Increasing liana biomass and carbon stocks in tropical dry evergreen forests of southern India

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Abstract

Tropical forests act as a great carbon reservoir covering about 30% of the global carbon content, however, structural alteration of these forests caused by forest disturbances adversely affects the carbon cycle. One such structural change happening in these tropical forests is the increasing dominance of lianas (woody climbers). Among various tropical forest types, lianas are an integral constituent of the tropical dry evergreen forests (TDEFs) found in peninsular India. A re-inventory of lianas was carried out to observe temporal changes in basal area and carbon stock in two 1-ha permanent plots of two disturbed tropical dry evergreen forest sites (TDEF; Oorani -OR and Puthupet - PP) over a 19-year interval (2001-2020). The total basal area in OR and PP increased respectively by 2.26 m^2 ha^{-1} and 0.93 m^2 ha^{-1}. The total biomass and the carbon stock in OR and PP increased by 82% and 51% respectively. The dominant species *Strychnos lenticellata* showed an increase in its basal area by three-fold in OR, whereas, in PP, a marginal increase of 4% was observed. The lower diameter class (1-6 cm) showed an increase in basal area in OR and PP by 101% and 16% respectively. The mid-diameter class (6-11 cm) was the top contributor of the total biomass/carbon in both OR and PP in the latest re-inventory (2020). The present results show that lianas, although known to negatively affect the forest biomass/carbon stock, play an important role in carbon sequestration, thus providing insights into their ecological importance which will certainly be useful in proposing strategies for the conservation of this forest type dominated by lianas.

Keywords: basal area; carbon stock; forest dynamics; long-term monitoring; woody climbers
Abbreviations: AGB – Aboveground Biomass; AGC – Aboveground Carbon; BGB – Belowground Biomass; CS – Carbon Stock; OR – Oorani; PP – Puthupet; SLA – Specific Leaf Area; TB – Total Biomass; TC – Total Carbon; TDEF – Tropical Dry Evergreen Forest

Introduction

Tropical forests are considered as great carbon reservoirs which accommodate over 30% of the global carbon (Malhi, 2012). Structural alteration of these forests as a result of increasing forest disturbances and other

environmental drivers may have potential consequences on the global carbon cycle (Schnitzer and Bongers, 2011; Babu and Parthasarathy, 2019). One of the major structural changes occurring in tropical forests is the increasing abundance and biomass of lianas, which may have inordinate impacts on carbon dynamics (Philips *et al*., 2002; Lewis, 2009). As a consequence of increasing human activities and the global climate change, this structural dynamism is bound to become more prominent in the tropics (Schnitzer and Bongers, 2002; Pandian and Parthasarathy, 2016). In tropical forests, the abundance of lianas relative to trees has increased by 1.7 – 4.6% annually (Philips *et al*., 2002). However, most studies from tropical forests have mainly focused on the role of climate on carbon stocks (Durán and Sánchez-Azofeifa, 2015), and the role of lianas have been overlooked.

Lianas are primarily woody vines which form an important constituent of tropical forests (Meunier *et al*., 2021). In mature tropical forests, lianas are an important structural component representing on an average 20 – 45% of the woody biomass (Schnitzer and Bongers, 2002). In liana-dense forest areas, they contribute about 30% of total aboveground biomass (AGB) and generally about 10% of AGB in tropical forests (DeWalt and Chave, 2004; Babu and Parthasarathy, 2019). Depending mainly on trees for structural and physical support (Stevens, 1987), lianas can have deleterious effects on host trees, like inducing mechanical stresses (Pérez-Salicrup and Barker, 2000), reducing their growth, recruitment, and survival (Schnitzer, 2005; van der Heijden and Phillips, 2009; Schnitzer and Carson, 2010), and also competing with trees for aboveground and belowground resources (Chen *et al*., 2008). Studies suggest that lianas are capable of reducing aboveground carbon (AGC) content to about 50% (Durán and Gianoli, 2013; Babu and Parthasarathy, 2019). In Amazonian tropical forests, lianas have been reported to bring about 18% of the variation in tree biomass (Laurance *et al*., 2014). Even though lianas contribute to the overall biomass of tropical forests, they cannot compensate for the reduction in tree biomass as a result of their low wood density and slender stems (Durán and Sánchez-Azofeifa, 2015). In tropical forests of Gigante Peninsula, central Panama, lianas considerably reduced tree carbon accumulation by 4.2-8.4% by affecting tree growth, whereas liana growth contributed only 24% of the tree biomass accumulation they displaced (Schnitzer *et al*., 2014). Studies have also reported that lianas have the capacity to bring down stand-level biomass growth by around 10% (van der Heijden *et al*., 2009) and also reduce net forest biomass assemblage down to 18% (Schnitzer *et al*., 2014).

