	27.69
Root C (t/ha)	4.16	11.03	17.97	11.06	4.14	8.42	11.23	7.93
Total tree C (t/ha)	19.41	50.00	79.00	49.48	19.33	38.17	49.37	35.63
Soil C (t/ha)	81.00	81.00	81.00	81.00	80.67	61.83	50.63	64.37
Total below-ground C (t/ha)	85.16	92.03	98.97	92.06	84.81	70.25	61.86	72.31
Total C sequestered in orchard (t/ha)	100.41	131.00	160.00	130.48	-	-	-	-

Although the carbon sequestered by weeds and litter is small in proportion, it plays a vital role in the overall carbon cycle within the orchard ecosystem. The reduction in weed biomass in older orchards suggests that canopy cover and root competition significantly impact weed growth, while litter contributes to sustaining soil carbon levels. In forest ecosystems, floor-level carbon typically accounts for less than 10% of the total carbon stored (22). This proportion can vary considerably in fruit orchards, depending on the management practices. Regular weeding often results in a lower percentage of floor carbon. Compared to others, the slightly higher weed and litter biomass observed in this study may be attributed to the vigorous growth of mango trees in these particular orchards (23).

Soil organic carbon (SOC) constitutes a significant portion of the total carbon sequestered in mango orchards, consistent with findings from other tropical horticultural systems (24). It has been shown that QEV in these tropical land-use conditions is achieved in approximately 25 years (25). The relatively high levels of SOC, particularly in older orchards, highlight the role of soil as a long-term carbon sink in mango cultivation. However, it is essential to note that soil carbon stocks in younger orchards may not have reached equilibrium yet, indicating the potential for further increases in carbon storage over time. These SOC levels are comparable to those reported for mango orchards and Indian forest soils (11, 26, 27).

In conclusion, the mango orchards of Dhenkanal and Rayagada exhibit significant potential for carbon sequestration in tree biomass and soil. It has been reported that the soil carbon stock in mango orchards in Mangalore is 41 tonnes/ha in the top 50 cm deep layer (26). Additionally, soil carbon stored in Indian forests ranges from 37.5 tonnes per hectare in tropical dry deciduous forests to 92.1 tonnes per hectare in littoral swamp forests. Previously under forest cover, the sites in this study contained substantial soil organic stocks, with values referring to 100 cm deep soil profiles. Consequently, the values obtained in this study are comparable to those reported for similar climatic regions (27). Compared to other parts of India, the higher carbon sequestration values in these areas can be attributed to favorable climatic conditions and soil characteristics. Ongoing research on soil fertility management, improved orchard practices and the development of high-yielding mango varieties could further enhance the carbon sequestration potential of mango orchards across India.

Conclusion

In developing effective climate change mitigation strategies, it is crucial to investigate changes in carbon (C) fluxes resulting from land-use change patterns. Understanding the dynamics of land use and land-use change within a specific region is vital to this process. The increasing prevalence of fruit crops on agricultural land significantly enhances carbon sequestration. This study found that carbon sequestration in orchards increased with tree age, with an average of 115.57 t C/ha sequestered in Dhenkanal and 130.48 t C/ha in Rayagada. In mango orchards, above-ground carbon constituted 24.45% and 27.69% of total carbon sequestered per hectare, with the recommended 8 m x 8 m spacing in Dhenkanal and Rayagada, respectively. Collecting fundamental data on carbon content across various land-use and land-use change categories at the regional level is crucial for effective climate change mitigation. This study provides novel data into carbon stocks in mango orchards relative to tree age, enhancing our understanding of the carbon cycle in cultivated mango ecosystems. Future research should involve mango orchards in various regions of the country, employing larger sample sizes to improve the quantification of carbon sequestration in mango orchards nationwide.

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Authors' contributions

SM_1 and GCA designed the concept of the study. DSK, SCS, SM_2 and DG helped to acquire data and collected samples. SM_1 performed the data compilation, sequence alignment and drafted the manuscript. ANG and TRR helped in modifications and coordination. AD helped in the statistical analysis. All the authors read and approved the final manuscript. (SM_1- Sipra Mohapatra and SM_2- Sucharita Mohapatra)

