Arboreal Taxa Diversity of Tropical Forests of Gandhamardan Hill Range, Eastern Ghats, India: An Approach to Sustainable Biodiversity Conservation

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ABSTRACT: The rich biodiversity repository of Gandhamardan hill ranges, Eastern Ghats, India is under severe threat from various magnitudes such as deforestation, unsustainable collection of medicinal plants, invasion of alien species, forest fire, urbanization and habitat destruction. The Protected Forests (PFs) have lost a number of wild species from their natural habitat pose to loss of biodiversity. The hill range having two preservation plots of 100ha each identified in Nrusinghanath (SITE-I) and Harishankar (SITE-II) range as study area. The present study inventoried a total of 10775 trees belonging to 91 tree species within a 17.6 hectare sampled area (441 plots). The predominant tree species are *Diospyros melanoxylon, Madhuca indica, Cleistanthus collinus, Anogeissus latifolia,* and *Lagerstroemia parviflora.* The Shannon- Weiner index (H') is 3.92 (SITE-I) and 3.31 (SITE- II) with Simpson's value 1.0. This value indicates that the tropical moist deciduous forests are also species diverse systems. Mean stand density was 671 ha^{-1} in SITE-I and 565 ha^{-1} in SITE-II. Stem density and species richness have consistently decreased with increasing girth class of tree species from 50 cm girth. The present study on phyto-diversity of tree species and participatory approaches on sustainable use of natural resources will provide the baseline information for effective and sustainable biodiversity conservation of tropical moist deciduous forest.

KEY WORDS: Arboreal taxa diversity, Eastern Ghats, Population structure, Sustainable conservation, Tropical forests.

INTRODUCTION

Tropical forests are the most biodiversity rich centre on Earth. Primary forests of Asia, particularly those of the Western Ghats and Eastern Ghats of peninsular India are disappearing at an alarming rate due to anthropogenic activities and are replaced by forests comprising inferior species on their land use pattern changed (Bahuguna, 1999). Quantitative analysis on tree species diversity will provide the floristic status and distribution pattern which may help in biodiversity conservation.

Quantitative studies on tree species diversity are very rare in Eastern Ghats of India. However, few works were done quantitative phytodiversity (Kadavul and Parthasarathy, 2000; Jayakumar et al., 2002; Natarajan et al., 2004), Orissa (Sahu et al., 2007) and Andhra Pradesh (Reddy et al., 2008).

The Eastern Ghats are located along the Peninsular India extending over 1750 km with average width of about 100 km and covering the area under 11º 03' to 22º 32' N latitudes and 77º 02' to 87º 02' E longitudes. Major part of the state Orissa comes under Eastern Ghats. Gandhamardan hill ranges belonging to Eastern Ghats of India lies between 20º 42' to 21º 00' N latitude and 82º 41' to 83º 05' E longitude in the North-West of Bolangir and South-West of Baragarh district, Orissa. The hill ranges contain an undulating mountain system ranging from 320 m to 1220 m height from mean sea level (MSL) which extends over several miles in north-east and south-west direction and receives annual rainfall ranging from 750 mm to 1600 mm. There are two preservation plots of 100 ha each identified at Nrusinghanath and Harishankar for quantitative analysis.

Gandhamardan hill range is one the floristically important tropical moist deciduous system of Eastern Ghats, India. Due to diversified topography and climate the hill range endowed with rich floristic diversity. Earlier a number of floristic works were carried out by many researchers (Raju, 1960; Panigrahi et al., 1964; Brahmam and Saxena, 1996; Mishra et al., 1994, 2001; Misra and Behera, 1998; Mishra and Das, 2003; Misra, 2004; Reddy and Pattanaik, 2009). But, phytosociological studies on tree species were not done in the past. The present study gives a quantitative structure on tree species at two different sites (SITE-I, Nrusinghanath and SITE-II, Harishankar) of Gandhamardan hill range with special emphasis on sustainable biodiversity conservation.

