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Diversity, Distribution and Biomass of Tree Community in a Tropical Dry Forest of Northern Sri Lanka

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Abstract: A study was conducted in a tropical dry forest in Northern Province of Sri Lanka. The study aims to assess the tree diversity, distribution and carbon stock. Field assessment was conducted in six sites of the state forest, namely *Kulamurippu*-A, *Kulamurippu*-B, Puthukudiyirupu, *Nagansolai*, *Andankulam* and *Theravil*. Sampling plots were randomly selected from each location at a size of 20 m × 20 m with three replicates. Samples were collected and herbarium specimens were prepared and submitted to the National Herbarium, Royal Botanical Garden, Peradeniya for species identification. Indices of Shannon−Wiener, evenness, species richness and IVI were used to assess the diversity and dominance of the species. Height and diameter of trees were measured to estimate biomass and carbon stock by using a tropical allometric equation. A total of 321 trees, comprising 31 species and six lianas from 20 families, were enumerated. The most representative family was ebenaceae with three species. The evaluated community presents an average density of 446 trees ha^{-1} and a basal area of 0.13 $m^2\,ha^{-1}$. The based on the Importance Value Index (IVI), the forest was dominated by *Drypetes sepearia* (Wight & Arn.) Pax & Hoffm. (39.42 %), *Manilkara hexandra* (Roxb.) Dubard (38.19 %), followed by *Chloroxylon* swietenia DC (27.88 %), *Diospyros ebenum* Koenig (25.38 %). and *Vitex altissimamilla* L. f. (24.39 %). These five species account for 155.26 % of IVI. Mean Shannon diversity index and evenness were 1.94±0.11 and 0.91±0.01, respectively. This suggested that tree species were equally distributed with medium species diversity compared to wet forest. Mean carbon stock of the forest reserve was 206.34±19.12 Mg C ha^{-1}, which was higher than other dry zone forests (92.62 Mg C ha^{-1}) and lower than wet zone forest (336.8 Mg ha^{-1}) in Sri Lanka. According to the IUCN red listed data, identified species were recorded as vulnerable (VU), near threaten (NT), endangered (EN), and least conservation (LC). Results of this study provide baseline information for formulation of conservation and management guidelines of forest ecosystems in the region.

Keywords: Diversity indices, Dry zone, IVI, Prevalence, State forest, Tropical forest

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Introduction

Forests provide a wealth of material outputs of subsistence or commercial value includes provisioning of goods, protection, supporting and cultural services due its rich diversity of species. In dry forest of Sri Lanka, most of the genera are represented by a single species and have high taxonomic diversity (MOE, 2012). The forest cover has remained intact largely despite the conflict in the past three decades (SI, 2017). The extent of forest cover is 168, 120 ha (64 %) of land area in the Mullaitivu district, of which 2,108 was deforested due severe logging during 1992 to 2010 (UNREDD, 2014; SI, 2017). A forest reserve in the district which includes dense, open, plantation and mangrove forest. The forest vegetation play many roles in the district for economic development and environmental conservation of the district. Therefore, understanding the tree species composition, diversity, and structure is a vital instrument in assessing sustainability of the forest in terms of conservation and management of the ecosystems (Madoffe, 2006; Addo-Fordjour, 2009).

Under the present scenario of global climate change and increasing deforestation rates, it has become crucial to quantify the carbon stocks and fluxes particularly in the tropics (Houghton, 2005). Natural forests store a large quantity of carbon, and there is currently great interest in assessing that quantity accurately, as forests are cleared the carbon is converted to carbon dioxide in the atmosphere. The average aboveground biomass for dry zone forests was 92.62 Mg ha^{-1} and the wet zone estimates was 336.8 Mg ha^{-1} (Sinharajah) (Kumarathunge, 2009). There is also a great deal of enthusiasm among our people to conserve the biodiversity of this country (MOE, 2012). However, little information available on flora species and carbon stock in the Mullaitivu district. Therefore a study was carried out with the objectives of identifying the flora species and quantifying carbon stock of different forests reserve in Mullaitivu district.

2. Materials and Methods

2.1 Study Sites

This study was carried out in the multiple sites of the forest reserve in Mullaitivu district and it is a dry forest in northern Sri Lanka. The district Mullaitivu is divided into two ranges as Mullaitivu and Olumadu. For the study, there were six location namely *Nagancholai* (NS), *Kulamurippu* (A) (KUA), *Kulamurippu* (B) (KUB), *Therawil* (TW), *Puthukudiyirupu* (PK) and *Andankulam* (AU) selected from Mullaitivu range of forest reserve which is identified by Department of Forest as protected areas. Locations of *Kulamurippu* (A), *Kulamurippu* (B) are sited under different divisional secretariat divisions of Maritimepattu and Oddusuddan, respectively. Secondary data of extent, types, range, beats and free landmines areas were collected from the Forest Department of Sri Lanka to identify the reserved forest in the Mullaitivu District. Three sample plots (20 m × 20 m) were selected randomly from each site for the assessment.

Figure 1: Sampling location in the forest reserve in Mullaitvu district (Source: Google map, 2018, SI, 2017)

2.2 Diversity of Species

The species were identified in the field with the help of local guiders and community people who are living near the forest reserve. Preliminary identification was done by experts with digital photo graphs for each specimens. Specimens of leaves, flowers and fruits of the species were collected and preserved based on the guidelines developed for herbarium preparation. Further, samples specimens of each species were submitted to the Department of National Botanical Gardens, Peradeniya for further identification at species levels. Diversity of the species was assessed by using Shannon−Wiener Index (SWI) (Shannon and Weaver, 1949) denoted by;

$$H = -\sum[(pi \times ln\ (pi)]$$

∑= summation, pi = proportion of total sample represented by species i , S = species richness, Hmax = ln(S) maximum diversity possible, E = evenness (= H/Hmax, (H: 1.5 - 3.5) (Pielou, 197; Yue *et al.* 2004). The value of H represents species heterogeneity and can be classified into low (H' < 1.5), medium (1.5–3.5) and high (H' > 3.5) (Pambudi and Rahayu, 2017). Tree height and diameter were measured to estimate the above ground, below ground and carbon content of the forest. Height of the tree was measured by using a clinometer Suunto PM-5/360 PC for all the trees above 5 cm in diameter at breast height (dbh) in the sample plot (Lotfalian *et al.*, 2007). Measure the stem diameter of each tree at 1.3 m above the soil surface using a diameter tape 283D/5M (Hairiah *et al*., 2001).

