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Impact of anthropogenic disturbances on the liana diversity and need for conservation of resource valued species - Evidences from Indian tropical dry evergreen forests

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ABSTRACT: Re-inventory of lianas were performed in two 1-ha permanent plots at a 19-year interval (2001–2020) in two tropical dry evergreen forest sites (TDEF; Oorani -OR and Puthupet - PP) of Coromandel Coast of India. Overall, 1964 lianas representing 30 species belonging to 24 genera and 18 families were recorded in this study. Liana species richness declined in both the sites since initial inventory. The TDEF sites revealed an overall increase in stem density for the families Loganiaceae, Papilionaceae, Tiliaceae, Combretaceae, and Celastraceae. The site PP subjected to extreme anthropogenic disturbances reported considerable decrease in its stem density. The diameter class 1–3 cm also revealed substantial decline in its stem density. The endemic species *Derris ovalifolia* showed an increase in its stem density in 19 years. Anthropogenic disturbances resulted in significant decrease in abundance of species such as *Gymnema sylvestre* and *Jasminum angustifolium*, which are known for their medicinal value. The present results provide insights on how anthropogenic disturbances alter species diversity, abundance, and resource values of lianas in TDEFs over a period of time, which will certainly be beneficial for proposing management strategies in the conservation of this forest type.

KEY WORDS: Conservation, density change, disturbance, permanent plots, re-inventory, resource values.

INTRODUCTION

Tropical dry forests are considered as one of the most threatened tropical ecosystems (Janzen, 1988), as around 90% of this forest type is susceptible to a wide array of constraints driven by anthropogenic activities (Miles *et al*., 2006). Covering only ~ 42% of the landmass in the tropics (Murphy and Lugo, 1995; Miles *et al*., 2006), tropical dry forests are mostly overlooked and less studied as compared to the tropical rainforests (Dirzo *et al*., 2011). Clearing of these forest areas for agriculture and other land use purposes is largely a major threat to these forest ecosystems (Khurana and Singh, 2001; Sanchez-Azofeifa *et al*., 2005). In India, tropical dry forests are represented by three forest types *viz*., tropical dry evergreen forests, tropical moist & dry deciduous forests, and tropical thorn forests (Champion and Seth, 1968). Nurturing largely evergreen species, with a diversified plethora of woody climbers known as lianas, the tropical dry evergreen forests (TDEFs) are mainly restricted to the Coromandel coast of India (Parthasarathy *et al*., 2008).

Considered as one of the important non-tree components, lianas contribute substantially to maintain the overall diversity of tropical forests (Gentry and Dodson, 1987). With contributing 18% to the taxonomic diversity of tropical forests, lianas also amount to 10-45% of the total woody species density (Gentry, 1992; Schnitzer, 2005; DeWalt *et al*., 2015). In TDEFs found in India, they represent 37% of the total species richness and constitute 43% of the overall species density (Babu and Parthasarathy, 2019). Lianas have the potential to aggravate the mortality rate of trees by three-folds as well as depreciate their growth by 84% (van der Heijden *et al*., 2013). Known for being adapted to disturbances (Hegarty and Caballe, 1992), lianas are seen to benefit reasonably from increasing disturbances caused by anthropogenic activities (Laurence *et al*., 2001; Addo-Fordjour *et al*., 2009; Schnitzer and Bongers, 2011). However, studies may also indicate that higher degrees of anthropogenic disturbances in the form of resource removal such as logging may result in a decrease in liana abundance (Addo-Fordjour *et al*., 2008). Besides anthropogenic factors, abiotic factors such as soil fertility have also been attributed to affect liana abundance and species richness in tropical forests (Schnitzer and Bongers, 2002). Lianas have also been reported to increase in abundance in forest edges and canopy gaps (Laurence *et al*., 2001). Their conspicuousness and high abundance can also be assigned to high availability of light (Putz, 1984).

Despite the deleterious effects on trees and their interference on the structure of tropical forests, lianas are seen to have positive aspects in terms of resource value (Parthasarathy *et al*., 2015a). For instance, Tra Bi *et al*. (2002) reported the use of 114 medicinally important liana species by the local people in Cote d'Ivoire, West Africa. Extracts made from lianas have been prescribed traditionally in the treatment of various diseases including malaria, urinary tract infection (UTI), dental problems, and even cancer (Tra Bi *et al.*, 2005; Parthasarathy *et al.*, 2015a). Besides providing economic services to humans, lianas provide ecological services to various faunal communities (Parthasarathy *et al.*, 2015a, b). They not only provide habitat and pathways among tree canopies for arboreal animals (Schnitzer and Carson, 2001), but also might constitute a major portion of the faunal diet (Bongers *et al.*, 2005; Martins, 2009).

Re-inventory studies concerning the changes in liana diversity and abundance have been carried out by various researchers around the globe and many have shown a pertinent increase in liana abundance over the years, exceptionally in the neotropical forests (Phillips *et al.*, 2002; Ingwell *et al.*, 2010; Schnitzer and Bongers, 2011; Yorke *et al.*, 2013; Tymen *et al.*, 2016). Increasing liana abundance was also evident in the high-intensity land-used areas of north-eastern Puerto Rico (Hogan *et al.*, 2017). Re-monitoring studies from the African tropical forests reported both decreasing trend (Bongers *et al.*, 2020) and increasing trend (Addo-Fordjour *et al.*, 2021) in liana abundance. Increasing liana abundance was also reported from the lesser-studied TDEFs in India (Khadanga *et al.*, 2015; Pandian and Parthasarathy, 2015). A few re-monitoring studies from the Amazonian forests have shown no significant change in their liana abundance (Smith *et al.*, 2017; Gerolamo *et al.*, 2018). Forest disturbances, including both natural and anthropogenic, can be indirect driving factors for changes in liana communities (Danneyrolles *et al.*, 2019). Also, the nature of the disturbances largely determines whether this influence is either on the positive side (increasing liana abundance) (Malizia *et al.*, 2010) or on the negative side (decreasing liana abundance) (Chittibabu and Parthasarathy, 2001).