In recent years, aggravation of forest disturbances has potentially contributed to a considerable increase in liana abundance and biomass in tropical forests (Schnitzer and Bongers, 2011; Pandian and Parthasarathy, 2015), which could be attributed to the ability of lianas to adapt in disturbance regimes (Hegarty and Caballe, 1992). Their increasing dominance in tropical forests is indicative of the fact that lianas may consequently alter carbon sequestration potential of these forests in the long run (van der Heijden and Phillips, 2009). It is suggestive that increasing forest disturbances may have positive influence on liana abundance and basal area on a local scale (Putz, 1984; Schnitzer and Carson, 2000), but on a larger scale this relationship may not be accurately evident (Schnitzer, 2005). The structural characteristics of a tropical forest and its physical environment may also have influence on the basal area and aboveground biomass of lianas (van der Heijden and Phillips, 2008).

Like in any other tropical forests, lianas form an integral component of the tropical dry evergreen forests (TDEFs) found in India (Babu and Parthasarathy, 2019). The TDEFs are short-statured forests, occurring mainly in small patches on the Coromandel coast of peninsular India (Parthasarathy *et al*., 2008). According to reports, TDEFs are considered as one of the liana-dense forests in Asia (DeWalt *et al*., 2015), and also studies from Indian TDEFs have reported lianas to be increasing in abundance over the years (Khadanga *et al*., 2015; Pandian and Parthasarathy, 2016; Nath *et al*., 2022). Even though inventories concerning liana diversity have been carried out in TDEFs (Reddy and Parthasarathy, 2006; Vivek and Parthasarathy, 2015; Babu and Parthasarathy, 2019), long-term monitoring data addressing their contribution to biomass and carbon stocks in these TDEFs are meagre or almost negligible (Pandian and Parthasarathy, 2016). Hence, the present study

was undertaken to re-monitor the changes addressing basal area, biomass, and carbon stock of lianas at a 19-year time interval in two disturbed tropical dry evergreen forest sites of southern India.

Materials and Methods

Study area

The present re-inventory was conducted in two 1-ha permanent plots of two tropical dry evergreen forest (TDEF) sites: Oorani (OR: lat. 12° 09'54" N and long. 79° 55'28" E) and Puthupet (PP: lat. 12° 03'27" N and long. 79° 52'13" E), located on the Coromandel coast of southern India. The two permanent plots were re-monitored after a period of 19 years to ascertain the anthropogenic induced changes on liana carbons stocks. The sites OR and PP, situated at a distance of 28 km and 15 km north of Puducherry town respectively, are susceptible to different levels of anthropogenic disturbances (Tables 1, 2). The site OR is comparatively less disturbed than PP, as the former is ~200 m away from human habitation. The climate data of the study sites reveal a tropical dissymmetric climate, consequently receiving heavy precipitation from both north-east and south-west monsoons. The amount of rainfall varies in this region due to the prevalent depression in the Bay of Bengal. In accordance with the classification of Champion and Seth (1968), the vegetation type of the two sites is described as tropical dry evergreen forest (TDEF; type 7/CI) (Khadanga *et al*., 2015; Nath *et al*., 2022).