2.3 Important Value Index

In order to evaluate the horizontal structure of the species in the study community, we used the following structural variables: abundance, dominance, frequency, with which we calculated the Importance Value Index (IVI). Diameters at breast height and other data generated from this study were used to calculate the basal area and relative dominance. From the identified species, number of individuals in species and relative frequency. Relative density was calculated based on a species occurrence in study plot. Importance Value Index (IVI) was performed based relative frequency, relative density and relative dominance (Gates, 1949; Curtis and Mc-Intosh, 1950; Misra and Puri, 1954; Curtis, 1951; Phillips, 1959; Misra, 1969; Mostacedo and Fredericksen, 2000; Müeller-Dombois and Ellenberg, 1974)

Relative density (RDe):

$$RDei = \left(\frac{Ai}{\sum Ai}\right) \times 100 = \frac{Density\ \ of\ a\ species}{Total\ density\ of\ all\ species} \times 100$$

or

$$RDei = \frac{Number\ of\ individuals\ of\ a\ species}{Total\ number\ of\ individuals\ of\ all\ species} \times 100$$

Where *RDei* is the relative abundance of species *i*=1…n, with respect to total abundance (*Ai*).

Relative dominance RDo:

$$RDoi = \left(\frac{Di}{\sum Di}\right) \times 100 = \frac{Basal\ area\ of\ a\ species}{Total\ basal\ area\ of\ all\ species} \times 100$$

Where, *RDoi* is the relative dominance of species i, with respect to total dominance (*Di*); Basal area is the stem cross sectional area at breast height of species i =1…n.

Relative frequency (Rf)

$$RFi = \left(\frac{Fi}{\sum Fi}\right) \times 100 = \frac{Frequency\ \ of\ a\ species}{Total\ frequancy\ of\ all\ species} \times 100$$

Where, *RFi* is the relative frequency of species *i* with respect to the total frequency (*Fi*); The Importance Value Index (*IVI*) is defined as:

$$IVI = \sum(RDei + RDoi + RFi$$

Where, *RDei* is the relative abundance; *RDoi* is the relative dominance, and *RFi* is the relative frequency. IV ranges between 0 - 300.

2.4 Biomass and Carbon Stock

Aboveground biomass (AGB) was calculated by using allometric equation (Chave *et al*., 2014).

$AGB=0.0673\times(\rho D^2 H)^{0.976}$

Where, AGB-Aboveground Biomass (kg tree^{-1}); ρ- wood density (gcm^{-3}), D-diameter at Brest height in cm, H-tree height in m. Belowground biomass (BGB) was calculated by using allometric equation developed for tropical forest by Cairns *et al*. (1997) is;

$BGB=exp^{(-1.0587+0.8836\ ln\ (AGB))}$

Where, BGB= belowground root biomass in kg tree^{-1}, ln = natural logarithm, exp = "e to the power of". Sum of aboveground and belowground biomass was total biomass (TBM). The carbon stock was estimated only from woody living tree species from the location except plant litter materials, broken or dieback tress, lianas, saplings and soil organic matters. The amount of the TBM estimation that had been acquired from the equation were converted to carbon stock of the single trees using conversion factor of 0.47 as suggested by IPCC (2006). Biomass and carbon stock were converted into Mg ha^{-1}. Total Carbon Stock (Mg C ha^{-1}) = TBM x 0.47. One way ANOVA test was done by using in SAS/STAT® 13.2 (SAS Institute Inc., Cary, NC, USA). Species diversity and other parameters were performed using Minitab® 17.3.0 (Minitab Inc, USA) and in Microsoft Excel (Microsoft Inc., Redmond, WA, USA). Kruskal Wallis was done to compare variables among the sites and Wilcoxon signed rank test was performed to find out the significance within one variables.

3. Results and Discussions

3.1 Diversity, Composition and Distributions of the Flora

A total number of 321 trees were assessed from 32 tree species and 18 families (Annex 1). In addition, there were six lianas species recorded and only two families of the species for lianas identified (Annex 2). Tree species richness was 32 in the forest reserve. Comparatively, species richness was increased with abundance of trees. Site Puthukudiyirupu (PU) had highest species richness and tree numbers than other sites (Table 1). Mean value of Shannon diversity index and evenness for the trees were 1.94 and 0.91, respectively and this showed that the forest had medium tree diversity and equally distributed among the study sites than other dry forest in Sri Lanka (Table 2). Evenness were not significantly differed among the study sites. The composition of species and plant families in secondary forests do not vary much with the forest type, their location and the abiotic conditions (Perera, 2012). Significantly, lowest tree diversity was recorded in the site *Kulamurippu* (KUB), with comparatively high species richness. Perera, (2012) reported that dry forests at comparatively high precipitation or soil moisture levels are richer in species and harbour more endemic species than the very dry areas of the island. Thus, the tropical seasonal forests are richer in species than the tropical semi-deciduous forests while northern lowland is richer in species than its eastern and southern counterparts.