MATERIALS AND METHODS

A. Field sampling

Phytosociological studies were carried out during 2008-09 by laying random quadrats (20 m×20 m for trees and 5 m×5 m for shrubs, climbers, twinners and herbs). All the plots were recorded for trees greater than or equal to 15cm GBH (Marimon et al., 2002 and Mishra et al., 2005) because individuals which are less than 15cm GBH are considered as saplings. Herbarium specimens were prepared and identified with the help of Flora of Presidency of Madras (Gamble and Fischer, 1915-1935) and Flora of Orissa (Saxena and Brahmam, 1996) and deposited at Institute of Minerals and Materials Technology (CSIR), Bhubaneswar. The spatial location (latitude, longitude and altitude) of each quadrat was collected using a Global Positioning System (GPS). Emphasis has been given to cover different elevation, slope, aspects, rainfall and temperature gradients to study overall spectrum of tree species diversity. (Fig. 1)

B. Data analysis

The vegetation data were quantitatively analyzed for tree species (78 species at Nrusinghanath and 77 species at Harishankar), Frequency (F%), Relative frequency (RF), Density (D), Relative density (RD), Dominance (DO), Relative dominance (RDO), Importance Value Index (IVI), Shannon-Weiner index (Shannon and Weiner, 1949) and Simpson's index (Simpson, 1949). IVI of each species were calculated by summation of the RF, RD and RDO (Curtis, 1959; Mishra, 1968). Population structure of tree species were analyzed across fixed girth classes.

Basal area (m^2) = Area occupied at breast height (1.3 m) = [pi* $(dbh/2)^2$].
Relative density = (Density of the species/Total density of all species) x 100.
Relative frequency = (Frequency of the species /Total frequency of all species) x 100.
Relative dominance = (Basal area of the species/Total basal area for all species) x 100.
Importance Value Index (IVI) = Sum of relative density + relative frequency + relative dominance.

Species diversity of each forest type was determined (Shannon and Weiner, 1963).

$$H' = -\Sigma [(ni/N) \log 2 (ni/N)]$$

Where, ni = IVI of individuals species in that vegetation type, N = IVI of all species

Concentration of dominance was also measured (Simpson, 1949).

$$C = -S (ni/N)$$

Where ni and N are the same as those for the Shannon–Weiner information function.

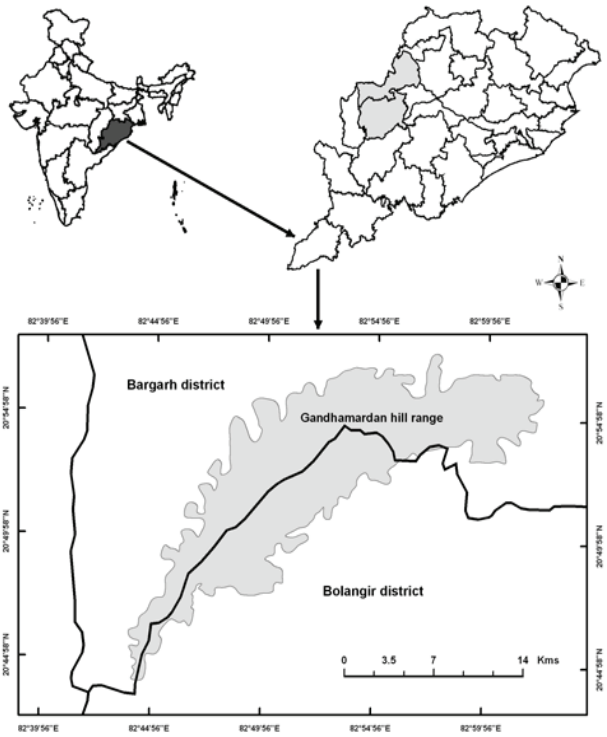

Fig. 1. Map of the Gandhamardan hill range.

