Tree biomass and carbon density estimation in the tropical dry forest of Southern Western Ghats, India

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United Nations Framework Convention on Climate Change highlights the significance of carbon storage and emission in forests towards climate change mitigation. The aim of this study was to quantify the tree biomass and carbon density (carbon storage) in the tropical dry forest of the Chinnar Wildlife Sanctuary of Kerala located in the Southern Western Ghats, India. We investigated the species-wise contribution of carbon (C) storage, as well as the species-wise and plot-wise correlation between carbon and other dendrometric variables. We also analysed the girth (diameter) wise distribution of carbon and tree density in the study region. The study was conducted in eight selected sample plots of the region, each with an area of 0.1 hectare. Species-specific volume and specific gravity relationship coupled with suitable regression equation were used to estimate biomass. Tree carbon was assumed to be 47% of the biomass. The results showed that the average biomass and carbon density of the vegetation were 64.13 t ha⁻¹ and 30.46 t-C ha⁻¹, respectively. Among the 32 species identified, Tamarindus indica L. (17%), Hardwickia binata Roxb. (14%), Terminalia arjuna (Roxb. ex DC.) Wight & Arn (10%) and Pleiospermium alatum (Wight & Arn.) Swingle (10%) were dominant as for carbon storage. The correlation analysis showed that basal area is a good predictor of tree biomass and carbon, while the role of tree density and tree diversity remain uncertain in determining carbon storage. With respect to diametric class distribution, tree density showed a reverse J-shaped pattern indicating the sustainable regeneration of the analysed forest, where the small- (diameter at breast height 3-9 cm) to medium-sized trees (diameter at breast height 10-69 cm) were found to contribute to more than 50% of biomass and carbon in the forest. The study provides useful information for carbon mitigation strategies in a tropical dry forest in the Southern Western Ghats.

Keywords: Above Ground Tree Biomass, Carbon, Tropical Dry Forest, Kerala, Southern Western Ghats

Introduction

Forests represent a significant part of the global carbon cycle and play an important role in carbon sequestration. Forests cover 40% of the terrestrial surface though they contribute by 90% and 70% to terrestrial biomass and productivity, respectively. Kormer et al. (2005). The significant role of forests in containing global carbon dioxide levels (CO₂) was acknowledged in Kyoto in December 1997. In the present climate change scenario, the international community is increasingly made aware of the fact that the alleviation of global warming cannot be achieved without the inclusion of forests in the mitigation plan. Reducing Emissions from Deforestation and Forest Degradation and enhancing forest carbon (REDD+) is a new initiative of the United Nations Framework Convention on Climate Change (UNFCCC). It is led by developing countries with rich forest cover and calls for economic incentives to reduce the emissions of greenhouse gases from deforestation and forest degradation in developing countries (Gibbs et al. 2007). Beyond carbon sequestration, REDD+ is also expected to play a major role in other ecosystem services and has the potential to generate benefits for indigenous and local communities. To achieve and optimize these “co-benefits”, the developing countries need to have well-established estimates of forest carbon densities or stocks for a successful implementation of mitigating policies and to take advantage of the REDD+ programme (Saatchi et al. 2011). According to Canadell & Raupach (2008), increasing the carbon density or stock of existing forests is also an important option in this regard. It is therefore vital to understand the potential role of forests, especially tropical forest, in curtailing the impact of global warming. As the climate change debate progresses, policy makers also require more scientific and reliable information on the current status of carbon storage that would benefit in effective resource management, in developing policies and setting priorities for the forest in...
The study region is the lower area of southern tropical dry forest in the Chinnar Wildlife Sanctuary (400–500 m a.s.l.) in Idukki district of Kerala, India. It is situated in the Southern Western Ghats part of peninsular India (Fig. 1a). Chinnar Wildlife Sanctuary comprises an area of 9,044 ha located between 77°09’56”E – 77°20’43”E longitude and 10.2506°N – 10.3521°N latitude, along the rain shadow region of the Southern Western Ghats. The terrain is undulating and rocky and the annual rainfall ranges from 300 to 500 mm in Chinnar (Kallarakal & Somen 1999). Since the area is located in the rain shadow region, unlike most forests of Kerala, only about 48 rainy days occur in a year during the northeast monsoon. The temperature ranges from a minimum of 13 °C during December to a maximum of 37.8 °C during April and May. The dry period lasts for 6–7 months at the lower elevations, while it shorter at higher altitude. Relative humidity also varies from 19 to 100% during the rainy months of October and November (KFD 2012). The climate of Chinnar is generally dry and soil is sandy loam with weak fine granular structure (Chandrashekara et al. 1998). The dominant height of vegetation is up to 16 meters in the dry deciduous forest, which covers about 50% of the total forest area (KFD 2012). The main tree species are Pleiospermum alatum (Wight & Arn.) Swingler, Canthium coromandelicum (Burm.f.) Alston, and Artalantia monophylla DC. Other major species include Chloroxylon swietenia DC. Cordia sinensis Lam., Acacia planifrons Wight & Arn., Azadirachta indica A. Juss., Dichrostachys cinerea (L.) Wight & Arn., Tamarindus indica L., Sapindus marginatus Vahl, Cordia gharaf (Forsk.) Ehrenb. ex Asch, Lepisanthes tetrphylla (Vahl) Radlk., Vitex leucoxylon L., Sapindus marginatus Vahl (see Tab. S1 in Supplementary material). Although the region falls within the protected area, anthropogenic interference such as tribal settlements and interstate highway (road) passing through the sanctuary poses a quite a threat to the biota in the ecosystem.
Tab. 1 - List of volume equations and specific gravity values used in the present study. (*): Average specific gravity; (GV): generalized volume equation; (V): species-specific volume equation; (D): diameter at breast height; (H): tree height.