According to the IUCN red listed data (MOE, 2012), species of five namely *Alseodaphne semicarpifolia* Nees., *Strychnos potatorum* L. f., *Chloroxylon swietenia* DC., *Dimocarpus gardneri* (Thw.) Leenh., *Manilkara hexandra* (Roxb.) Dubard. identified as vulnerable species (VU), four species of near threaten (NT) namely *Xylopia nigricans* Hook.f. & Thoms., *Diospyros affinis* Thw., *Memecylon petiolatum* Trimen ex Alston., *Vitex altissima milla* L. f., three species endangered (EN) namely *Diospyros ebenum* Koenig., Diospyros ebenoides Kosterm., *Xantolis tomentosa* (Roxb.) Raf. and eight species of least conservation (LC) namely *Polyalthia coffeoides* (Thw. ex Hook.f. & Thoms.) Thw., *Polyalthia korinti* (Dunal)

Table 1: Tree species abundance, richness, and diversity indices in different sites (1200 m^2)

Study sites	No. of Individuals	No. of Families	No. of genera	No. of species	SWI	Evenness
NS	56	10	10	12	2.29 ±(0.11)[a]	0.94 ±(0.06)[a]
KUA	54	10	11	15	2.06 ±(0.05)[ab]	0.93 ±(0.01)[a]
TW	54	10	10	13	2.03 ±(0.17)[ab]	0.92 ±(0.01)[a]
PK	58	13	14	21	1.96 ±(0.02)[ab]	0.91±(0.06)[a]
AK	47	11	14	16	1.76 ±(0.05)[bc]	0.88±(0.01)[a]
KUB	52	12	14	18	1.54 ±(0.18)[c]	0.86 ±(0.06)[a]
Total forest	321	18	21	32	1.94±(0.11)	0.91±(0.01)

Note: *Nagancholai* (NS), *Kulamurippu* (A) (KUA), *Kulamurippu* (B) (KUB), *Therawil* (TW), *Puthukudiyirupu* (PK) and *Andankulam* (AK): Values of SWI and Evenness were given with Mean ±SE. Mean with similar letters were not significant at p=0.01.

Thw., *Drypetes sepearia* (Wight & Arn.) Pax & Hoffm., *Careya arborea* Roxb., *Memecylon umbellatum* Burm.f., *Atlantica ceylanica* (Am.) Oliver., *Micromelum minutum* (Forst. f.) Wight & Arn., *Dimocarpus longan* Lour., were recorded in the forest reserve. Among them, four species of *Xylopia nigricans* Hook.f. & Thoms., *Diospyros ebenoides* Kosterm., *Memecylon petiolatum* Trimen ex Alston., *Micromelum minutum* (Forst. f.) Wight & Arn. were recorded as endemic species. Sri Lanka has over 3,000 angiosperms from 214 families and 1,522 genera. Of these about a quarter are endemic (Seneratne, 2001). MALF (1995) reprothed that several valuable timber species such as satinwood (*Chloroxylon swietenia*), ebony (*Diospyros ebenum*), calamander (*Diospyros quaesita*) are also now listed as Endangered due to selective removal of mature trees. From the report of Dassanayake and Fosberg (1980−2004), 43 woody plants endemic to the country grow in the dry land of Sri Lanka. These include 26 tree, 2 liana and 15 shrub species.

3.2 Distribution of Trees Species

Occurrences of species was differed in the reserved forests. Table 2 provides a list of the five most dominant species in each study sites in the forest. Table 3 gives an information of relative density (RDe), relative frequency (Rf) and relative dominance (RDo) and importance value index (IVI) of trees in the whole forest reserve. Among the study sites, there were five dominant tree species had greater than 24 % of important value index (IVI) (Table 3) and these were *D. sepearia* (39.42 %), *Manilhara hexandra* (38.19 %), followed by *C. swietenia* (27.88 %), D. ebenum (25.38 %). and *V. altissimamilla* (24.39 %). However, in overall, all of this species were not found in a single location.

There were eight species such as *C. swietenia, D. affinis, D. ebenoides, D. ebenum, D. sepearia, Manilhara hexandra, Memecylon petiolatum,* and *V. altissima* milla common in all of these six locations (Annex 3). The Ebenaceae is most represented family with three species. The forest is comparatively wetted than other dry forest. Due to this, species of *Dimocarpus* and *Strychnos* were distributed in the study areas.

Table 2: Top five most abundant species in different sites based on important value index

Study Sites	Species
Site1 KU (B)	*Drypetes sepearia* (Wight & Arn.) Pax & Hoffm. (WERAI), *Manilkara hexandra* (Roxb.) Dubard (PALAI), *Xylopia nigricans* Hook.f. & Thoms (SEVINTHAI), *Diospyros ebenum* Koenig (KARUNGALI), *Vitex altissima milla* L. f. (KADDAMANAKU)
Site 2 PK	*Manilkara hexandra* (Roxb.) Dubard., *Vitex altissima milla* L. f.*Chloroxylon swietenia* DC (MUTHIRAI), THANNI THAMPARA, PAJIRI
Site 3 KU (A)	*Chloroxylon swietenia* DC., *Vitex altissima milla* L. f., *Xylopia nigricans* Hook.f. & Thoms., *Dimocarpus gardneri* (Thw.) Leenh. (MORRAI), *Diospyros ebenum* Koenig
Site 4 NS	*Chloroxylon swietenia* DC., *Pterospermum suberifolium* (L.) (VINNANKU), *Drypetes sepearia* (Wight & Arn.) Pax & Hoffm., *Diospyros ebenum* Koenig, *Manilkara hexandra* (Roxb.) Dubard
Site 5 AK	*Drypetes sepearia* (Wight & Arn.) Pax & Hoffm., *Manilkara hexandra* (Roxb.) Dubard., *Diospyros ebenum* Koenig., *Schelechera oleosa* (Lour.) Oken (KOON), *Pterospermum suberifolium* (L.)
Site 6 TW	*Manilkara hexandra* (Roxb.) Dubard., *Drypetes sepearia* (Wight & Arn.) Pax & Hoffm., *Chloroxylon swietenia* DC., *Vitex altissima milla* L. f., *Xylopia nigricans* Hook.f. & Thoms

Note: Note: *Kulamurippu* (B) (KUB), *Puthukudiyirupu* (PK), *Kulamurippu* (A) (KUA), *Nagansolai* (NS) *Andankulam* (AK) and *Therawil* (TW)

Alwis and Eriyagama, (1969) revealed that spatial heterogeneity in the soil moisture contents resulted in the formation of different forest communities which deviated from the typical *Manilkara hexandra-Chloroxylon swietenia-Drypetes sepiaria* community of lowland tropical seasonal forests in Sri Lanka. Even though, the forest is secondary origin (de Rosayro, 1961), high species richness and diversity was recorded in the district than other dry forest in Sri Lanka. Perea (2012) reported that Euphorbiaceae species are the most prominent in dry forest vegetation and their proportional abundance is high in areas where more harsh environments exist.