Permanent plots re-monitored at short-time and long time-interval help in recording the changes occurring at species and community level (Sheil and May, 1996). Re-monitoring also aids in evaluating both existing and previous management approaches and their impacts on the forest ecosystems (Baithalu *et al.*, 2013; Addo-Fordjour *et al.*, 2021). A number of inventories are available from tropical forests addressing liana dynamics, however, the number of re-inventories conducted is comparably very less, especially in the TDEFs of peninsular India (Khadanga *et al.*, 2015; Pandian and Parthasarathy, 2015). Hence, the present study was undertaken with an aim to investigate changes in liana diversity 19-years after original inventory and assess resource values in two disturbed tropical dry evergreen forest sites of peninsular India.

MATERIALS AND METHODS

Study area

The current liana re-inventory was carried out in two 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) on the Coromandel coast of India (Fig. 1). The sites OR and PP, located at 28 km and 15 km north of Puducherry town respectively, are subjected to various anthropogenic disturbances such as site encroachment, impact from temple visitors, resource removal, etc. (Khadanga *et al.*, 2015).

The vegetation type of the two study sites is characterized as tropical dry evergreen forest (TDEF; Parthasarathy *et al.*, 2008). OR covers an area of about 1.5 ha and PP covers an area of about 5 ha. Tropical dissymmetrical climate prevails in the study sites, accompanied by bulk rainfall, receiving from both north-east and south-west monsoons. Climate data for the sites report a mean annual temperature of 29.5°C and a mean annual precipitation of 114 cm (Khadanga *et al.*, 2015).

Data collection

Two 1-hectare permanent plots, one each at OR and PP, established in 2001 (Reddy and Parthasarathy, 2003), re-inventoried in December 2011 (Khadanga *et al.*, 2015), were re-censused again in 2020 to ascertain changes in liana diversity and density. At OR, two 200 m × 25 m transects located on either side of the centrally dividing mud road was marked and sub-divided into ten 25 m × 20 m quadrats in each sub-plot for easy enumeration (Fig. 1). At PP, one plot of 50 m × 200 m dimension was marked and sub-divided into twenty 50 m × 10 m quadrats and re-inventoried (Fig. 1). All lianas, including both existing and newly recruited individuals ≥ 1 cm diameter, were re-measured at 1.3 m from the rooting point following the standard protocols (Gerwing *et al.*, 2006).

Data analysis

Liana richness was determined directly by noting down the number of species in each plot. Diversity indices such as Shannon-Weiner (H'), Simpson (D), and Fisher's alpha (α) were computed using PAST 3.26 (Hammer *et al.*, 2001) following Magurran (2004) and Fisher *et al.* (1943). The formulations of the mentioned diversity indices are as follows:

Shannon-Weiner, H' $= -\sum p_i \text{In } p_i$

Where, p_i is the proportion (n_i/N) of abundance of one particular species found (n_i) divided by the total abundance (N).

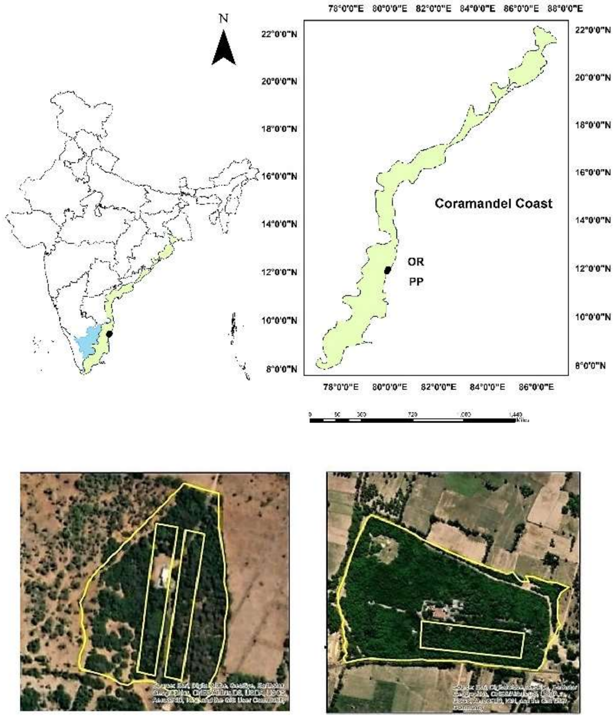
Simpson, D $= 1 - \sum \frac{n_i\ (n_i - 1)}{N(N-1)}$

Where, n_i is the abundance of one particular species found and N is the total abundance.

Fisher's alpha (α), S $= \alpha \text{ In } (1 + \frac{N}{\alpha})$

Where, N is the total abundance.

Changes in liana species richness and density were recorded in both the sites and compared with the previous two inventories. Rarefaction-extrapolation curves were obtained to compare species diversity between the three censuses using Hill numbers family. Hill numbers signify



OORANI (OR) PUTHUPET (PP)

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

diversity indices consolidating both species richness and abundance (Hill, 1973). The first member (q = 0) considers only species richness, irrespective of their relative abundance; the second member (q = 1) represents Shannon's entropy index, considering individuals equivalently; and the third member (q = 2) represents inverse of Simpson's concentration, considering dominant species (Chao *et al.*, 2014). All of these analyses were conducted in the package "iNEXT" (https://cran.r-project.org/package=iNEXT) (Hsieh *et al.*, 2016).