Table 1. Site characteristics and sampled area of Oorani (OR) and Puthupet (PP) tropical dry evergreen forest sites on Coromandel coast of southern India

Variable	OR	PP
Latitude range (° N)	12.165°	12.0585°
Longitude range (° E)	79.9244°	79.87027778°
Forest area (ha)	1.5	5
Altitudinal range (m)	10	11
Terrain (°)	Almost flat (2-5°)	Almost flat (2-5°)
Soil type	Granular coastal sandy soil	Alluvial soil
Rock type	Quaternary, Tertiary and Mesozoic sediments with Archaeans	Quaternary, Tertiary and Mesozoic sediments with Archaeans
Soil texture	Loamy	Sandy loam
Mean annual rainfall (cm)	114	114
Mean annual temperature (°C)	29.5	29.5
No. of plots sampled	1	1
Total area of sample plots (ha)	1	1

Plot design and data collection

For liana inventories, two permanent plots were first established in 2001 (Reddy and Parthasarathy, 2003) and re-censused in 2011 (Khadanga *et al*., 2015). In the present re-census, at OR, ten quadrats of 25 m × 20 m dimension from two 200 m × 25 m sub-plot, located on either side of a centrally dividing mud road, were marked and re-inventoried. At PP, twenty 50 m × 10 m quadrats from a single plot of 50 m × 200 m dimension were marked for easy enumeration (Figure 1). All lianas ≥ 1 cm diameter, including both existing and newly recruited individuals, were measured at 1.3 m from the rooting point as per the standard protocol (Gerwing *et al*., 2006). In addition, the degree of disturbance was characterized using a semi-quantitative scale following Veblen *et al*. (1992) with modifications. A five-point scale (0 = none, 1 = low, 2 = medium, 3 = high, 4 = very high) was designed to examine the disturbance based upon visual characterization within the sample plot. The disturbance factors associated with site encroachment, temple visitors, and resource removal were

taken into account (Table 2). The observed degree of disturbance was compared with the past inventoried disturbance scores.
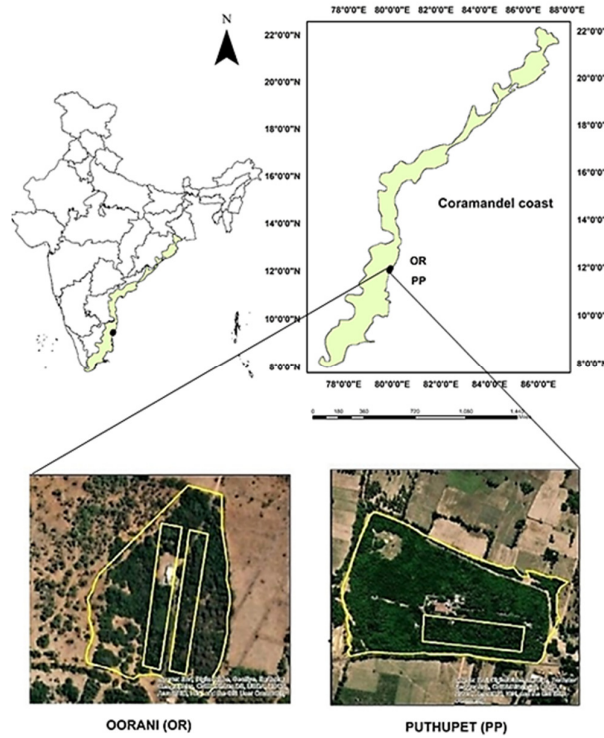

Figure 1. Map showing the location of two tropical dry evergreen forest sites on the Coromandel coast of southern India (Oorani - OR and Puthupet - PP)

Table 2. Disturbance score (0 = none, 1 = low, 2 = medium, 3 = high, 4 = very high) for two tropical dry evergreen forest sites (OR - Oorani and PP - Puthupet) on the Coromandel coast of peninsular India

Attributes	Study site					
	OR			PP		
	2001	2011	2020	2001	2011	2020
1. Site encroachment (land use within forest)						
a. Temple construction	1	1	2	1	3	3
b. Forest clearance for shops	0	0	0	1	2	4
c. Bridle path	1	2	3	2	4	4
d. Tank construction	0	0	1	0	2	3
2. Temple visitors' impact: area used for						
a. Vehicle parking	0	1	1	2	4	4
b. Cooking inside forest	0	0	0	2	4	4
c. Festive occasion use	0	1	1	2	4	4
d. Waste dump	0	0	1	2	4	4
e. Grazing	0	0	1	1	1	3
f. Cultural attachment of local people	1	2	2	2	4	4
3. Resource removal						
a. Firewood	1	2	2	2	3	4
b. Timber	0	1	1	1	2	4
c. Others: medicinal plants, edibles, etc.	1	2	2	2	2	3
Total Score	**5**	**12**	**17**	**20**	**39**	**48**

Statistical analysis

The measured lianas were noted directly in every quadrat, divided accordingly into different diameter classes, and were studied for changes in basal area, biomass, and carbon stock by comparing with the previous inventories. The measured diameter values were considered for calculating the aboveground and belowground biomass of lianas.