<table>
<thead>
<tr>
<th>No.</th>
<th>Tree species</th>
<th>Volume equation</th>
<th>Specific gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Albizia amara (Roxb.) B. Boivin</td>
<td>V = -0.033-0.526-D+6.396-D²</td>
<td>0.950</td>
</tr>
<tr>
<td>2</td>
<td>Atalantia monophylla DC.</td>
<td>GV = 0.16948-1.85075-D+10.63682-D²</td>
<td>*</td>
</tr>
<tr>
<td>3</td>
<td>Azadirachta Indica A. Juss.</td>
<td>GV = 0.16948-1.85075-D+10.63682-D²</td>
<td>0.680</td>
</tr>
<tr>
<td>4</td>
<td>Bauhinia racemosa Lam</td>
<td>V = -0.04262-6.09491-D²</td>
<td>*</td>
</tr>
<tr>
<td>5</td>
<td>Caesalpinia coromandelica (Burman. f.) Alston</td>
<td>GV = 0.16948-1.85075-D+10.63682-D²</td>
<td>0.805</td>
</tr>
<tr>
<td>6</td>
<td>Caesalpinia sp.</td>
<td>GV = 0.16948-1.85075-D+10.63682-D²</td>
<td>0.805</td>
</tr>
<tr>
<td>7</td>
<td>Choroxylon swietenia DC.</td>
<td>GV = 0.16948-1.85075-D+10.63682-D²</td>
<td>0.980</td>
</tr>
<tr>
<td>8</td>
<td>Commiphora berrii (Arn.) Engl.</td>
<td>GV = 0.16948-1.85075-D+10.63682-D²</td>
<td>*</td>
</tr>
<tr>
<td>9</td>
<td>Commiphora caudata (Wight &amp; Arn.) Engl.</td>
<td>GV = 0.16948-1.85075-D+10.63682-D²</td>
<td>*</td>
</tr>
<tr>
<td>10</td>
<td>Cordia gharaf ( Forsk.) Ehrenb. ex Asch</td>
<td>V = -0.49388-7.56417-D-31.49373-D²*50.93877-D³</td>
<td>0.495</td>
</tr>
<tr>
<td>11</td>
<td>Dichrostachys cinerea (L.) Wight &amp; Arn.</td>
<td>GV = 0.16948-1.85075-D+10.63682-D²</td>
<td>*</td>
</tr>
<tr>
<td>12</td>
<td>Diospyros cordifolia Roxb.</td>
<td>V = 0.02087-4.73571-D+10.63682-D²</td>
<td>*</td>
</tr>
<tr>
<td>13</td>
<td>Diospyros ebenum J. Koenig ex Retz.</td>
<td>V = 0.02284-1.06958-D+6.11017-D²</td>
<td>*</td>
</tr>
<tr>
<td>14</td>
<td>Diospyros ovalifolia Wight.</td>
<td>V = 0.0790+0.4149-DH</td>
<td>0.600</td>
</tr>
<tr>
<td>15</td>
<td>Erythraea corallina L.</td>
<td>V = 0.0306-0.5210-D²</td>
<td>*</td>
</tr>
<tr>
<td>16</td>
<td>Euphorbia antiquorum L.</td>
<td>V = 0.0351-0.1676-D²</td>
<td>*</td>
</tr>
<tr>
<td>17</td>
<td>Ficus microcarpa L.f.</td>