Diameter class data were subjected to Shapiro-Wilk test to check the normality prior to Kruskal Wallis test to determine the statistical difference for all three time periods. All of these statistical analyses 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.r-project.org/package=ggplot2) and "ggpubr" (https://cran.r-project.org/package=ggpubr) of software R 4.2.1 (R Core Team, 2021). The liana species enumerated in the study sites were also assessed for their resource value, referring to available literature (Parthasarathy *et al.*, 2015b), along with their density change.

RESULTS

Changes in liana diversity

The present re-censuses of the sites OR and PP yielded 1964 liana individuals in total. At OR, overall, 18 species in 16 genera and 15 families were recorded. PP was found to be more diverse than OR, yielding overall 27 species representing 22 genera and 18 families. Over the span of 19 years, there was a net decrease of six species at OR (Fig. 2A). A total of 450 individuals increased at OR, whereas PP showed a decreasing trend with a decline of 133 individuals. The stem density of OR increased by 55%, whereas the stem density of PP decreased by 15% (Table 1; Fig. 2).

Species richness decreased at the two sites since initial inventory, with OR recording a greater decrease in the number of species. This was corroborated by the rarefaction-extrapolation curves as the first member (q = 0) decreased for the two sites over these 19 years (Fig. 2A, 2B). Consequently, a considerably lower Shannon diversity index was reported in OR in 2020 (H' = 2.07) than 2001 (H' = 2.34). This result was also validated by the rarefaction-extrapolation curves as the second member (q = 1) decreased in OR since the initial census (Fig. 2A). In contrast, PP registered a higher Shannon diversity index in 2020 (H' = 2.77) than 2001 (H' = 2.69). This was apparent as the second member (q = 1) increased since the initial census (Fig. 2B).

Changes in density of lianas

The density of many liana species have changed considerably since their initial inventory. In OR, the predominant species *Strychnos lenticellata* showed an increase of 320 stems in the first decade (2001–11), whereas it reported decrease of 83 stems in the next nine years (2011–20). Despite this decline, it contributed to 30% of the total stem density in the latest re-inventory (2020) (Table 1). Similarly, in PP, *S. lenticellata* showed an increase of 143 stems in the first decade (2001–11); however, this increase was overshadowed by the decrease of 172 stems reported in the next nine years (2011–20) (Table 1).

In OR, *Derris ovalifolia* (+82 stems), *Reissantia indica* (+58 stems), *Grewia rhamnifolia* (+50 stems), *Capparis rotundifolia* (+42 stems), and *Combretum albidum* (+34 stems) recorded an increase in their stem density between the intial and final census. These five dominant species contributed 57% of the total stem density in the latest re-inventory (2020) (Table 1). Whereas in PP, *Grewia serrulata* (+62 stems), *Acacia caesia* (+44 stems), *Combretum albidum* (+41 stems), and *Pachygone ovata* (+31 stems) recorded increase in their stem density, contributing 25% of the total stem density (Table 1).

Jasminum angustifolium sufferred maximal decrease in stem density over 19 years, with a net decrease of about 67 stems and 77 stems at OR and PP, respectively (Table 1). In PP, *Gymnema sylvestre* recorded considerable decrease in its stem density with a net reduction of 72 stems. In PP, a total of 16 species out of the 28 species recorded in the initial inventory, showed a decrease in