The basal area of lianas was calculated using the equation:

Basal area = (circumference or girth)^2 /4π (1)

The aboveground biomass (AGB) of lianas was calculated following the allometric equation by Schnitzer *et al.* (2006):

AGB = exp [– 1.484 + 2.657 ln (D)], where D is the diameter.   (2)

The belowground biomass (BGB) for lianas was determined by multiplying aboveground biomass with 0.26 (Cairns *et al.*, 1997), i.e.,

BGB = AGB × 0.26   (3)

The carbon stock (CS) was computed to be 50% of the total biomass (AGB+BGB) (IPCC, 2005), i.e.,

CS = (AGB + BGB)/2   (4)

Shapiro-Wilk test was performed to check normality prior to Kruskal-Wallis's test and ANOVA to check the statistical difference in the basal area and AGB of lianas among the diameter classes for all three time-periods. All statistical analysis were performed using the package "*vegan*" (*https://cran.r-project.org/package=vegan*) and the graphical interpretations were done with the help of packages "*ggplot2*" (*https://cran.rproject.org/package=ggplot2*) and "*ggpubr*" (*https://cran.rproject.org/package=ggpubr*) of software R 4.2.1 (R Core Team, 2021).

Results and Discussion

Changes in liana basal area, biomass and carbon stocks

The present re-inventory (2020) of the two sites recorded a total of 1964 liana individuals, representing 30 species in 24 genera and 18 families. Considerable changes were observed in the total basal area, biomass, and carbon stock in the two permanent plots Oorani (OR) and Puthupet (PP). The total basal area in OR increased by as much as 82% (2.26 m^2 ha^{-1}) since the initial inventory (2001). Likewise, the total basal area in PP increased by 51% (0.93 m^2 ha^{-1}) during the 19-year interval (Table 3). The total biomass (AGB+BGB) and the carbon stocks in OR and PP increased by 82% and 51% respectively. However, the results also revealed that the total biomass and carbon stock in OR decreased marginally during the nine-year period (2011-2020) (Table 3). This minimal decrease during the nine-year interval could be attributed to moderate anthropogenic disturbances occurring in the site (Table 2), in terms of resource removal by local people and/or construction of a temple in the study plot (Nath *et al.*, 2022). For instance, some of the liana species found in OR such as *Carissa spinarum*, *Tinospora cordifolia*, *Premna corymbosa*, and *Jasminum angustifolium* are often exploited by the local residents for their medicinal value and as sources of cattle feed (Parthasarathy *et al.*, 2015a; Nath *et al.*, 2022). For PP, it is mentionable that the stem density of lianas decreased (-133 stems) over the 19 years (Table 3, Appendix 2). However, changes observed in the basal area and biomass were on the positive side (Appendix 2). The possible reason could be that decrease in stem density of lianas inversely contributed to an increase in basal area and biomass of the existing lianas, which could be attributed to proper resource utilization by the existing lianas resulting in increase in their girth. For instance, in PP, it was observed that the lower diameter class (1-6 cm) suffered considerable decline in stem density during the 19-year interval (Nath *et al.*, 2022), which could have facilitated the mid-diameter class (6-11 cm) and the large diameter class (11-21 cm) lianas in better resource allocation, thus resulting in their increased basal area. Also, the large diameter class