Table 3: Relative density (RDe), frequency (Rf) and dominance (RDo) with importance value index (IVI)

Species	RDe%	Rf%	RDo%	IVI
Drypetes sepearia (Wight & Arn.) Pax & Hoffm.	14.95	9.49	14.97	39.42
Manilkara hexandra (Roxb.) Dubard	10.90	8.86	18.43	38.19
Chloroxylon swietenia DC	9.03	7.59	11.25	27.88
Diospyros ebenum Koenig	5.30	8.23	11.86	25.38
Vitex altissima milla L. f.	5.92	7.59	10.88	24.39
Xylopia nigricans Hook.f. & Thoms	8.41	6.96	2.83	18.20
Pterospermum suberifolium (L.) Willd.	5.92	5.06	2.28	13.26
Memecylon petiolatum Trimen ex Alston	7.79	3.80	0.85	12.44
Xantolis tomentosa (Roxb.) Raf.	1.56	5.06	2.05	8.67
Alseodaphne semicarpifolia Nees	1.56	3.80	3.25	8.61
Dimocarpus gardneri (Thw.) Leenh.	1.87	3.80	2.55	8.22
Careya arborea Roxb.	2.18	1.90	1.79	5.87
PAJIRI	1.56	1.90	2.23	5.69
Berrya cordifolia (Willd.) Burret	2.80	1.90	0.90	5.60
Diospyros ebenoides Kosterm	3.74	1.27	0.18	5.18
Polyalthia korinti (Dunal) Thw.	0.62	3.80	0.22	4.64
THANNITHAMPARA	1.87	1.90	0.87	4.64
Schelechera oleosa (Lour.) Oken	0.31	0.63	3.35	4.29
Polyalthia coffeoides (Thw. ex Hook.f. & Thoms.) Thw.	0.93	2.53	0.52	3.99
SADAVAKKAI	1.25	1.27	1.12	3.63
Dimocarpus longan Lour.	0.62	1.27	1.19	3.08
Premna tomaentosa Willd.	0.62	1.27	0.57	2.46
Atlantica ceylanica (Am.) Oliver	1.25	0.63	0.51	2.39
Mesua ferrea L.	0.93	0.63	0.78	2.35
Bredelia retusa (L.) A. Juss.	0.62	1.27	0.38	2.27
Premna tomaentosa Willd.	0.62	0.63	0.86	2.12
Syzygium gardneri Thw.	0.62	0.63	0.40	1.66
IYAVAKAI	0.31	0.63	0.36	1.30

Drypetes sepiaria is a universally distributed species which dominates the forest understorey. *Manilhara hexandra* is also a unique species in the dry zone which dominate in dry areas but the species is either rare or absent in cooler and moist conditions. In comparatively wetter areas, a mixture of Annonaceae, Ebenaceae, Melastomataceae and Sapindaceae species tend to grow more frequently with some Euphorbiaceae, Rutaceae or Sapotaceae species. *Dimocarpus gardneri* and *D. longan* and *Strychnos minor* and *S. trichocalyx* grow in Kilinochchi forest which is comparatively wetter than the forests at Bundala.

3.3 Structure the Forest

Table 4 shows the structural characters, biomass and carbon stock in each study sites of the forest reserve. The forest reserve was distributed with a mean density of 446 trees ha^{-1}. The number of trees per unit area differed significantly among study sites (Table 4). PK site had the highest tree density of 484 trees ha^{-1}, followed by NS with 467 trees ha^{-1}. KUA and TW both had same density of 450 trees ha^{-1}. AK had the lowest tree density of 392 trees ha^{-1}. The mean DBH, basal area and carbon stock of the studied plots were 30.6 cm and 0.13 m^2 ha^{-1}, and 671.6 kg $tree^{-1}$, respectively. AK site had the largest stand basal areas, while KUB had the smallest basal areas. Mean carbon stock was high in AK and it was 1160.2 kg $tree^{-1}$ due to highest stand basal area recorded. Total basal area of the forest reserve was 48.88 m^2 ha^{-1}

Table 4: The structural attributes of the forest reserve in different sites in the district

Sites	Tree number	Density No ha^{-1}	Diameter (cm)	Height (m)	Carbon stock (kg $tree^{-1}$)	Basal Area m^2 ha^{-1}
Site1 KUB	52	433.33	29.6±2.4 (10−84)	9.3±0.6 (5−23)	545.7±146 (15−4902)	0.1±0.02 (0−0.8)
Site 2 PK	58	483.33	30.2±1.7 (7−62)	11.5±0.6 (5−21)	563.8±98.4 (8−3478)	0.12±0.01 (0.01−0.42)
Site 3 KUA	54	450	28.18±2.4 (1−111)	13±0.7 (5−24)	596±140 (9−6990)	0.12±0.03 (0.01−1.34)
Site 4 NS	56	466.67	30.7±1.8 (8−61)	13.8± 0.7 (5−24)	603.6±76.5 (12−2888)	0.12±0.01 (0.01−0.41)
Site 5 AK	47	391.67	35.1±3.8 (8−117)	13.2±0.7 (6−22)	1160.2±339 (11-12731)	0.21±0.05 (0.01−1.49)
Site 6 TW	54	450	30.4±1.9 (10−72)	12.8±0.6 (6−23)	638.8±130 (22−5213)	0.12±0.02 (0.01−0.57
Average	53.5	445.83	30.6±1 (7−117)	12.3±0.3 (5−24)	671.6±67.2 (8−12731)	0.13±0.01 (0.01−1.49)

Note: Note: *Kulamurippu* (B) (KUB), *Puthukudiyirupu* (PK), *Kulamurippu* (A) (KUA), *Nagansolai* (NS) *Andankulam* (AK) and *Therawil* (TW): Values of SWI and Evenness were given with Mean ±SE. Mean with similar letters were not significant at p=0.01.