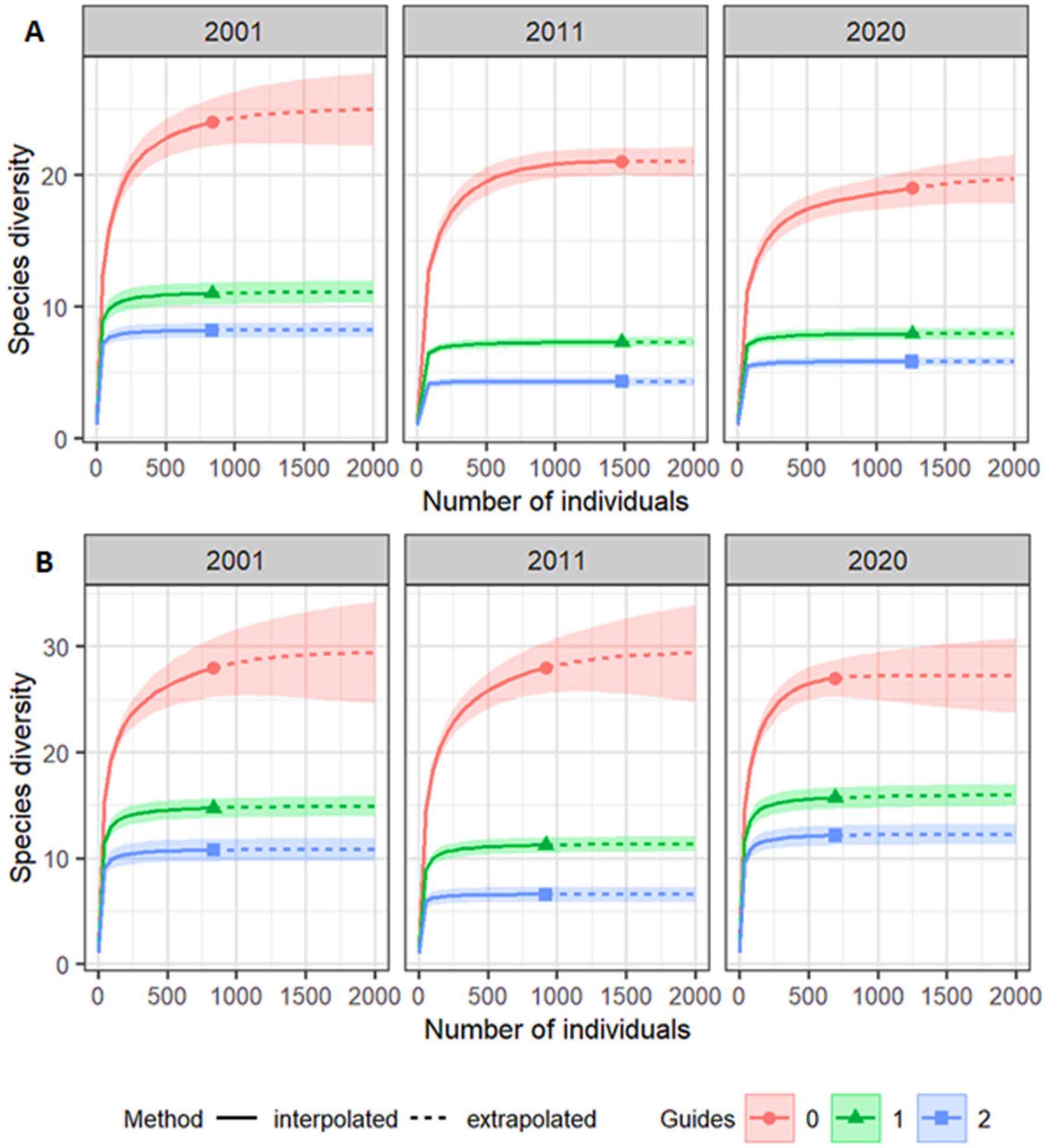


Fig. 2. Rarefaction-extrapolation curves showing species richness and abundance of lianas at two TDEF sites **A)** Oorani - OR and **B**) Puthupet - PP on the Coromandel coast of India. The solid lines and the dashed lines represent the rarefaction (interpolation) curves and the extrapolation curves. The symbols at the end of the rarefaction curves represent recorded species richness (0) and diversity indices: Shannon entropy (1) and inverse Simpson (2) for the different census years

stem density in the nine years (2011–20), i.e., stem density decreased for more than 50% of the species during this period (Table 1).

Changes in density of endemic species - *Derris ovalifolia*

Derris ovalifolia, regarded as an endemic species to India (Balachandran and Rajendiran, 2014; Krishnamurthy *et al*., 2014), recorded a considerable increase in its stem density in both the sites (82 stems in OR and 14 stems in PP) (Table 1). The lower diameter class (1–3 cm) showed no significant change in net stem density over the 19-year period. Increasing stem density was recorded for the three diameter classes 3–6 cm (+50 stems), 6–10 cm (+38 stems), and 10–15 cm (+7 stems) since the initial inventory (2001) (Fig. 3).

Changes in species richness and density by climbing mode

Among the five climbing modes recognized in the study sites, the species richness decreased for three climbing

Table 1. Nineteen years of changes in liana communities in Oorani (OR) and Puthupet (PP) tropical dry evergreen forests on the Coromandel coast of India.

Sl. No.	**Family/ Species**	**CM**	**OR**				**PP**			
			2001	**2011**	**2020**	**NC**	**2001**	**2011**	**2020**	**NC**
	Apocynaceae									
1	*Carissa spinarum* L.	Scr-A	11	3	4	-7	65	46	30	-35
2	*Gymnema sylvestre* (Retz.) R.Br. ex Sm.	ST	0	0	0	0	73	28	1	-72
3	*Ichnocarpus frutescens* (L.) W.T. Aiton	ST	0	0	0	0	0	48	0	0
	Aristolochiaceae									
4	*Aristolochia indica* L.	ST	0	0	0	0	0	1	0	0
	Capparaceae									
5	*Capparis brevispina* DC.	Scr-A	7	21	9	2	46	31	14	-32
6	*Capparis rotundifolia* Rottler	Scr-A	25	30	67	42	0	1	0	0
7	*Capparis sepiaria* L.	Scr-A	1	0	0	-1	10	2	7	-3
8	*Capparis zeylanica* L.	Scr-A	4	8	7	3	18	8	7	-11
	Celastraceae									
9	*Reissantia indica* (Willd.) N. Hallé	Scr-UA	152	166	210	58	18	9	23	5
10	*Salacia chinensis* L.	ST	0	0	0	0	2	0	3	1
	Combretaceae									
11	*Combretum albidum* G. Don	ST	125	161	159	34	20	31	61	41
	Convolvulaceae									
12	*Rivea hypocrateriformis* Choisy	ST	2	8	0	-2	1	0	0	-1
	Cucurbitaceae									
13	*Coccinia grandis* (L.) Voigt	TC	2	4	15	13	12	6	4	-8
	Fabaceae									
14	*Abrus precatorius* L.	ST	0	0	0	0	7	0	0	-7
	Icacinaceae									
15	*Pyrenacantha volubilis* Hook.	ST	0	0	0	0	2	0	0	-2
	Lilaceae									
16	*Asparagus racemosus* Willd.	Scr-A	7	0	0	-7	2	3	0	-2
	Linaceae									
17	*Hugonia mystax* L.	HC	22	30	16	-6	57	41	54	-3
	Loganiaceae									
18	*Strychnos lenticellata* A.W. Hill	TC	150	470	387	237	151	294	122	-29
	Menispermaceae									
19	*Pachygone ovata* (Poir.) Diels	ST	6	11	23	17	24	46	55	31
20	*Tinospora cordifolia* (Willd.) Miers ex Hook. F. & Thomson	ST	15	18	1	-14	0	11	0	0
	Mimosaceae									
21	*Acacia caesia* (L.) Willd.	Scr-A	1	3	6	5	11	12	55	44
	Moraceae									
22	*Maclura spinosa* (Willd.) C. C. Berg	Scr-A	3	2	0	-3	11	3	7	-4
	Olacaceae									
23	*Olax psittacorum* (Willd.) Vahl	Scr-UA	0	0	0	0	5	6	2	-3
	Oleaceae									
24	*Jasminum angustifolium* (L.) Willd.	ST	81	98	14	-67	130	162	53	-77
25	*Jasminum auriculatum* Vahl	ST	0	0	0	0	0	2	5	5
	Opiliaceae									
26	*Cansjera rheedei* J. F. Gmel.	Scr-A	7	7	42	35	4	8	6	2
	Papilionaceae									
27	*Derris ovalifolia* (Wight & Arn.) Benth.	ST	113	131	195	82	1	0	15	14
	Passifloraceae									
28	*Adenia wightiana* (Wall.ex Wight & Arn.) Engl.	TC	0	0	0	0	0	9	0	0
	Rhamnaceae									
29	*Ventilago maderaspatana* Gaertn.	ST	0	0	0	0	26	19	14	-12
30	*Ziziphus oenoplia* (L.) Mill.	Scr-A	0	0	0	0	1	1	3	2
	Tiliaceae									
31	*Grewia serrulata* DC.	Scr-UA	0	0	0	0	0	20	62	62
32	*Grewia rhamnifolia* Roth	Scr-UA	47	68	97	50	72	36	43	-29
	Verbenaceae									
33	*Lantana camara* L.	Scr-A	0	0	0	0	0	0	15	15
34	*Premna corymbosa* Rottler & Willd.	ST	16	12	4	-12	42	54	37	-5
	Vitaceae									
35	*Cayratia pedata* (Lam.) Gagnep.	TC	7	8	6	-1	0	0	0	0
36	*Cissus quadrangularis* L.	TC	2	0	0	-2	19	0	2	-17
37	*Cissus vitiginea* L.	TC	6	0	0	-6	5	2	2	-3
		Total	**812**	**1259**	**1262**	**450**	**835**	**940**	**702**	**-133**