suffered minimal to no decline in stem density over these 19 years (Nath *et al.*, 2022). All-inclusive, the results were on the positive side for the two sites which coincide with the results of Pandian and Parthasarathy (2016), wherein the aboveground biomass of lianas increased in four differently disturbed inland TDEF sites (Araiyapatti – 18.5 Mg ha^{-1}; Karisakkadu – 0.74 Mg ha^{-1}; Maramadakki – 3.6 Mg ha^{-1}; and Shanmuganathapuram – 9.5 Mg ha^{-1}) over a period of ten years (2003-2013). Likewise, Laurance *et al.* (2014) reported increasing liana biomass of 7.7-8.0 tones ha^{-1} in Amazonian forests over 14 years, with also a similar increase in basal area of lianas. Similar results of increasing biomass were also reported by Chave *et al.* (2008) from tropical forests of South America. The role of climbing mechanisms and the physiognomy of different liana species favored by forest disturbances may have contributed to an increase in basal area. In particular, it was observed that stem twiners and scramblers were the two climbing mechanisms which significantly contributed to basal area. In most TDEFs, twiners and scramblers have been reported to be pre-dominant in abundance (Parthasarathy *et al.*, 2015b). This may be indicative of their ability to adapt and proliferate in varying environmental conditions. Stem-twiners were reported to be more abundant in disturbed tropical forests than undisturbed forests (Addo-Fordjour and Rahmad, 2015), which show that forest disturbances may somewhat facilitate this climbing mechanism. Likewise, Villagra *et al.* (2021) reported scramblers to be abundant in disturbed forests associated with high specific leaf area (SLA) and it is directly linked with rapid growth rate (Coley, 1988). In our study sites deciduous species dominate the forest stand. They are often short-living plants with high photosynthetic efficiency (Krober *et al.*, 2015; de Souza *et al.*, 2020) and are known to have better plasticity to varying light conditions (Givinish, 2002). This could be a possible reason why deciduous species contributed the most to basal area, as they can grow and survive better compared to the other plant habit types.

Table 3. Changes in basal area (m^2 ha^{-1}), biomass (kg ha^{-1}), and carbon stock (kg C ha^{-1}) in two forest sites (OR - Oorani and PP - Puthupet)

Parameter	OR			PP		
	2001	2011	2020	2001	2011	2020
Stem density	812	1259	1262	835	940	702
Basal area	2.77	5.83	5.03	1.82	2.25	2.75
Biomass						
Aboveground biomass (AGB)	21838.23	42422.35	32933.87	9384.61	13400.22	17099.82
Belowground biomass (BGB)	5677.94	11029.81	8562.81	2440	3484.06	4445.99
Total biomass (TB)	27516.18	53452.16	41496.68	11824.61	16884.28	21545.81
Carbon						
Total carbon (TC)	13758.09	26726.08	20748.34	5912.31	8442.14	10772.91

Changes in species-wise contribution of basal area, biomass and carbon stock

The basal area, biomass, and carbon stock of many liana species changed significantly since their initial inventory in the two sites. In OR, the dominant species *Strychnos lenticellata* showed an increase in its basal area by three-fold over the 19-year interval and contributed about 15% to the total basal area of the latest inventory (2020). This increase in basal area could be attributed to increasing stem density of the species over the years benefitted from forest disturbances (Nath *et al.*, 2022). This increase in basal area could also be attributed to the ability of *S. lenticellata* to utilize available site resources and its phenotypic plasticity to flourish in different environmental conditions (Babu and Parthasarathy, 2019). Additionally, *S. lenticellata* is a shade-tolerant species exhibiting two climbing mechanisms (stem twining and tendril climbing) and effective dispersal strategies (Khadanga *et al.*, 2015; Vivek and Parthasarathy, 2015; Nath *et al.*, 2022), which could have favored substantially in its growth and increase in basal area. Moreover, this species isn't much exploited by the local people as it has minimal to no resource value in terms of medicinal use or edibility to humans