Stem density of low land tropical forests at different sites was ranges from 535 to 522 stems ha^{-1} (Bandara *et al.*, 2017). Total basal area of the two floodplain dry forests was ranges from 34.7 and 29.4 m^2 ha^{-1} in Mexican Tropical Dry Forest Landscapes (Jaramillo *et al.*, 2003)

3.4 Biomass and Carbon Stock

Mean values of the total biomass and carbon stock of the forest were 439 Mg ha^{-1} and 206 Mg C ha^{-1}, respectively. Comparatively, the site AK had a highest aboveground, belowground, and total biomass which were 462 Mg ha^{-1}, 79 Mg ha^{-1}, and 540 Mg ha^{-1}, respectively (Table 5). This was due to highest stand basal area recorded in AK site (Table 4). The AK location had highest aboveground, belowground and total carbon stock which were 217 Mg C ha^{-1}, 37 ±3 Mg C ha^{-1}, and 254 ±20 Mg C ha^{-1}, respectively (Table 5). Mean diameter and basal area of the AK was 30.4 cm and 0.21 m^2ha^{-1}, respectively. The site KUA had a significantly lowest biomass and carbon stock and were 364 Mg ha^{-1} and 171 Mg C ha^{-1}, respectively (Table 5). Mean diameter and basal area of the KUA was 28.18 cm and 0.12 m^2ha^{-1}, respectively (Table 4).

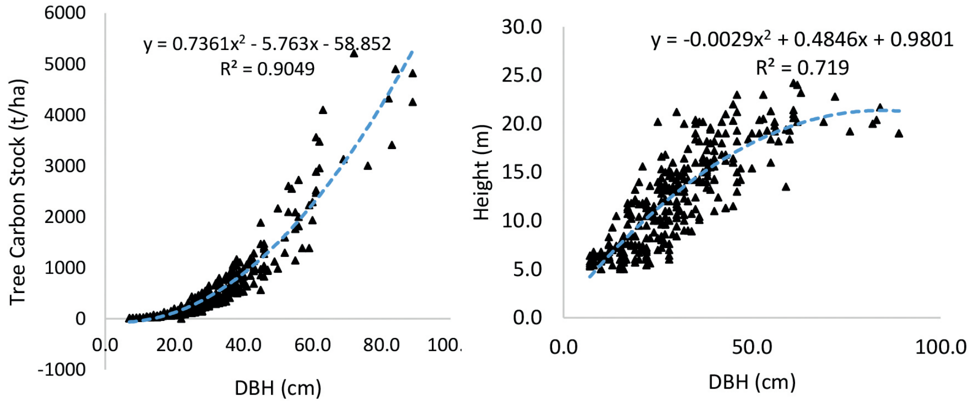
Table 5: Biomass and carbon stock of aboveground, belowground and total in the study sites

Sites	AGB	AGC	BGB	BGC	TB	TC
Site1: KUB	368.45 ±37.09^{ab}	173.17 ±17.43^{ab}	64.29 ±5.75^{ab}	30.22 ±2.70^{ab}	432.74 ±42.85^{ab}	203.39 ±20.14^{ab}
Site2: PK	363.71 ±44.36^{ab}	170.94 ±20.84^{ab}	63.52 ±6.89^{ab}	29.86 ±3.24^{ab}	427.23 ±51.25^{ab}	200.8 ±24.04^{ab}
Site3: KUA	309.04 ±18.04^{b}	145.25 ±8.48^{b}	55.08 ±2.84^{b}	25.89 ±1.33^{b}	364.12 ±20.89^{b}	171.13 ± 9.81^{b}
Site4: NS	367.31 ±28.15^{ab}	172.63 ±13.23^{ab}	64.14 ±4.36^{ab}	30.15 ±2.0^{ab}	431.45 ±32.27^{ab}	202.78 ±15.28^{ab}
Site5: AK	462.04 ±36.72^{a}	217.16 ±17.27^{a}	78.56 ±5.51^{a}	36.92 ±2.59^{a}	540.6 ±42.27^{a}	254.08 ±19.86^{a}
Site6: TW	373.05 ±47.14^{ab}	175.33 ±22.15^{ab}	64.97 ±7.22^{ab}	30.53 ±3.39^{ab}	438.02 ±54.36^{ab}	205.87 ±25.52^{ab}
Total Forest	373.9 ±20.1	175.74 ±9.6	65.1 ±3.1	30.6 ±1.4	439 ±23.2	206.34 ±19.12

Note: *Kulamurippu* (B) (KUB), *Puthukudiyirupu* (PK), *Kulamurippu* (A) (KUA), *Nagansolai* (NS) *Andankulam* (AK) and *Therawil* (TW): Values of SWI and Evenness were given with Mean ±SE. Mean with similar letters were not significant at p=0.01. AGB: Aboveground biomass, AGC: Aboveground Carbon; BGB: Belowground biomass, BGC: Belowground; TB: Total biomass, TC: total carbon (Mega gram C^{-1} ha)

Prentice, (2001) shown that plant C density ranges from 120 to 194 Mg C ha^{-1} in tropical forests. In Sri Lanka, Kuruppuarachchi, (2011) reported that dry zone forest of Sigiriya sanctuary which the corresponding values of carbon stock is 77.0 Mg C ha^{-1}. The wet zone forest Udawattakele contained higher plant biomass C (249 Mg C ha^{-1}). Average carbon stock value from 1992 to 2010 is 153–162 Mg C ha^{-1} in dry monsoon forest which lower than low land rain forest ranges from 203–225 Mg C ha^{-1} (Mattsson, 2012) and Sinharajah rain forest, it was 336.8 Mg ha^{-1} (Kumarathunge, 2009).