*NC – Net Change; CM – Climbing mode: HC – Hook climber; Scr-A – Scrambler-armed; Scr-UA – Scrambler-unarmed; TC – Tendril climber; ST – Stem twiner.

Table 2. Changes in liana species richness and density by climbing mode in Oorani (OR) and Puthupet (PP).

Climbing mechanism	OR								PP							
	Species richness				Stem density				Species richness				Stem density			
	2001	2011	2020	NC	2001	2011	2020	NC	2001	2011	2020	NC	2001	2011	2020	NC
Stem twiner	7	7	6	-1	358	439	434	76	11	10	8	-3	290	402	210	-80
Tendril climber	5	3	3	-2	167	482	408	241	4	4	4	0	187	311	130	-57
Hook climber	1	1	1	0	22	30	16	-6	1	1	1	0	57	41	54	-3
Scrambler-armed	9	7	5	-4	66	74	93	27	7	10	8	1	162	115	138	-24
Scrambler-unarmed	2	2	3	1	199	234	311	112	5	4	6	1	139	71	170	31

*NC- Net Change

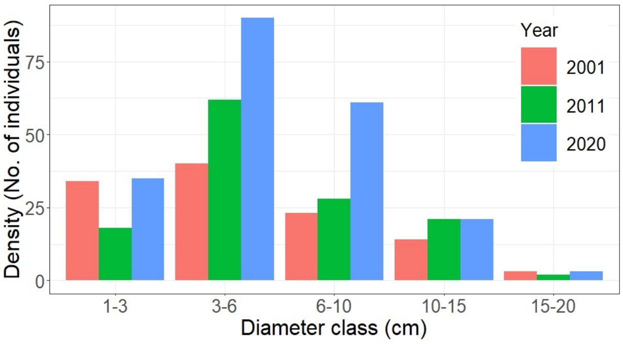


Fig. 3. Changes in density across the diameter class of Derris ovalifolia over nineteen years (data pooled together for both the sites)

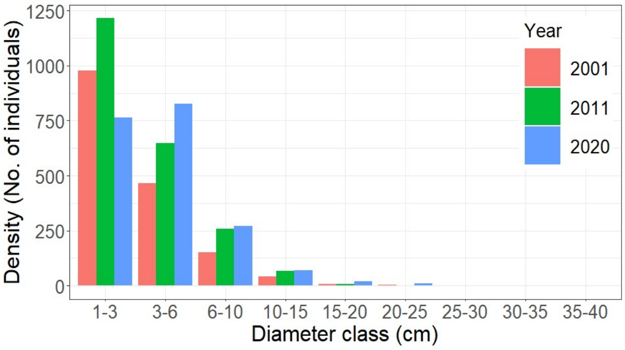


Fig. 4. Changes in density across the diameter class over nineteen years (data pooled together for both the sites)

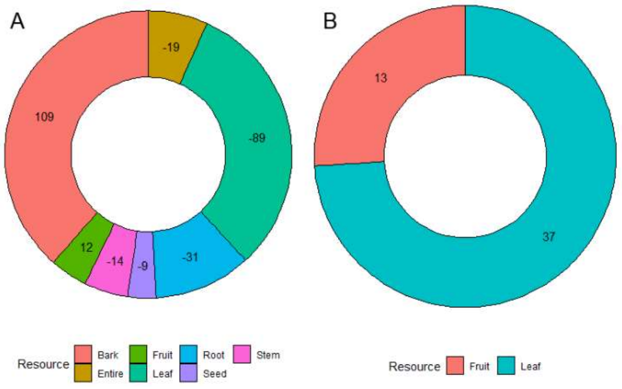


Fig. 5. Donut charts depicting the changes in resource value: (**A**) varied resource use including medicinal and cattle feed and (**B**) Edible to humans. Numbers with a minus sign depicts a decrease in density.

modes (stem twiners, tendril climbers, and armed scramblers) in OR. In PP, the species richness of stem twiners decreased, whereas the species richness of armed scramblers and unarmed scramblers increased in 19-years. The species richness of hook climbers remained unchanged at the two sites. In OR, except for hook climbers, the stem density increased in all other climbing modes. However, in PP, except for unarmed scramblers, the stem density decreased in all other climbing mechanisms (Table 2).