(Parthasarathy *et al.*, 2015a). High light availability in OR as a result of the existing mud road may also be an indirect factor contributing to this increase, as lianas are known to grow prolifically in high light intensity areas (Putz, 1984). The other dominant species such as *Derris ovalifolia* (+0.67 m^2 ha^{-1}), *Grewia rhamnifolia* (+0.58 m^2 ha^{-1}), *Reissantia indica* (+0.31 m^2 ha^{-1}), and *Combretum albidum* (+0.20 m^2 ha^{-1}) also recorded an increase in basal area between the initial and final census. These four dominant species contributed about 71% to the total basal area of the present inventory (2020) (Appendix 1). In PP, the dominant species *S. lenticellata* reported a marginal increase of only 4% in its basal area. For instance, PP registered a decline in stem density of *S. lenticellata* during the 19-year interval (2001-2020) (Nath *et al.*, 2022), which could be a possible reason behind this insignificant increase. This minimal increase in basal area is also evident of the fact that PP is much more disturbed than OR, which in the long term has negatively affected the structure of the forest. This is because high anthropogenic disturbances may also result in decreasing liana abundance (Chittibabu and Parthasarathy, 2001), which in turn negatively influences the basal area. Other species such as *C. albidum* (+0.34 m^2 ha^{-1}), *Grewia serrulata* (+0.29 m^2 ha^{-1}), and *Pachygone ovata* (+0.11 m^2 ha^{-1}) also showed an increase in basal area with contributing 36% to the total basal area in the latest inventory (2020) (Appendix 2). *Jasminum angustifolium* and *Gymnema sylvestre* suffered greater decrease in basal area in the two sites since initial inventory (Appendix 1, Appendix 2). This could be attributed to the resource value (in terms of medicinal use) of these two species for which they are often exploited by the local residents, for instance, *G. sylvestre* is known to have anti-diabetic properties and *J. angustifolium* is used for treating skin diseases (Parthasarthy *et al.*, 2015a; Nath *et al.*, 2022).

In OR, *S. lenticellata*, *D. ovalifolia*, *G. rhamnifolia*, *R. indica*, and *C. albidum* were the top contributors of total biomass in the recent inventory (2020), contributing about 11.72%, 27.35%, 15.54%, 15.32%, and 22.68% respectively (Appendix 1). Similarly, in PP, the top contributors of total biomass included *C. albidum* (16.48%), *G. serrulata* (15.99%), and *G. rhamnifolia* (17.44%) (Appendix 2). In OR, the aboveground biomass (AGB) increment for *D. ovalifolia*, *R. indica*, and *C. albidum* was found to be 43%, 42%, and 27% respectively since initial inventory. *S. lenticellata* and *G. rhamnifolia* were the two species which showed 100% increment in AGB (Appendix 1). In PP, *G. sylvestre* reported the highest decrease in AGB; found to be about 99% (Appendix 2). The leaf functional traits of some of these top contributor species might have significantly favored them over the other liana species, which consequently resulted in a higher increment in their biomass. Species such as *G. rhamnifolia*, *R. indica*, and *C. albidum* have been reported to have higher specific leaf area (SLA) compared to other liana species (Vivek and Parthasarathy, 2018). The SLA of a species is considered to be a major deciding factor of relative plant growth rate and net assimilation rate (Cornelissen *et al.*, 2003). Higher SLA of a species is associated with higher turnover rate, which resultantly accelerates the plant growth rate (Coley, 1988). In PP, over-exploitation of *G. sylvestre* for its medicinal value could be an apparent reason behind its decline in density, thus in biomass (Appendix 2).

Diameter class distribution
Considerable changes in basal area across the diameter classes were observed at the two sites. In OR, the lower diameter class (1-6 cm) reported a basal area increment of 101% (+0.87 m^2 ha^{-1}) over the 19-year period (Figure 2A). This increase in basal area in the lower diameter class could be associated with the higher recruitment rates of lianas favored by forest disturbances. Likewise, an increasing trend in the basal area of the lower diameter class was reported in PP with an increment of 16% (Figure 2B). Increase in basal area for the diameter class 6-11 cm was reported from the two sites; with basal area increment of 83% and 153% in OR and PP respectively. In OR, the larger diameter classes (11-16 cm and 16-21 cm) together showed an overall positive change in basal area during the 19-year interval (2001-2020), wherein the basal area for these two diameter classes increased by 120% from 2001-2011 and then decreased by 20% from 2011-2020. Altogether, an increase in basal area by 76% was observed for these two diameter classes over the 19 years (Figure 2A). Whereas, in PP,