<td>V = 0.0315+0.3856-D²</td>
<td>0.530</td>
</tr>
<tr>
<td>18</td>
<td>Ficus sp.</td>
<td>V = 0.0315-0.3856-D²</td>
<td>*</td>
</tr>
<tr>
<td>19</td>
<td>Gmelina arborea Roxb.</td>
<td>V = 0.25058-3.55124-D+16.41720-D²</td>
<td>0.470</td>
</tr>
<tr>
<td>20</td>
<td>Grewia villosa Wild.</td>
<td>V = 0.0150-0.281-D²</td>
<td>0.651</td>
</tr>
<tr>
<td>21</td>
<td>Gymrocarpus americanus Jacq.</td>
<td>GV = 0.16948-1.85075-D+10.63682-D²</td>
<td>0.305</td>
</tr>
<tr>
<td>22</td>
<td>Hardwickia binata Roxb. (Endemic)</td>
<td>V = -0.023583-0.279452-D²</td>
<td>0.733</td>
</tr>
<tr>
<td>23</td>
<td>Ixora pavettia Andr.</td>
<td>GV = 0.16948-1.85075-D+10.63682-D²</td>
<td>0.860</td>
</tr>
<tr>
<td>24</td>
<td>Lepisanthes tetraphylla (Vahl) Radik.</td>
<td>GV = 0.16948-1.85075-D+10.63682-D²</td>
<td>*</td>
</tr>
<tr>
<td>25</td>
<td>Mitrephora heyneana (Hook. f. &amp; Thomson) Thwaites</td>
<td>GV = 0.16948-1.85075-D+10.63682-D²</td>
<td>0.645</td>
</tr>
<tr>
<td>26</td>
<td>Pleioperpermium actatum (Wight &amp; Arn.) Swingle</td>
<td>GV = 0.16948-1.85075-D+10.63682-D²</td>
<td>0.890</td>
</tr>
<tr>
<td>27</td>
<td>Sapindus emarginatus Vahl</td>
<td>GV = 0.16948-1.85075-D+10.63682-D²</td>
<td>*</td>
</tr>
<tr>
<td>28</td>
<td>Strychnos nux-vomica L.</td>
<td>GV = 0.16948-1.85075-D+10.63682-D²</td>
<td>*</td>
</tr>
<tr>
<td>29</td>
<td>Strychnos potatorum L.f.</td>
<td>GV = 0.16948-1.85075-D+10.63682-D²</td>
<td>0.750</td>
</tr>
<tr>
<td>30</td>
<td>Tamarindus indica L.</td>
<td>GV = 0.16948-1.85075-D+10.63682-D²</td>
<td>0.960</td>
</tr>
<tr>
<td>31</td>
<td>Terminalia arjuna (Roxb. ex DC.) Wight &amp; Arn.</td>
<td>V = -0.033-0.526-D+6.396-D²</td>
<td>*</td>
</tr>
<tr>
<td>32</td>
<td>Vitex leucoxylon L.f.</td>
<td>V = 0.066+0.287-D²</td>
<td>0.771</td>
</tr>
</tbody>
</table>
estimated biomass of trees with DBH ≥ 10 cm (volume + specific gravity) to obtain the total plot biomass (stem biomass) in t 0.1 ha⁻¹, which was finally extrapolated into tonnes per hectare (t ha⁻¹).