Changes in density across diameter class

The lower diameter class 1–3 cm (–213 stems) reported decrease in stem density in 19 years. The diameter classes 3–6 cm (+361 stems), 6–10 cm (+120 stems), 10–15 cm (+27 stems), and 15–20 cm (+15 stems) showed increase in their stem density. The diameter classes (1–3 cm and 3–6 cm) constituted 81% of the total stem density in current inventory (2020) (Fig. 4). The allocation of individual stems among the diameter classes in three inventories did differ significant across the sites (OR: χ^2 = 24.267; p = 0.002067; PP: χ^2 = 16.111; p = 0.006533).

Changes in Resource value (RV)

The study revealed considerable changes in the resource value of the TDEF sites. *Jasminum angustifolium*, known for treating various ailments, reported net decrease of 144 stems from the two sites, thus suggesting the resource value loss in 19-year period. Other medicinally valued species such as *Gymnema sylvestre*, *Premna corymbosa* and *Abrus precatorius* also recorded decrease in stem density from the sites (Table 1). The highly resourceful species *Cissus quadrangularis* whose parts (bark, leaf, root, etc.) are known for medicinal value have shown a decrease of 19 stems. Species such as *Acacia caesia*, *Combretum albidum*, *Ventilago maderaspatana*, etc. which provide bark as an economic resource recorded an overall increase of 109 stems. Similarly, changes were noted down for the other plant parts (Fig. 5A). Species providing leaf and fruits as edible resources increased by 37 and 13 stems, respectively (Fig. 5B).

DISCUSSION

Re-inventory studies concerning liana dynamics are very limited and mostly vary from one another in terms of their aspects and objectives considered. Moreover, the existing scenario of anthropogenic disturbances in the TDEFs and the meagre data available from these parts make it a difficult task to produce a well-grounded comparison across various tropical forests. This study mainly concentrated on the changes in liana diversity and resource value in two disturbed tropical dry evergreen forest sites OR and PP, on the Coromandel coast of India.

The present liana re-inventory reported a net decrease of six species and one species from OR and PP, respectively. This coincided with the comprehensive decline of liana species in the Gabonese rainforest, wherein a total of 15 species were lost from the site over 13 years (Caballé and Martin, 2001). Loss of species such as *Adenia wightiana, Aristolochia indica, Asparagus racemosus*, *Pyrenacantha volubilis*, and *Rivea hypocrateriformis* which were represented by few individuals in the previous inventories could be associated with natural causes or anthropogenic causes such as logging by local people. Contrasting results were observed by Pandian and Parthasarathy (2015), wherein the study revealed a net increase of four species in other TDEF sites. Bongers and Ewango (2015) reported no change in the number of species in 13-year study (1994–2007) in the Ituri mixed forest, DR Congo. Addo-Fordjour *et al.* (2021) reported mixed results of reduced density and loss of some species, but increased density of some other species over an 11-year period in the Bobiri Forest Reserve, Ghana.

Studies have also shown that species richness of lianas was upheld exclusive of their stem density, thus suggesting that a mechanism known as resource partitioning may exist among lianas (Schnitzer and Bongers, 2002). For instance, the site OR which recorded a greater density of lianas (1262 stems) represented only 18 species. In contrast, the site PP with a lesser density of lianas (702 stems) represented a greater number of species (27 spp.).

The stem density at OR increased by 55% over 19-year period, which could be attributed to moderate anthropogenic disturbances prevailing in the site. This increasing trend of liana abundance was also reported by Addo-Fordjour *et al.* (2021; 61-108% increase over 11 years), Hogan *et al.* (2017; 100% increase over 14 years), and Chave *et al.* (2008; 1.8% increase over 10 years). Nonetheless, our study contrasts with Bongers *et al.* (2020) which observed a dramatic decline of 33% in liana abundance over 13-year period, Ceballos and Malizia (2017) in which stem density decreased by 13.3% over 12 years, and Thomas *et al.* (2015), wherein stem density of lianas decreased by 16% over 10 years. The conflicting trends in liana dynamics show that there is no universal trend in change in liana abundance as reported by Addo-Fordjour *et al.* (2021). The trend in liana abundance dynamics may be dictated by local conditions, and historical and evolutionary processes that occur in the specific forests (Addo-Fordjour *et al.*, 2021). Thus, areas which differ in climatic conditions, past land-use, and evolutionary history may show different trends with respect to liana abundance dynamics.

The liana abundance at site PP declined by 15% since initial inventory (2001). This decrease in stem density could be attributed to the high pressure of human activity associated with the site, revealing that liana abundance may decrease in highly disturbed forests. A decrease in host species (trees) abundance with increasing forest disturbances could possibly be a reason for this decreasing trend (Allen *et al.*, 2005; Addo-Fordjour *et al.*, 2009), which was evident in PP, wherein the overall tree abundance decreased from 1,329 in 1992 to 591 in 2012 (a net decrease of 747 stems over 20 years) as reported by Baithalu *et al.* (2013). The occurrence of cyclone Thane in December 2011 on the Coromandel coast (Girija and Asokan, 2019) could possibly be attributed as a natural cause contributing to this decline as the site PP is just 1km away from the coast.

Strychnos lenticellata was the most abundant species contributing 25% (509 stems) of the total stem density. The greater stem density reflects the ability of this species to exploit available site resources (Babu and Parthasarathy, 2019) and shows its phenotypic plasticity to proliferate in varying environmental conditions. The dominance of *S. lenticellata* could also be attributed to the fact that it exhibits two climbing mechanisms (stem twining and tendril climbing) and the effective dispersal strategies (Khadanga *et al.*, 2015; Vivek and Parthasarathy, 2015), giving it an advantage over the other liana species. Another possible reason could be that this species doesn't provide much resource value in terms of its medicinal use or edibility to humans, for which it is not exploited by the local people (Parthasarathy *et al.*, 2015b).