RESULTS

Forest composition

A total of 91 tree species were recorded from the study area, out of which 78 species belonging to 63 genera and 33 families from Nrusinghnath (SITE-I) and 77 species under 61 genera and 33 families from Harishankar (SITE-II). Importance value index (IVI) of tree species indicated that *Madhuca indica* Gmel. (82.946) is the dominant species at all the study sites among the tree species followed by *Diospyros melanoxylon* (46.046), *Cleistanthus collinus* (28.89), *Anogeissus latifolia* (22.057) and *Buchnania lanzan* (15.027). The top ten dominant species based on IVI value in two sites are mentioned in Tables 1 & 2. The Shannon- Weiner index (H') is 3.92 (SITE-I) and 3.31 (SITE- II) with Simpson's value 1.0. This value indicates the tropical moist deciduous forests are also species diverse systems. (Fig. 2)

There were 64 invasive exotic species also found, which will be serious threat to the forest ecosystem in the future (Reddy and Pattanaik, 2009). Important among them are *Ageratum conyzoides* L., *Chromolaena odorata* (L.) R. King & H. Robins., *Crotalaria pallida* Ait., *Hyptis suaveolens* (L.) Poit., *Lantana camara* L., *Mimosa pudica* L., *Parthenium hysterophorus* L. and *Triumfetta rhomboidea* Jacq.

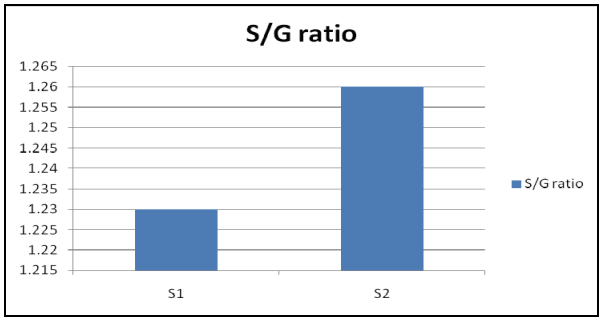

Fig. 2. Species/Genus ratio of tree layers at two sites of Gandhamardan hill.

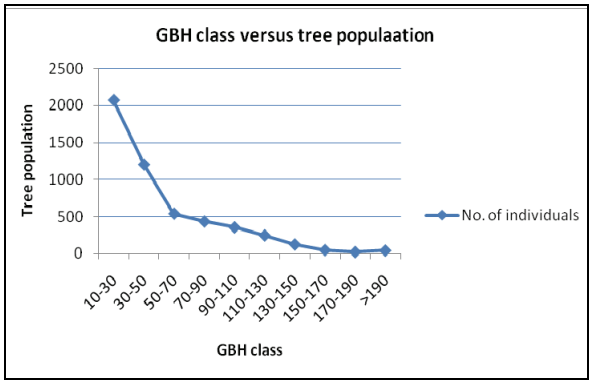

Fig. 3. Relation between girth class and tree population in SITE-I.

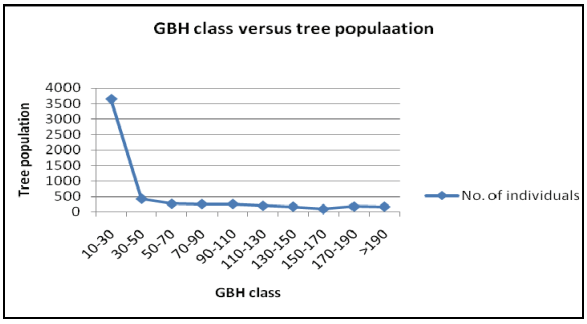

Fig. 4. Relation between girth class and tree population in SITE-II.

Forest Structure

SITE-I (Nrusinghnath)

Stem density and species richness have consistently decreased with increasing girth class of tree species from 50 cm girth. The distribution of the basal area across different gbh interval shows that the gbh class having 10-30 cm and 30-50 cm contributed to about 47.43% and 48.71% of species richness respectively. It means minority of species dominate the majority of available resources (Table 3). The highest GBH was measured in the case of *Ficus benghalensis* (350 m), *Terminalia chebula* (290 cm), *Schrebera swietenioides* (285 cm), *Haldinia cordifolia* (280 cm), *Diospyros melanoxylon* (263 cm). (Fig. 3)

The mean tree height is 11 m with a height range from 1 to 46 m. Tree distribution by height class intervals shows that around 42.40% of individuals are in the height class of 5-10 m, followed by 31.14% in the height of 15-20 m. Whereas 4.94% of individuals are in the height class of >20 m. The height class <5 m are around 8.88% represents regeneration and adaptability is very low due to biotic interference. The tallest individual trees were *Anogeissus latifolia* (46 m), *Madhuca indica* (42 m), *Diospyros melanoxylon* (38 m), *Terminalia alata* (34 cm), *Lagerstroemia parviflora* (34 m).