**Estimation of total biomass and carbon density of trees in the plot**

As canopy branches and leaves were not included in this study, the stem dry biomass was multiplied by a biomass expansion factor of 1.5 to obtain the total above-ground biomass of each tree. The biomass expansion factor adopted in this study is species-based, according to the different density classes of Indian forest types previously reported (Kishwan et al. 2009). The below ground biomass (BGB) was calculated from the obtained above-ground biomass considering a shoot/root ratio of 0.26 (Cairns et al. 1997). This ratio is commonly used and did not differ much with respect to latitude, soil texture or tree type (Ravin-dranath & Ostwald 2008). The total biomass within each plot was then obtained by summing AGB and BGB. Since the carbon content varies from 45% to 50% of the total biomass in different ecosystems according to different studies, we cautiously considered the carbon content to be 47% of the dry woody biomass for regional-level carbon pool estimations (Raghubanshi et al. 1990). Biomass values were then multiplied by a factor of 0.47 to obtain the amount of carbon existing in dry wood biomass. Biomass and carbon obtained from each subplot were summed to obtain the site standing biomass and carbon (expressed in tonnes dry weight). The average value of the standing biomass and carbon of the eight subplots was thus considered as the total biomass and carbon density of the forest ecosystem, expressed in t ha⁻¹.

**Relationship between carbon and other dendrometric variables**

Pearson’s correlation analysis was carried out using the software SPSS® ver. 12.0 to test the relationship between carbon density and other dendrometric variables like tree density (in terms of number of trees), basal area and tree diversity (in terms of number of species). To this purpose, both species- and plot-wise correlation approaches were adopted. As for the former, all the species occurring in different subplots were taken together and the relationships among variables examined, whereas in the case of plot-wise correlation, the relationships among variables was examined across the 8 subplots, regardless of the species.

**Results and discussion**

**General characteristics of the forest**

A large heterogeneity of tree diameter and height was observed among the subplots, reflecting the growth differences among different tree species in each subplot (Tab. 2, Tab. 3). Indeed, tree growth is highly variable in the tropical forest (Feeley et al. 2007), thus a detailed appraisal of species composition, environmental and genetic factors, ecological history, management practises (especially in the context of climate change), is required in order to comprehend growth variations of tree species in the forest. Further, previous studies suggested that climate change can affect the distribution of tree species in the forest (Zhu et al. 2012) which in turn will change the regional patterns of forest biodiversity even at the plot level (Potter & Woodall 2012).

**Estimation of biomass, carbon and other dendrometric variables**

Tree density (number of trees) ranged from 35 to 112 trees for the 32 species recorded in this study. The average DBH of the subplots varied between 5.84 and 20.25 cm. Tree height ranged between 2.81 and 5.94 m, whereas the total basal area ranged between 0.37 and 3.4 m² across subplots. The estimated AGB varied between 1.22 and 15.98 t 0.1 ha⁻¹ and BGB varied between 0.31 and 4.15 t 0.1 ha⁻¹. Combining AGB and BGB over all the plots and computing its weighted average, the total tree biomass (dry weight) of the site was found to be 64.13 ± 23.65 t ha⁻¹. Since the carbon constitutes generally half of the biomass weight (dry weight), in this study the carbon density of the tropical dry forest was estimated to be 30.46 ± 11.23 t-C ha⁻¹ (Tab. 2).

According to Murphy & Lugo (1986), the aboveground carbon density in tropical dry forest varies between 14 and 123 t-C ha⁻¹. Chaturvedi et al. (2011) reported a carbon density ranging from 15.6 to 151 t-C ha⁻¹ in tropical dry forests of India. Even though the above ground biomass carbon (AGBC) obtained in the present study is well within the limits of tropical dry forests, the results obtained are comparatively lower than the values reported in other tropical dry forest of India and elsewhere (Návar 2009). This might be due to a larger number of short structured trees or younger stands (3-9 cm DBH, 10-69 DBH) compared to larger trees (>70 DBH cm) in the studied area. Moreover, the loss of water accumulated in the stem would result in a reductions in stem diameter of trees in the dry (deciduous) forest (Daubenmire 1972). Hence, the observed dendrometric variables (DBH, height, basal area and biomass) likely reflect the preponderance of short structured trees, mainly shaped by the climatic conditions of the area (Tab. 2).