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References

1. Gitay H, Brown S, Easterling WE, Jallow B, Antle J, Apps MJ, et al. Chapter 5: Ecosystems and their services. In: IPCC Working Group II contribution to the Third Assessment Report on mitigation of climate impacts, adaptation, and vulnerability. 2001;235-342.
2. Achard F, Eva HD, Stibig HJ, Mayaux P, Gallego J, Richards T. Determination of deforestation rates of the world's humid tropical forests. Science. 2002;297:999-1002. https://doi.org/10.1126/science.1070656
3. Houghton RA. Revised estimates of the annual net flux of carbon to the atmosphere from changes in land use and land management (1850-2000). Tellus B: Chem Phys Meteorol. 2003;55:378-90. https://doi.org/10.1034/j.1600-0889.2003.01450.x
4. Fearnside PM, Laurance WF. Tropical deforestation and greenhouse gas emissions. Ecol Appl. 2004;14(4):982-86. https://doi.org/10.1890/03-5225
5. Hudson JM, Gherini SA, Goldstein RA. Modeling the global carbon cycle: nitrogen fertilisation of the terrestrial biosphere and the "missing" CO_2 sink. Global Biogeochem Cy. 1994;8:307-33. https://doi.org/10.1029/94GB01044
6. Houghton RA. Tropical deforestation as a source of greenhouse gas emissions. In: Tropical Deforestation and Climate Change, Editors. IPAM - Instituto de Pesquisa Ambiental da Amazônia; Washington DC - USA: Environ. lDef; 2005. https://www.osti.gov/etdeweb/biblio/20880378
7. *Dadhwal VK, Kushwaha SP, Singh S, Patel NR, Nayak RK, Patil P.* Recent results from eo studies on indian carbon cycle assessment. Int Arch Photogramm Remote Sens Spat Inf Sci,. 2011; Volume XXXVIII-8/W20. https://doi.org/10.5194/isprsarchives-XXXVIII-8-W20-3-2011
8. Ravindranath NH, Somasekhar BS, Gadgil M. Carbon flows in Indian forest. Clim Change. 1997;35(3):297-320. https://doi.org/10.1023/A:1005303405404
9. NHB and horticulture statistics division department of agriculture, cooperation and farmers welfare ministry of agriculture and farmers welfare Government of India.
10. Production: Horticulture Crops: Fruits: Mango: Odisha. CEIC.
11. Ganeshamurthy AN, Ravindra V, Venugopalan R, Malarvizhi Mathiazhaganand, Bhat RM. Biomass distribution and development of allometric equations for non-destructive estimation of carbon sequestration in grafted mango trees. J Agric Sci. 2016;8:201-11. https://doi.org/10.5539/jas.v8n8p201
12. Nelson DW, Sommers LE. Total carbon, organic carbon, and organic matter. In: Sparks DL, Page AL, Helmke PA, Loeppert RH, Soltanpour PN, Tabatabai MA, Johnston CT, Sumner ME, editors. Methods of soil analysis: Part 3. Chemical methods. Madison (WI): Soil Science Society of America; 1996;961-1010. https://doi.org/10.2136/sssabookser5.3.c34
13. Bernoux M, Carvalho MCS, Volkoff B, Cerri CC. Brazil's soil carbon stocks. Soil Sci Soc Am J. 2002;66:888-96. https://doi.org/10.2136/sssaj2002.8880
14. Dash PK, Mishra A, Saren S. Characterization and taxonomic classification of soils under a toposequence located in Eastern India. Environment and Ecology. 2019;37:1240-49. https://www.cabidigitallibrary.org/doi/pdf/10.5555/20193520812
15. Ganeshamurthy AN, Reddy YTN. Fitness of mango for colonization in low fertility soils and dry lands: Examination of leaf life-span, leaf nutrient resorption and nutrient use efficiency in elite mango varieties. Agric Res. 2015;4(3):254-60. https://doi.org/10.1007/s40003-015-0164-8
16. Selvaraj A, Sivasankari J, Dhivya P, Thirunavukkarasu A, et al. Carbon sequestration potential, physicochemical and microbiological properties of selected trees *Mangifera indica* L., *Manilkara zapota* L., *Cocos nucifera* L. and *Tectona grandis* L. Biosci disc. 2016;7(2):131-39. https://jbsd.in/Vol%207%20No%202/Ananthi131-139.pdf
17. Eneji IS, Ofoegbu Obinna, Emmanuel T. Sequestration and carbon storage potential of tropical forest reserve and tree species located within Benue state of Nigeria. J Geosci Environ Prot. 2014;2:157-66. https://doi.org/10.4236/gep.2014.22022
18. Chavan BL, Rasal GB. Potentiality of carbon sequestration in six year ages young plant from University campus of Aurangabad. Global J Res Eng. 2011;7:15-20.
19. Sureshbhai PJ, Thakur NS, Jha SK, Kumar V. Productivity and carbon sequestration under prevalent agroforestry systems in Navsari district, Gujarat, India. Int J Curr Microbiol App Sci. 2017;6(9):3405-22. https://doi.org/10.20546/ijcmas.2017.609.419
20. Sharma S, Rana VS, Prasad H, Johnson Lakra, Umesh Sharma. Appraisal of carbon capture, storage and utilization through fruit crops. Front Environ Sci. 2021;9:1-10. https://doi.org/10.3389/fenvs.2021.700768
21. Mitra SK, Gurung MR, Pathak PK. Guava production and improvement in India: An overview: International workshop on tropical and subtropical fruits. Acta Hortic. 2008;4:787. https://doi.org/10.17660/ActaHortic.2008.787.4
22. Usuga JCL, Toro JAR, Alzate MVR, Tapias AJL. Estimation of biomass and carbon stocks in plants, soil and forest floor in different tropical forests. For. Ecol Manag. 2010;260(10):1906-13. https://doi.org/10.1016/j.foreco.2010.08.040

23. Ganeshamurthy AN, Rupa TR, Alivelu K, Rajendiran S, Laxman RH. A Biomass Estimation Model for Nondestructive Estimation of Guava Tree Biomass. Res Sq. 2022;1-15. https://doi.org/10.21203/rs.3.rs-2310563/v1

24. Chandran P, Ray SK, Durge SL, Raja P, Nimkar AM, Bhattacharyya T. Scope of horticultural land-use system in enhancing carbon sequestration in ferruginous soils of the semi-arid tropics. Curr Sci. 2009;7:1039-46. https://doi.org/10.13140/2.1.4014.1764

25. Ganeshamurthy AN. Annual report, IIHR, Bengaluru, India. 2012.

26. Gupta MK. Soil organic carbon pools under different land use in Haridwar district of Uttarakhand. Indian For. 2011;137(1):1-8. https://doi.org/10.54207/bsmps1000-2008-45GJM2

27. Chhabra A, Palria S, Dadhwal AK. Soil organic carbon pools in Indian forests. For Ecol Manag. 2003;173:187-99. https://doi.org/10.1016/S0378-1127(02)00016-6