SITE-II (Harishankar)

Stem density and species richness have also similarly decreased with increasing girth class of tree species from 50 cm girth as in SITE-I. The distribution of the basal area across different gbh interval shows that the gbh class having 10-30 cm and 30-50 cm contributed to about 79.22% and 68.83% of species richness respectively. It means minority of species dominate the majority of available resources (Table 4). The highest GBH was measured in the case of *Haldinia cordifolia* (416 cm), *Ficus benghalensis* (375 cm), *Dalbergia paniculata* (352), *Shorea robusta* (343 cm), Madhuca indica (333 cm), *Terminalia alata* (331 cm), *Careya arborea* (327 cm). (Fig. 4)

The mean tree height is 10 m with a height range from 1 to 46 m. Tree distribution by height class intervals shows that around 53.91% of individuals are in the height class of 5-10 m, followed by 20.29% in the height of 10-15 m. Whereas 8.29% of individuals are in the height class of >20 m. The height class <5 m are around 7.27% represents regeneration and adaptability is very low due to biotic interference. The tallest individual trees were *Terminalia bellirica* (45 m), *Anogeissus latifolia* (42 m), *Pterocarpus marsupium* (42 m), *Haldinia cordifolia* (41 m), *Mitragyna parviflora* (40 m).

DISCUSSION

The predominant forest types in Gandhamardan hill range of Eastern Ghats is tropical moist deciduous (Champion and Seth, 1968). A total of 10775 trees belonging to 91 tree species from 441 sample plots (17.64 ha) were enumerated. Mean stand density was 671 ha^{-1} in Site-I and 565 ha^{-1} in SITE-II. The mean stand density in two sites are well within the range of 276-905 stems ha^{-1} reported for trees = 10 cm gbh in tropics (Murali et al., 1996; Sundarapandian and Swamy, 1997;

Table 1. Ecological dominance of top ten tree species based on IVI values in SITE-I (Nrusingnath).

Sl. No.	Species	Relative Frequency (RF)	Relative Density (RD)	Relative Dominance (RDO)	IVI value
1	*Diospyros melanoxylon* Roxb.	7.228	0.804	28.014	36.046
2	*Cleistanthus collinus* (Roxb.) Benth.ex.Hook.f.	8.174	1.153	19.563	28.89
3	*Anogeissus latifolia* (Roxb. Ex DC.) Wall.ex Guill. & Perr.	6.970	0.704	14.383	22.057
4	*Madhuca indica* Gmel.	15.916	0.076	5.640	21.632
5	*Buchnania lanzan* Spreng.	4.345	8.287	2.395	15.027
6	*Terminalia alata* Heyne ex Roth.	4.775	0.265	8.627	13.667
7	*Cochlospermum religiosum* (L.) Alston	0.128	3.588	7.156	10.872
8	*Pterocarpus marsupium* Roxb.	1.677	6.672	2.394	10.743
9	*Lagerstroemia parviflora* Roxb.	5.507	0.278	4.933	10.718
10	*Litsea glutinosa* (Lour.) Robins.	0.042	1.258	7.50	8.8

Table 2. Ecological dominance of top ten tree species based on IVI values in SITE- II (Harishankar).

Sl. No.	Species	Relative Frequency (RF)	Relative Density (RD)	Relative Dominance (RDO)	IVI value
1	*Madhuca indica* Gmel.	16.918	0.243	65.785	82.946
2	*Cleistanthus collinus* (Roxb.) Benth.ex.Hook.f.	8.733	3.599	3.782	16.114
3	*Diospyros melanoxylon* Roxb.	7.360	2.510	5.240	15.11
4	*Anogeissus latifolia* (Roxb. Ex DC.) Wall.ex Guill. & Perr.	7.727	4.398	0.950	12.14
5	*Ficus hispida* L.f.	0.042	1.258	7.500	8.8
6	*Mangifera indica* L.	0.091	7.869	0.004	7.964
7	*Ziziphus jujuba* Mill.	0.091	7.869	0.001	7.961
8	*Ziziphus xylopyrus* (Retz.) Willd.	5.852	1.116	0.689	7.657
9	*Lagerstroemia parviflora* Roxb.	5.807	0.869	0.001	6.677
10	*Bauhinia malabarica* Roxb.	0.042	1.258	4.636	5.936

Table 3. Population density of tree species across Girth Class intervals in SITE-I.