The tropical dry forest is composed of a mosaic of different plant types showing...
varying adaptations to seasonal drought (Borchert 2000). Local differences in the extent and intensity of seasonal drought might have caused (to some extent) the observed spatial variation in the carbon content between plots. Moreover, the presence of a stream running near some of the study subplots could have locally reduced the water stress by keeping the soil moist and supplied trees with more nutrients, thus favoring tree growth as compared with the dry conditions occurring across the region. The occurrences in the examined plots of large species such as Terminalia arjuna (Roxb. ex DC.) Wight & Arn. and Vitex leucoxylon L.f. which are generally found along stream banks, can support the above considerations. Furthermore, the intensity of human disturbance across the forest could be highly heterogeneous. Hence, the spatial heterogeneity of carbon density among the studied plots can be attributed to various biotic, abiotic and anthropogenic factors. Nonetheless, the carbon density values observed in this study are comparatively lower than those reported for other forest types in India (tropical moist deciduous forests, tropical semi-evergreen forests, tropical evergreen forests and tropical rainforests – Baishya et al. 2009, Saatchi et al. 2011).

Species-wise contribution to carbon storage and its relationship with other dendrometric variables
In this work, we aimed to identify the leading carbon storing species in the area by considering trees with DBH > 10 cm. A substantial portion of carbon density (92%) in the forest system was contributed by diameter class ≥ 10 cm, with a tree density share of 33% when compared to the other class (DBH < 10 cm) of trees (see below). Among the 32 species recorded in the selected area, Tamarindus indica L. showed the maximum carbon storage capacity (17%) followed by Hardwickia binata Roxb. (14%), Terminalia arjuna (Roxb. ex DC.) Wight & Arn. (10%) and Pleiospermium alatum (Wight & Arn.) Swingle (10% – Tab. 3). These top four species stored almost half

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### Table 2: Estimated values (± standard error, SE) of biomass, carbon and other dendrometric variables in the 8 subplots analyzed. (n): Total number.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Subplot</th>
<th>Average ± SE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Tree density (stems 0.1 ha⁻¹)</td>
<td>55</td>
<td>59</td>
</tr>
<tr>
<td>Tree density (stems ha⁻¹)</td>
<td>550</td>
<td>590</td>
</tr>
<tr>
<td>Average DBH (cm)</td>
<td>14.69</td>
<td>8.67</td>
</tr>
<tr>
<td>Average height (m)</td>
<td>5.01</td>
<td>3.41</td>
</tr>
<tr>
<td>Number of species (species 0.1 ha⁻¹)</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Total tree basal area (m² 0.1 ha⁻¹)</td>
<td>1.4</td>
<td>0.79</td>
</tr>
<tr>
<td>Total tree basal area (m² ha⁻¹)</td>
<td>14.05</td>
<td>7.88</td>
</tr>
<tr>
<td>Total AGB (t 0.1ha⁻¹)</td>
<td>10.53</td>
<td>3.32</td>
</tr>
<tr>
<td>Total AGB (t ha⁻¹)</td>
<td>105.3</td>
<td>33.2</td>
</tr>
<tr>
<td>Total AGBC (t-C ha⁻¹)</td>
<td>50.02</td>
<td>15.77</td>
</tr>
<tr>
<td>Total BGB (t-0.1ha⁻¹)</td>
<td>2.74</td>
<td>0.86</td>
</tr>
<tr>
<td>Total tree biomass -AGB+BGB (t-0.1ha⁻¹)</td>
<td>13.27</td>
<td>4.19</td>
</tr>
<tr>
<td>Total tree carbon (t-0.1ha⁻¹)</td>
<td>6.30</td>
<td>1.99</td>
</tr>
<tr>
<td>Total tree biomass -AGB+BGB (t ha⁻¹)</td>
<td>132.78</td>
<td>41.9</td>
</tr>
<tr>
<td>Total tree carbon (t-C ha⁻¹)</td>
<td>63.07</td>
<td>19.9</td>
</tr>
</tbody>
</table>

### Table 3: Species-wise (top 5 species with DBH > 10 cm) contribution to carbon storage recorded in the eight subplots, covering an overall area of 0.8 ha.