an overall decrease in basal area was recorded for the larger diameter classes (11-16 cm and 16-21 cm). The larger diameter class (11-16 cm) reported a decrease in basal area by 21% from 2001-2020, but the larger diameter class (16-21 cm) reported a substantial increase in basal area during the 19-year interval. Therefore, all inclusive, a minimal decrease of 5% was recorded in PP (Figure 2B).
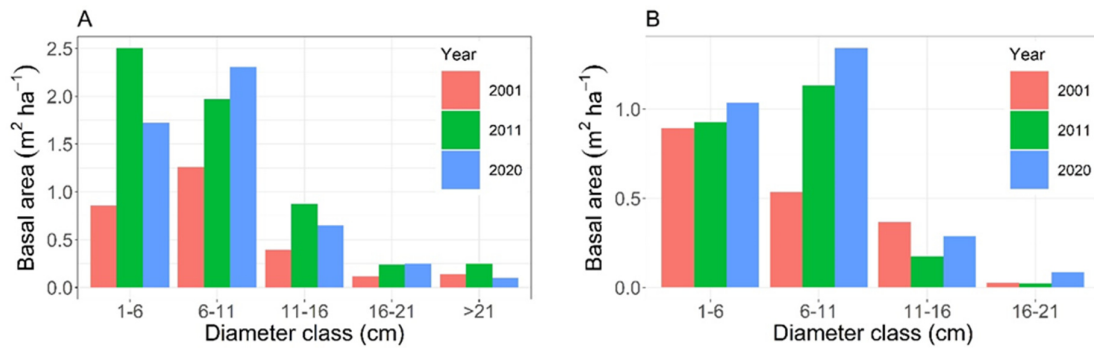

Figure 2. Diameter class distribution showing changes in basal area in two forest sites (OR - Oorani and PP - Puthupet): **A)** OR and **B)** PP, over nineteen years
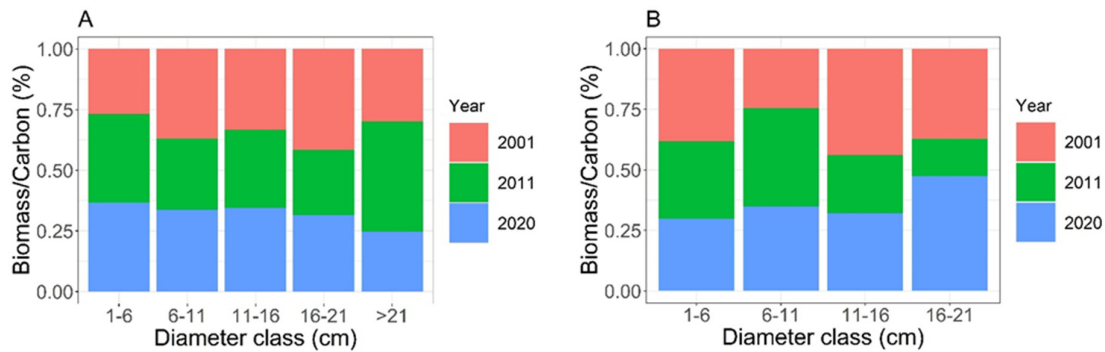
Figure 3. Diameter class distribution showing changes in biomass/carbon in two forest sites (OR - Oorani and PP - Puthupet): **A)** OR and **B)** PP, over nineteen years
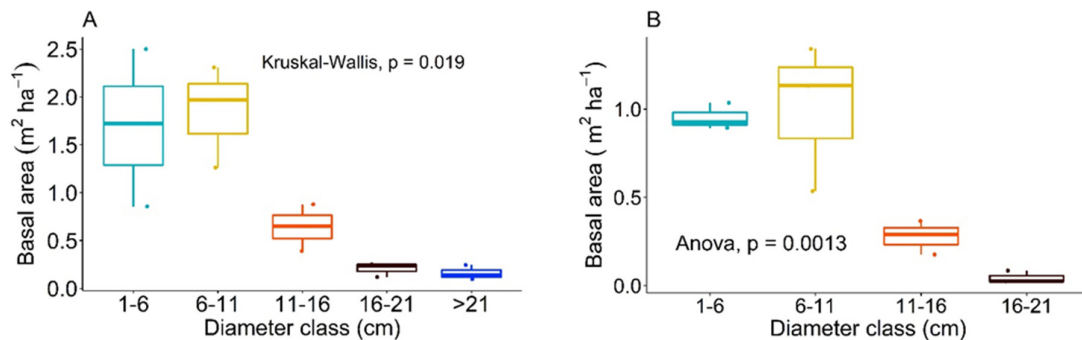