Gbh class (cm)	No. of species	% of species	No. of individuals	% of individuals
10-30	37	47.43	2073	40.65
30-50	38	48.71	1205	23.63
50-70	14	17.94	542	10.62
70-90	11	14.10	435	8.53
90-110	8	10.25	356	6.98
110-130	1	1.28	248	4.86
130-150	4	5.12	125	2.45
150-170	1	1.28	49	0.96
170-190	2	2.56	23	0.45
>190	2	2.56	43	0.84
Grand Total	78	100	5099	100

Table 4. Population density of tree species across Girth Class intervals in SITE-II.

Gbh class (cm)	No. of species	% of species	No. of individuals	% of individuals
10-30	61	79.22	3640	64.12
30-50	53	68.83	428	7.53
50-70	46	59.74	270	4.75
70-90	43	55.84	262	4.61
90-110	38	49.35	263	4.63
110-130	35	45.45	201	3.54
130-150	28	36.36	172	3.03
150-170	19	24.67	95	1.67
170-190	18	23.37	174	3.06
>190	26	35.06	171	3.01
Grand Total	77	100	5676	100

Ghate et al., 1998). The differences in basal area of tree layer among study sites may be due to difference in altitude, species composition, age of trees, degree of disturbances and successional stages of the stands. The value obtained for basal area in the present study is comparable to the Indian tropical forests (Visalakshi, 1995).

Within the forest types, the most abundant families were Rubiaceae and Fabaceae, representing 10 and 6 tree species (SITE-I) and 11 and 6 tree species (SITE-II) respectively. Similar such predominance was recorded from Shervarayan hills (Kadavul and Parthasarathy, 1999a). Martin and Aber (1997) reported Leguminosae as the most abundant family in neo-tropical forests. A

variation in representation of tree species and the proportion of dominant species in the forest types can directly be related to rainfall distribution and topographic conditions of the region.

The diversity index is generally higher for tropical forests and the reported range is 5.1 and 5.4 for young and old stands, respectively (Knight, 1975). Many researchers have reported the diversity value for Indian forests in the range of 0.8 to 4.1 (Parthasarthy et al., 1992; Visalakshi, 1995). The present study resulted the Shannon- Weiner index (H') value 3.92 (SITE-I) and 3.31 (SITE-II) with Simpson's value 1.0. Thus, the diversity values of tree species obtained in the present study is well within the reported range of Indian tropical forests. This value indicates the tropical moist deciduous forests are also species diverse systems. But due to more anthropogenic activities species diversity is low as compared to other tropical forests (Knight, 1975).

The data on species/genus ratio helps to compare the rate of species development because high ratio indicates recent diversification (Fig. 2). Tropical areas have low species/genus ratio, indicating that the tropical species have emerged over a long period of time (Ricklefs and Miller, 2000). In the present study, all the study sites show lower S/G ratio in the tree layer (1.23 at Nrusinghanath and 1.26 at Harishankar) thus conformity with the findings of (Ricklefs and Miller, 2000). The overall expanding population structure indicates that study area represents regeneration and adaptability is very low due to biotic interference.

Girth class frequency showed J-shaped population structure of trees exhibited in the study sites are in conformity with many other forest stands in Eastern and Western Ghats such as Shervarayan hills (Kadavul and Parathasarthy, 1999a); Kalrayan hills (Kadavul and Parthasarathy, 1999b); Kakachi (Ganesh et al., 1996); Uppangala (Pascal and Pelissier, 1996); Mylodai-Courtallum resreve forest (Parthasarathy and Karthikeyan, 1997a).