Figure 2 shows that the relationship of carbon stock and tree height over diameter of the trees. Result of figure 2 (a) clearly indicated that carbon stock of a tree were increased with increasing rate over diameter of the trees. Figure 2 (b) shows that height of the tree was increased with deceasing rate over diameter of the trees. The forest was distributed with a mean height and diameter of 12.3 m and 30.6 cm, respectively (Table 4).



(a) (b)

Figure 2: A dependent variables of tree carbon and height with independent variables of diameter class of the trees. (a) Tree carbon stock (kg tree^{-1}) vs. diameter (DBH); (b) tree height vs. diameter (DBH).

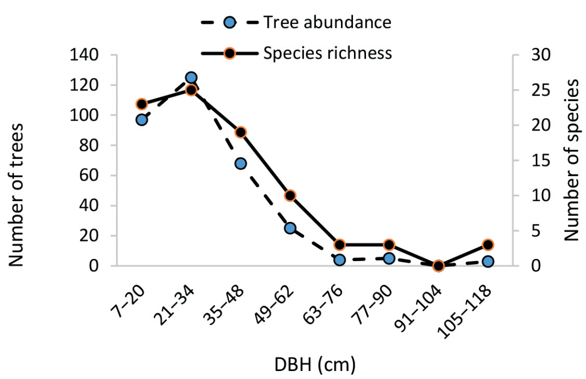
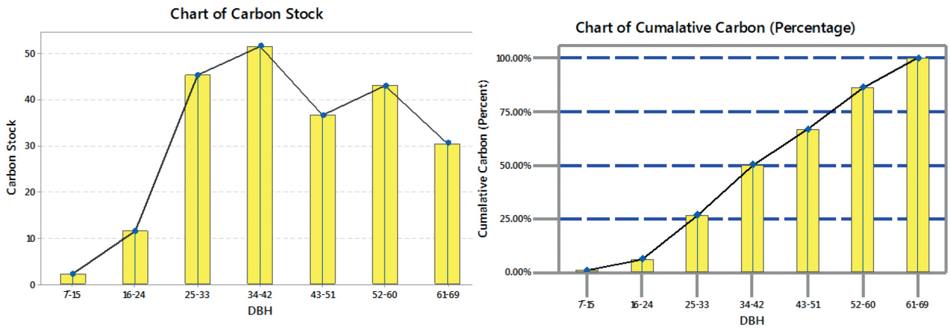


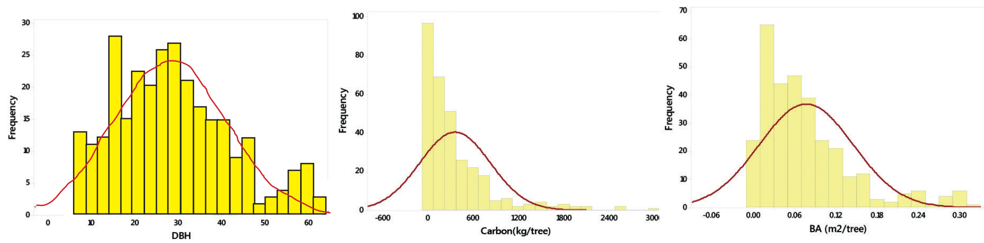
Figure 3: A dependent variables number of trees, species richness with independent variables of diameter class of the trees. Number of trees and species richness vs. diameter class (DBH)

Figure 3 shows that number of trees and species richness were left skewed and normally distributed with diameter of the tree at breast height (DBH). Figure 4 (a) shows that trees which falls between 34−42 cm diameter class had highest tree carbon which accounted more than 50 MgC ha^{-1}. More than 40 Mg C ha^{-1} of tree carbon stored by the diameter classes of 25−33,54−42 and 25−22 cm. Figure 3 and Figure 4 (b) illustrated that trees in the diameter classes >42 cm together had the lowest species richness (10 %) and abundance (8 %), yet contributed more than 50% of the total carbon stored in trees. Trees in the diameter classes >51 cm contributed to more than 75 % of the total carbon stored in trees.



(a) (b)

Figure 4: A dependent variables of tree carbon with independent variables of diameter class of the trees. (a) Tree carbon stock (MgC ha^{-1}) vs. diameter (DBH); (b) cumulative tree carbon stock (MgC ha^{-1}) vs. diameter (DBH)



(a) (b) (c)

Figure 5: A dependent variables of tree abundance (number of trees) with independent variables of diameter, carbon stock and basal area (a) Tree abundance vs. diameter (DBH, cm); (b) Tree abundance vs. carbon stock (kg tree^{-1}) and (c) Tree abundance vs. basal area (BA, m^{2}tree^{-1}).

Figure 5 shows the information about the class of diameter, carbon and basal area with number of trees. Figure 5 (b) and (c) illustrated that diameter class was normally distributed with tree abundance whereas carbon stock and basal area were right skewed . Figure 6 illustrated that that mean carbon stock and basal area were shows the similar trend among the species. The highest mean carbon stock was recorded for *Manilhara hexandra* (876 kg tree^{-1}) and it was, followed by *Chloroxylon swietenia* (800 kg tree^{-1}). More than 10 tree species had greater than 300 kg carbon tree^{-1}. There were 5 species had the tree carbon between 300−200 kg tree^{-1}.