Figure 4. Statistical difference in basal area across diameter class in two forest sites (OR - Oorani and PP - Puthupet): **A)** OR and **B)** PP, over nineteen years
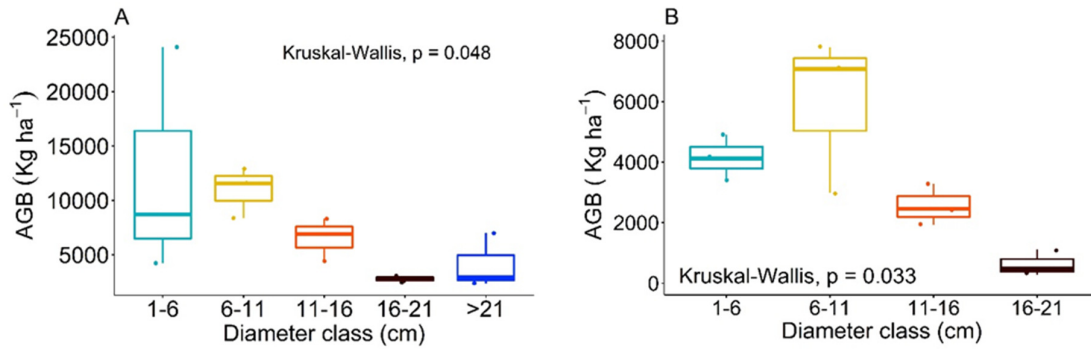
Figure 5. Statistical difference in aboveground biomass (AGB) across diameter class in two forest sites (OR - Oorani and PP - Puthupet): **A)** OR and **B)** PP, over nineteen years

In OR, the diameter class 1-6 cm contributed to about 19% of the total biomass/carbon in the first inventory (2001), however, in the latest re-inventory (2020), the mentioned diameter class contributed to about 26% of the total biomass/carbon. Contrastingly in PP, the diameter class 1-6 cm was observed to contribute about 29% of the total biomass/carbon in the present re-inventory (2020) as against a contribution of about 38% in the first inventory (2001) (Figure 3A, 3B). In the latest re-inventory (2020), the diameter class 6-11 cm was the top contributor of the total biomass/carbon in both OR and PP (Figures 3A, 3B). Kruskal-Wallis/Anova test showed that the allocation of basal area and aboveground biomass among the various diameter classes in the three inventories did differ significantly [(Basal area: OR: χ^2 = 11.833; p = 0.0186; PP: χ^2 = 9.4615; p = 0.0237); (AGB: OR: χ^2 = 9.5667; p = 0.0484; PP: χ^2 = 8.7436; p = 0.0329)] (Figures 4A, 4B; Figures 5A, 5B).

Conclusions

The present re-inventory showed increased basal area, biomass, and carbon stock of lianas in the two sites OR and PP over the 19-year period. Forest disturbances, both natural and anthropogenic, were undeniably the driving factors favoring this change. Although lianas are known to negatively impact the overall biomass and carbon stock of a forest, the present results show that lianas also play an important role in carbon sequestration, especially in these lesser-studied liana rich tropical dry evergreen forests (TDEFs) of peninsular India. Some of the liana species occurring in these TDEFs have been significantly contributing to the overall carbon stock of these forests, thus reflecting onto the importance of liana species and their conservation. Moreover, the over-exploitation of some of the resourceful species might have negative consequences in the long run, for which there is a need for strengthening the existing management strategies by involving local communities.

Authors' Contributions

SN: Field work, data collection, data analysis and manuscript writing; KNB: Study design, field work, data analysis and manuscript review; AAD: Field work, data analysis and manuscript review; NP: Conceptualization, study design and manuscript review. All authors read and approved the final manuscript.

Ethical approval (for researches involving animals or humans)

Not applicable.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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