<table>
<thead>
<tr>
<th>No.</th>
<th>Species</th>
<th>Tree density (no. trees)</th>
<th>Total tree basal area (m²)</th>
<th>Total tree carbon (t)</th>
<th>Average tree carbon (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tamarindus indica L.</td>
<td>8</td>
<td>1.36</td>
<td>3.76 (17%)</td>
<td>0.47</td>
</tr>
<tr>
<td>2</td>
<td>Hardwickia binata Roxb.</td>
<td>2</td>
<td>0.67</td>
<td>3.10 (14%)</td>
<td>1.55</td>
</tr>
<tr>
<td>3</td>
<td>Terminalia arjuna (Roxb. ex DC.) Wight &amp; Arn.</td>
<td>1</td>
<td>0.97</td>
<td>2.35 (10%)</td>
<td>2.35</td>
</tr>
<tr>
<td>4</td>
<td>Pleiospermium alatum (Wight &amp; Arn.) Swingle</td>
<td>31</td>
<td>0.41</td>
<td>2.27 (10%)</td>
<td>0.07</td>
</tr>
<tr>
<td>5</td>
<td>Atalantia monophylla DC.</td>
<td>23</td>
<td>0.29</td>
<td>1.44 (6%)</td>
<td>0.06</td>
</tr>
</tbody>
</table>
the carbon (50.90%) that is stored by all the

dominant species identified in the area. It is

worth noting that Tamarindus indica is not

native to this region and commonly con-

fined to areas adjacent to human settling-

ments, though its wide use as for food and

medicines could have contributed to its

spread in the studied area. In addition, the

favorable conditions provided by the

stream might also have influenced its luxu-

riant growth. However, in the context of

conservation, the relative significance of

native and non-native species are to be

studied with respect to their ecosystem

functions.

Tree size coupled with tree density pro-

vides an indication of the aboveground car-

bon storage, which is an important param-

er of forest structure (Nagendra 2012).
The result indicated that species-wise tree

carbon (DBH ≥ 10 cm) had a strong positive

correlation with basal area (R^2 = 0.84, p <

0.001). Such parameter may be conve-

niency used as an indicator for biomass

and carbon, since it integrates the effect of

both the number and size of trees (Bur-

rows et al. 2000). On the other hand, tree

carbon showed a weak (though significant)

positive relationship with tree density (R^2 =

0.18, p < 0.05 – Fig. 3a, Fig. 3b). All the

above findings could help selecting the most

suitable species and species combina-

tions for enhancing carbon sequestration in

the studied area.

Plot-wise relationship between carbon

and other dendrometric variables

In this study, we examined the relation-

ship between carbon and other tree vari-

dables of the different studied plots using all

the trees, regardless of their diameter

(DBH < 10 cm and DBH ≥ 10 cm – Fig. 4a,

Fig. 4b, Fig. 4c). In this case, tree density

showed a non-significant negative relation-

ship with carbon (R^2 = 0.02, p = 0.731). This

might be due to the occurrence of a large

number of small trees (DBH 3-9 cm) in dif-

ferent plots, which altogether constitute 67% of trees and represent a negligible (8%) carbon share in the area (Fig. 5). Thus, the plot-wise correlation analysis revealed that forest plots with higher tree density are not rich in carbon. This finding is in agree-

ment with the evidence that carbon in tree

biomass increases with DBH, basal area and

height, but not with tree density (Hui et al. 2012). Pragasan (2014) observed a positive relationship between tree density

and carbon in the case of plot-wise correla-

tion, when trees with DBH > 10 cm were

considered.