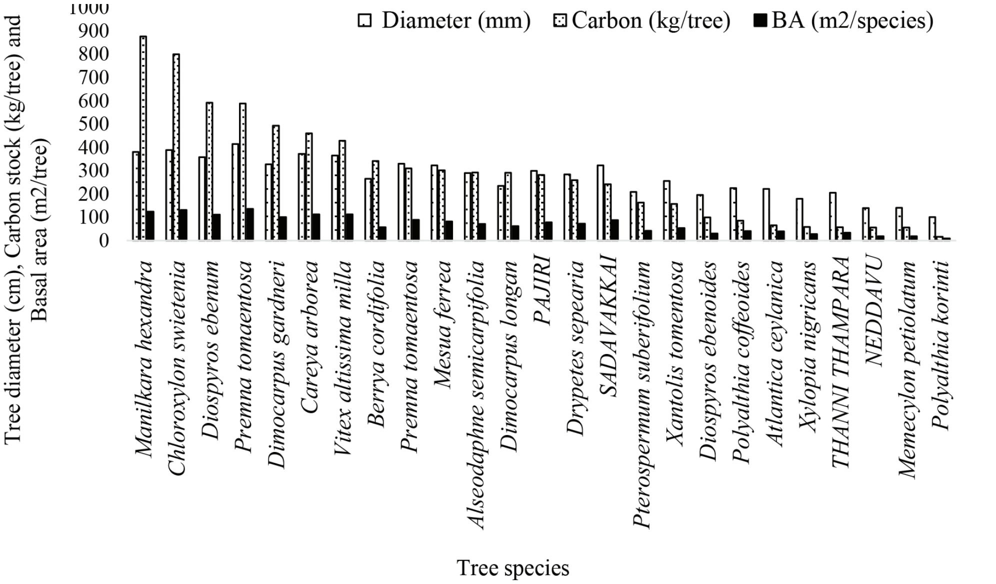


Figure 6: Mean diameter (cm), carbon stock (kg tree^{-1}), and basal area (m^{2}ha^{-1}) for tree species in the study sites.

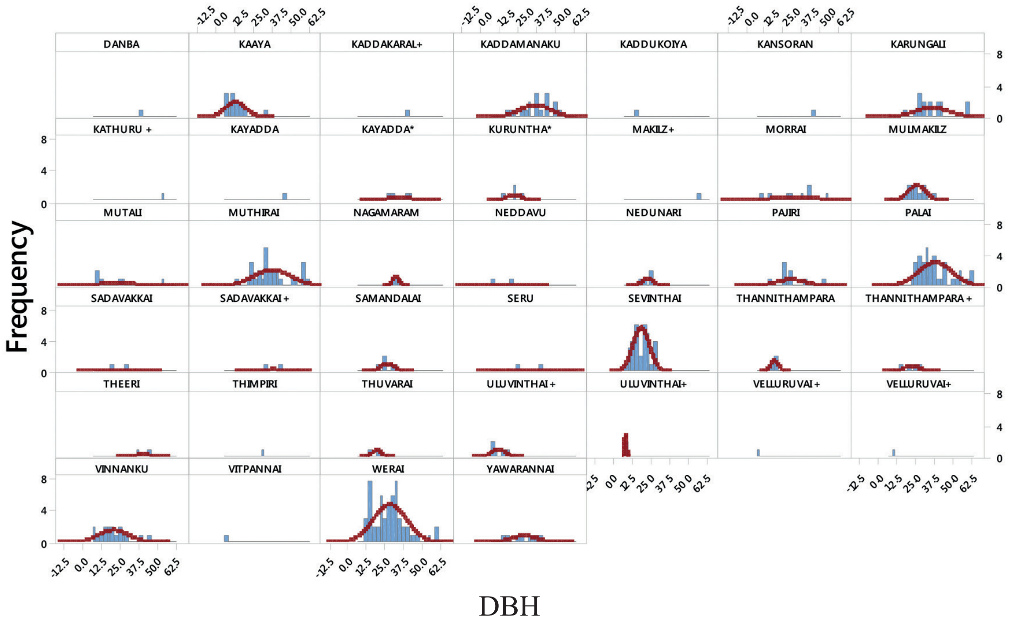


Figure 7: Number of individuals over diameter class distributions for tree species viewed individually. Botanical name of each species was given in annex 1.

Diameter of *Xylopia nigricans* (Sevintha) was well and normally distributed with other species of *Drypetes sepearia* (Weera), Thanni thampara, *Manilkara hexandra* (palai), *Pterospermum suberifolium* (vinnanku), *Diospyros ebenum* (karungali) in the study sites. Right skewed was observed in *Memecylon petiolatum* (Kaaya) less than 12.5 cm diameter while left skewed observed for *Chloroxylon swietenia* (muthirai) and *Vitex altissima milla* (kadamamnku) greater than 25 cm diameter. Highest frequency was recorded for Weerai followed by Sevinthai which falls between 12.5 5to 37.5 cm diameter class (Figure 7).

4. Conclusions

This study focuses the diversity, distribution and carbon stock of a dry forest in Northern Province of Sri Lanka. The forest had rich tree diversity and carbon stock compared to other n dry forest in the country. While species richness and abundance decreases with increasing diameter class, carbon storage increases with increasing diameter class. The selective preservation of certain species including relisted endanger species in the study sites are significantly important.

A total of 31 trees and six lianas species belongs to 20 families were recorded. The species were distributed equally with medium diversity. The forest was dominated by *Drypetes sepearia* (Wight & Arn.) Pax & Hoffm. Mean biomass and carbon stock of the forest reserve were 439 ± 41 and 206 ±19 Mg ha^{-1}, respectively. These findings provide baseline information about the forest structure, species composition and carbon stock for forest management plan.