At OR, 40% of its total stem density was contributed by its smaller diameter class (1–3 cm). The slower increment in the girth of lianas because of nutrient-poor soil could possibly be a reason why abundance of lianas is higher in the smaller diameter class, as OR is situated on granular coastal sandy soil (Pragasan and Parthasarathy, 2005; Vivek and Parthasarathy, 2015). Udayakumar and Sekar (2021) also reported that TDEFs are nutrient-poor forests with very low concentrations of nitrogen and phosphorus. As apparent, OR is smaller in area and naturally disturbed because of the existing mud road (Fig. 6A), for which there is more light availability in its understory; similarly in the canopy gaps (Fig. 6A). Thus, their higher recruitment rate could be another reason for this high liana abundance in the lower girth class as high light availability and gap habitats help lianas to sprout prolifically and produce new stems (Putz, 1984;

Table 3. List of lianas and their resource values in two tropical dry evergreen forest sites OR and PP.

Sl.	Species	Family	Resource L	S	B	R	FR	SE	E	Medicinal value	Others
1	*Abrus precatorius*	Fabaceae	*					*		Uterine stimulant, abortifacient & hepatitis	Cattle feed
2	*Acacia caesia*	Mimosaceae			*				*	Anti-inflammatory, antiseptic & emmenagogue	Cattle feed
3	*Capparis sepiaria*	Capparaceae	*			*				Antiseptic, antipyretic	
4	*Capparis zeylanica*	Capparaceae	*			*				Swellings & boils, sedative, anticholerin	Cattle feed
5	*Carissa spinarum*	Apocynaceae				*			*	Purgative, cardiotonic	Cattle feed & fruits edible
6	*Cayratia pedata*	Vitaceae	*						*	Astringent, diuretic, spasmolytic	
7	*Cissus quadrangularis*	Vitaceae							*	Scurvy, fracture-healing	
8	*Gymnema sylvestre*	Apocynaceae	*							Antidiabetic, emetic, diuretic	
9	*Hugonia mystax*	Linaceae	*			*				Anti-inflammatory, febrifuge, swellings	Cattle feed
10	*Jasminum angustifolium*	Oleaceae	*							Emetic, treating ringworm	Cattle feed
11	*Premna corymbosa*	Verbenaceae	*							Galactogogue, rheumatism	
12	*Maclura spinosa*	Moraceae		*						Cholera	
13	*Reissantia indica*	Celastraceae	*							Wound-healing, respiratory disorders	Cattle feed
14	*Rivea hypocrateriformis*	Convolvulaceae	*							Astringent, tonic after child birth	Cattle feed
15	*Salacia chinensis*	Celastraceae				*				Diabetes, amenorrhea, dysmenorrhoeal	
16	*Tinospora cordifolia*	Menispermaceae	*	*						Antipyretic, fever, diabetes	Cattle feed
17	*Ventilago maderaspatana*	Rhamnaceae	*		*					Febrifuge, skin diseases, scabies	Cattle feed
18	*Ziziphus oenoplia*	Rhamnaceae	*			*	*			Hyperacidity, ascaris infection, stomachic	Cattle feed
19	*Capparis brevispina*	Capparaceae				*				Toothache	
20	*Capparis rotundifolia*	Capparaceae	*			*				Headache	cattle feed
21	*Combretum albidum*	Combretaceae	*		*					Treating skin diseases	cattle feed
22	*Coccinia grandis*	Cucurbitaceae				*	*			Headache	
23	*Pyrenacantha volubilis*	Icacinaceae						*		Breast cancer	
24	*Pachygone ovata*	Menispermaceae	*				*			Analgesic properties	Fruit is edible
25	*Cansjera rheedei*	Opiliaceae	*							Poisonous bites	Leaf is edible
26	*Grewia rhamnifolia*	Tiliaceae	*				*			Stomach disorders	cattle feed
27	*Cissus vitiginea*	Vitaceae					*			Relief of flatulence	
28	*Olax psittacorum*	Olacaceae			*					Anaemia & diabetes	

L – leaf; S – stem; B – bark; R – root; FR – fruit; SE – seed; E – entire

Schnitzer *et al.*, 2000). Higher stem density in smaller diameter classes have also been reported by other studies from Indian TDEFs (Muthumperumal and Parthasarathy, 2010; Anbarashan and Parthasarathy, 2013; Khadanga *et al.*, 2015; Vivek and Parthasarathy, 2015). In PP, the smaller diameter class (1–3 cm) contributed to 36% of the total stem density in the present inventory (2020). However, PP also revealed a decrease of 56% stem density in the smaller diameter class (1–3 cm). High degrees of anthropogenic disturbances and frequent cutting of lianas in the site could be a reason for this decline. Mascaro *et al.* (2004) reported a similar mortality rate in lower diameter-class in Costa Rican forests.

Derris ovalifolia, an important species endemic to India (Balachandran and Rajendiran, 2014; Krishnamurthy *et al.*, 2014), is found to be occurring in only a few TDEFs along the Coromandel coast of India (Parthasarathy *et al.*, 2015b), including the sites OR and PP. The results revealed an increase in its abundance in both the sites over 19-year period, especially in the site OR. Despite this increase in abundance, the study also revealed that forest disturbances have unquestionably increased in the two sites, which was quite evident in terms of cut stems, temple construction, excessive grazing, human trails, etc. (Fig. 6). For instance, a recent temple construction in OR has compromised an area about 1000 m^2, which might have reduced the number of individuals of many resource providing species, including the endemic species *Derris ovalifolia* from the site, if not more individuals of it possibly could have been reported in the present study. Similarly, in PP, a portion of the forest patch has been cleared for religious purposes (Fig. 6D). If the present trends of anthropogenic disturbances continue and increase in intensity, then we could expect a dramatic decline of such liana species in future. Thus, reflecting onto the need for conservation of these TDEF sites.