Tree diversity (in terms of number of

species) also showed a moderate positive

relationship with carbon density, though

not significant (R^2 = 0.47, p = 0.098). These

results are in agreement with the available

literature (Borah et al. 2013). It may be in-

ferred that promoting tree diversity may

accelerate CO2 sequestration from the at-

mosphere to a certain extent and thus be

relevant in a climate-change context. Al-

though some experimental works carried

out in different ecosystems showed that

plant diversity often promotes stability

and primary productivity and consequently

carbon accumulation (Miles et al. 2010),

the relationship between plant diversity and

carbon density in tropical forests still re-

mains unclear.

In this study, the strong positive relation-

ship observed between carbon density and

basal area (R^2 = 0.92, p < 0.001) is in accor-

dance with numerous previous studies in

India (Mani & Parthasarathy 2007, Chatur-

vedi et al. 2011). Moreover, the kind of as-

sociation established between carbon and

basal area could also be used in predicting

forest carbon in the region.

Overall, the results of the correlation

analysis (both species- and plot-wise) indi-

cate that basal area has a strong relation-

ship with carbon storage, while contrasting

results have been obtained with tree den-

sity and tree diversity. This is contrary to

our first hypothesis that all the three vari-

ables could be considered as good indica-

tors of biomass and carbon storage in the

forest.

Resolving the relationship of dendromet-

ric variables with carbon stock is central to

predict their possible contribution to cli-

mate change mitigation. Without under-

standing the interactions between these

factors, it is difficult to predict the effects

of future change on carbon cycling or tran-

late results between sites with differ-

ent characteristics.

Diametric class distribution of tree

density and carbon

The diameter distribution of trees can be

used as an indicator of changes in popula-

tion structure and species composition

Fig. 4 - Plot-wise (0.1 ha area) relationship between carbon and other dendrometric variables. (a) Tree carbon and tree density; (b) tree carbon and tree diversity (number of tree species); (c) tree carbon and basal area.

Fig. 5 - Distribution of tree density (%) and tree carbon (%) across different diametric classes.
the tropical dry forest of Kerala in South-ern Western Ghats was estimated to be 64.13 ± 23.65 t ha⁻¹ and 30.46 ± 11.23 t C ha⁻¹, respectively, which are consistent with ear-lier studies. Based on our results, several species showing larger size with high car-bon storage can be considered for affor-estation/reforestation purposes to enrich the forest carbon density of the area.

Regarding our first hypothesis, we con-firmed that basal area could be a useful proxy for biomass and carbon, while tree density and tree diversity gave inconclusive results. With respect to the second hypothe-sis, we found that smaller or moderate trees have greater carbon storage as com-pared to larger trees in the tropical dry for-est.

Since our present findings are based on a limited field study dataset, further studies on shrubs, herbs, litter, deadwood, soil or-ganic carbon and other biotic and abiotic factors are needed to substantiate the to-tal carbon budget of the area. Further, re-placing the general volume equations used in this study with more species-specific vol-ume equations and the corresponding spe-cific gravity for a vast majority of tree spe-cies in the dry forest, is required to im-prove the precision of estimates. Despite the above-mentioned limitations, consider-ing the increasing importance of forest car-bon sequestration and climate change miti-gation, our findings could help defin-ing strategies for sustainable management and conservation of tropical dry forests, and also contributes to the national carbon inventory program of India.

Acknowledgements
We gratefully acknowledge the funding from the Indian Institute of Remote Sens-ing (IIRS), Dehradun, Indian Space Re-search Organisation (ISRO), Department of Space, Government of India. The authors acknowledge Directorate of Environment and Climate Change, Government of Kerala for the support extended for this work. We are grateful to members of School of Envi-ronmental Sciences for their assistance during data collection. The authors thank the Forest Department, Government of Kerala for the permission and assistance in data collection. We are indebted to Dr. Sar-nam Singh for his invaluable contributions to the work. We express our gratitude to Dr. Susan Varghese, Prof. Jacob Eappen Kunnath, Dr. Appu Jacob John, and Prof. Vijo Thomas Kurian for proofreading and editing the manuscript. Finally, thanks to the anonymous reviewers for their criti-cism and their constructive comments that improved the quality of this manuscript.

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