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Annexure

Annex 1: Identified Tree Species in Mullaitivu Reserved Forest

Family	Scientific Name	Common Name	NCS
Annonaceae	*Polyalthia coffeoides* (Thw. ex Hook.f. & Thoms.) Thw.	NA (E), Nedunari (T), Omara (S)	LC
Annonaceae	*Polyalthia korinti* (Dunal) Thw.	NA (E), Uluvintai (T), Mi-Wenna (S)	LC
Annonaceae	*Xylopia nigricans* Hook.f. & Thoms	NA (E), See-Vindai (T), Heen-Kenda (S)	NT*
Clusiaceae	*Mesua ferrea* L.	Iron wood (E), Nagamaram (T), Naa (S)	
Ebenaceae	*Diospyros ebenum* Koenig	Ebony (E), Karunkali (T), Kaluwera (S)	EN
Ebenaceae	*Diospyros affinis* Thw.	NA (E), Karumpanicha (T), Eta-thimpiri (S)	NT
Ebenaceae	*Diospyros ebenoides* Kosterm	NA (E), Juwarai/ Thuwarai (T), NA (S)	EN*
Euphorbiaceae	*Drypetes sepearia* (Wight & Arn.) Pax & Hoffm.	Wera (E), Werai (T), Weera (S)	LC
Euphorbiaceae	*Bredelia retusa* (L.) A. Juss.	NA (E), Kaddakaral (T), Ketakaela (S)	
Fabaceae	UK	NA (E), Iyalvakai (T), NA (S)	
Lauraceae	*Alseodaphne semicarpifolia* Nees	NA (E), Yawarana (T), Wewarana (S)	VU
Lecythidaceae	*Careya arborea* Roxb.	NA (E), Kayadda (T), Kakadda (S)	LC
Loganiaceae	*Strychnos potatorum* L. f.	NA (E), Theen thukki (T), NA (S)	VU
Melastomataceae	*Memecylon petiolatum* Trimen ex Alston	NA (E), Kaaya (T), NA (S)	NT*
Melastomataceae	*Memecylon umbellatum* Burm.f.	NA (E), Pandi kaaya (T), Koora kaha (S)	LC
Myrataceae	*Syzygium gardneri* Thw.	NA (E), Nengal (T), Danba (S)	
Rubiaceae	UK	NA (E), Pajari (T), NA (S)	
Rutaceae	*Chloroxylon swietenia* DC	Satin wood (E), Muthirai (T), Brutha (S)	VU

Rutaceae	*Atlantica ceylanica* (Am.) Oliver	NA (E), Kurunthu (T), Yakinara (S)	LC
Rutaceae	*Micromelum minutum* (Forst. f.) Wight & Arn.	NA (E), Kakaipalai (T), Wal karapincha (S)	LC*
Sapindaceae	*Dimocarpus gardneri* (Thw.) Leenh.	NA (E), Morrai (T), Norrai (S)	VU
Sapindaceae	*Dimocarpus longan* Lour.	NA (E), Mutali (T), Rasa mora (S)	LC
Sapindaceae	*Schelechera oleosa* (Lour.) Oken	NA (E), Koolan (T), Koon (S)	
Sapotacea	*Manilkara hexandra* (Roxb.) Dubard	CeylonIron wood (E), Paalai (T), Palu (S)	VU
Sapotaceae	*Xantolis tomentosa* (Roxb.) Raf.	NA (E), Mulmakilz (T), NA (S)	EN
Sterculiaceae	*Pterospermum suberifolium* (L.) Willd.	NA (E), Vinnanku (T), Velank (S)	
Tiliaceae	*Berrya cordifolia* (Willd.) Burret	Trincomalle wood (E), Savandala (T), Hal-milla (S)	
Verbenaceae	*Vitex altissima milla* L. f.	NA (E), Kaddamannaku (T), Milla (S)	NT
Verbenaceae	*Premna tomaentosa* Willd.	NA (E), Theeri (T), Seru (S)	
NA	UK	NA (E), Sadavakkai (T), NA (S)	
NA	UK	NA (E), Thanni thampara (T), NA (S)	

UK-Unknown, NA-Not available, NCS-National Conservation Status: LC-Least Concern, NT-Near Threatened, VU-Vulnerable, EN-Endangered

Annex 3: Occurrence of Species and Species Richness in each Sampling Sites

Scientific Name	**KUB**	**PK**	**KUA**	**NS**	**AK**	**TW**	**Occurrence of sp.**
Alseodaphne semicarpifolia Nees	√	√	×	×	×	√	3/6
Atlantica ceylanica (Am.) Oliver	√	×	×	×	×	×	1/6
Berrya cordifolia (Willd.) Burret	×	×	×	√	√	×	2/6
Bredelia retusa (L.) A. Juss.	√	√	×	×	×	×	2/6
Careya arborea Roxb.	×	√	√	×	×	×	2/6
Chloroxylon swietenia DC	√	√	√	√	√	√	6/6
Dimocarpus gardneri (Thw.) Leenh.	√	×	√	×	×	×	2/6
Dimocarpus longan Lour.	√	×	√	×	×	×	2/6
Diospyros affinis Thw.	√	√	√	√	√	√	6/6
Diospyros ebenoides Kosterm	√	√	√	√	√	√	6/6
Diospyros ebenum Koenig	√	√	√	√	√	√	6/6
Drypetes sepearia (Wight & Arn.) Pax & Hoffm.	√	√	√	√	√	√	6/6
Manilkara hexandra (Roxb.) Dubard	√	√	√	√	√	√	6/6
Memecylon petiolatum Trimen ex Alston	√	√	√	√	√	√	6/6
Memecylon umbellatum Burm.f.	×	√	×	×	×	√	2/6
Mesua ferrea L.	×	×	×	√	×	×	1/6
Micromelum minutum (Forst. f.) Wight & Arn.	√	×	×	×	×	×	1/6
Polyalthia coffeoides (Thw. ex Hook.f. & Thoms.) Thw.	×	×	√	×	√	×	2/6
Polyalthia korinti (Dunal) Thw.	×	√	×	×	×	√	2/6
Premna tomaentosa Willd.	×	√	×	×	√	×	3/6

Pterospermum suberifolium (L.) Willd.	√	√	×	√	√	√	5/6
Schelechera oleosa (Lour.) Oken	×	×	×	×	√	×	1/6
Strychnos potatorum L. f.	√	×	×	×	×	×	1/6
Syzygium gardneri Thw.	×	×	×	×	√	×	1/6
Vitex altissima milla L. f.	√	√	√	√	√	√	6/6
Xantolis tomentosa (Roxb.) Raf.	√	√	√	√	√	×	5/6
Xylopia nigricans Hook.f. & Thoms	√	√	×	×	√	√	4/6
UK	×	√	×	×	×	×	1/6
UK	×	√	√	×	×	×	2/6
UK	×	√	×	×	×	×	1/6
UK	×	√	×	×	×	×	1/6
Species richness	18/32	21/32	15/32	12/32	16/32	13/32	

Kulamurippu (B) (KUB), *Puthukudiyirupu* (PK), *Kulamurippu* (A) (KUA), *Nagansolai* (NS) and *Andankulam* (AK), *Therawil* (TW)