In this study, lianas exhibited five types of climbing mechanisms. In OR, stem twiner was most abundant contributing 34% of the total stem density. This coincided with similar results from other tropical forests (Cai *et al.*, 2009; Muthumperumal and Parthasarathy, 2010; Anbarashan and Parthasarathy, 2013). The species richness of three climbing modes (stem twiner, tendril climber and armed-scrambler) declined in 19 years. Frequent cutting of lianas by local people for firewood could be one of the reasons for this decline. Unavailability or decrease in the number of host species could also be another reason, as lianas cannot proliferate without the support of trees, which was evident as net tree density decreased by 617 stems (1992–2020) in the study site PP (Dilshad *et al*., 2020).

The TDEFs are known to provide various economic good services to the local residents in terms of medicinal use, edibles, cattle feed, etc. The sites OR and PP are home to a good number of liana species which are economically rewarding. A total of 28 species out of 37 species enumerated in the study provide economic services (Table 3). The highly resourceful species *Cissus quadrangularis* whose almost every part can be medicinally used has decreased by 90% of its total individuals reported in the last inventory. Species such as *Gymnema sylvestre*, *Premna corymbosa*, *Salacia chinensis*, etc., provide medicinal ailment for diabetes. Similarly, *Abrus precatorius*, *Jasminum angustifolium* and *Premna corymbosa* provide medicinal ailment for other diseases and are also good sources of cattle feed. Among the various species, the leaves of *Cansjera rheedei*, and fruits of *Ziziphus oenoplia* and *Coccinia grandis* are used for human consumption (Parthasarathy *et al*., 2015a, b). The results revealed that 64% of such valuable liana species have declined from the two sites as a result of the prevailing anthropogenic disturbances. Loss of such species will have potential impacts on the livelihood of the resource users, thus suggesting the need for better management strategies which will help in the maintenance of these forest resources in the long run.

CONCLUSIONS

The re-inventory of the two TDEF sites Oorani (OR) and Puthupet (PP), revealed considerable changes in the liana species composition and their density. Depending upon the intensity of the anthropogenic disturbances, both the sites show varied results, with an increase in liana abundance at OR and a decrease in liana abundance at PP. The data obtained in this study in addition to the occurrence data of *Derris ovalifolia* from the TDEFs, will aid in future threat assessment of this endemic species as per the International Union for Conservation of Nature (IUCN) standards. The loss of the resource-providing species will have a great impact on the faunal communities as well as the dependent local people, thus realizing the need for adopting proper management policies. Overall, this study will be a beneficial asset in proposing conservation measures for the TDEFs in India, which we might otherwise lose due to ever-increasing anthropogenic disturbances. With the incorporation of remote sensing (RS) and geographic information system (GIS), further studies can be carried out to record changes happening across the disturbance regimes of these TDEFs at multi-temporal scale.

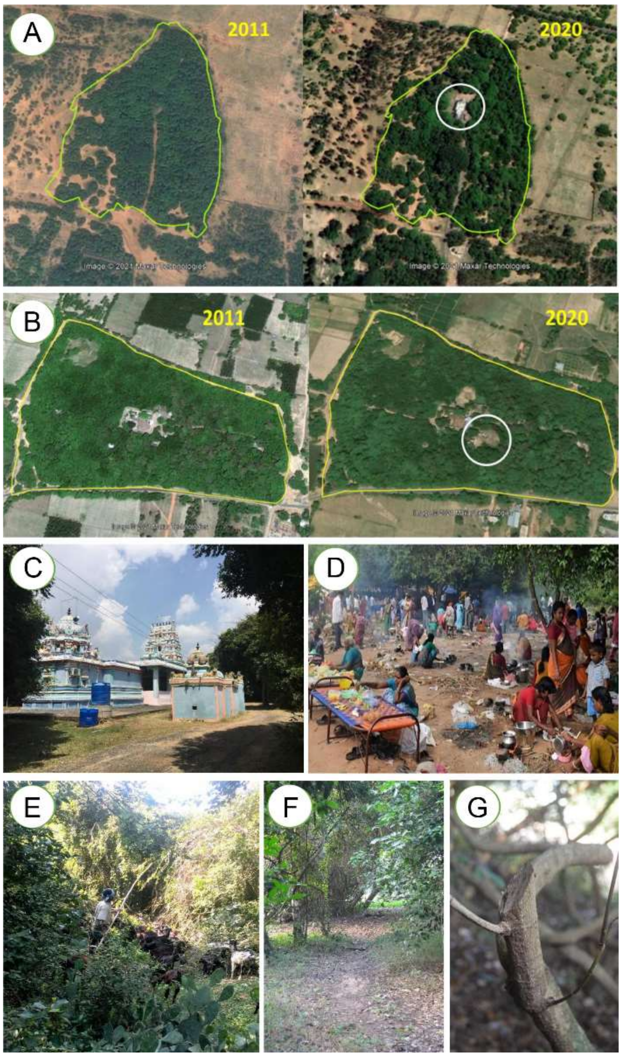


Fig. 6. Anthropogenic threats: (**A**) Land use change in OR in last nine years (**B**) Land use change in PP in last nine years (**C**) Recently built temple in OR (**D**) Land used by pilgrims for cooking activities in the festive season (**E**) Resource extraction and grazing (**F**) Human trails within the plot in PP (**G**) Cut stem of a liana species

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