An Approach to Sustainable Biodiversity Conservation: Anthropogenic activity and natural succession processes negatively affect the arboreal taxa diversity in Gandhamardan hill ranges. A practice for removal of forest biomass in the form of grazing, lopping, surface burning and litter removal at a given time is a continuous disturbance affecting the stability of the ecosystem in the area. Quantitative analysis with reference to IVI, density, diversity and frequency distribution could well act as indicators of anthropogenic disturbances that are affecting the various forest types. The present studies would help the conservation managers, researchers, scientists in understanding the structure and composition of the tropical forests and participatory approach for sustaining biodiversity conservation.

Local rural communities have an integral and intimate link with the natural resources and ecosystems surrounding them and that their knowledge base, cultural traditions and practices relating to biological and other natural resources remain undisputedly a critical component in the conservation of biodiversity, (Kothari, 1997; Kothari and Anuradha, 1999; Borrini-Feyerabend, 2004; Borrini-Feyerabend et al., 2004a; Brosius et al., 2005). The involvement of local and indigenous communities in biodiversity conservation especially in PAs (Protected Areas) is all about collaborative management which practitioners and researchers in the weld such as Borrini-Feyerabend (2004); Borrini-Feyerabend et al. (2004a); Brosius et al. (2005) and Borrini-Feyerabend et al. (2004b, 2007) aptly described as sharing power and knowledge. The traditional planning for PAs in India emphasizes management of natural resource or wild habitats/species as basic approach towards conservation (Sawarkar, 1995). The medicinal flora of the Gandhamardan hill range are depleting rapidly because of unsustainable harvesting, lack of awareness, and unrestricted grazing by domestic animals from nearby villages (Panigrahi, 1963; Pattanaik and Reddy, 2007). Unsustainable collection of medicinal plants has placed them in threatened and vulnerable categories in Conservation Assessment and Management Prioritasion (CAMP) of Orissa. Therefore, sustainable utilization of medicinal plants, restriction on fire wood collection and movement of pilgrims all around the adjoining forest areas near to the temple are some of the urgent actions should be implemented to conserve the natural resources of the Gandhamardan hill range.

According to the Convention for Biological Diversity, the second worst threat to the existence of biodiversity is the biological invasion of exotic species (WCMC, 1992). So, urgent steps should be taken to control the predominance of *Ageratum conyzoides* L., *Chromolaena odorata* (L.) R. King & H. Robins., *Crotalaria pallida* Ait.*, Hyptis suaveolens* (L.) Poit. *and Lantana camara* L.

In- Situ and Ex- Situ conservation are the two major solutions for the threatened group of species such as *Cordia macleodii* (Griff.) Hook. f. & Thoms., *Litsea glutinosa* (Lour.) Robins., *Pterocarpus marsupium* Roxb., *Schrebera swietenioides* Roxb. etc. The government, local non-government organizations (NGOs) should promote participatory research in breeding and participatory knowledge management involving scientists, government officials and tribal families. It is urgent to improve the socio-economic conditions of people living around the hills to minimize the anthropogenic activities for sustainable biodiversity conservation of this sacred hill range. This approach is highly essential for the developing countries where

dependence on natural resources by the rural population remains as their livelihood.

CONCLUSIONS

Protecting biodiversity is not only involve setting aside chunks of areas as reserve but also all the ecological processes such as predation, pollination, parasitism, seed dispersal and herbivores involving complex interactions between several species of plants and animals. A comprehensive approach to forest conservation must therefore incorporate the sustainable management of its natural resources. Innovative steps should be taken for the overcoming threats like climate change, population explosion, introduced species etc. The present investigation highlights the dominant species which should be given immediate attention for conservation and propagation through in-*situ, ex-situ* or latest biotechnological approaches like (tissue culture, conservation of seeds and conservation of DNA etc)

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印度東高只山干吐馬塔那丘稜地區熱帶森林之森林植物多樣性：生物多樣性及保育永續經營之探討

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摘要：印度東高只山干吐馬塔那丘稜地區豐富的生物多樣性近來遭受到不同層面的威脅，包括森林砍伐、藥用植物濫採、外來物種入侵、森林野火、都市化及棲地破壞等。在此森林保護區 (Protected Forest) 中，有相當數量的野生種的消失造繩該地區生物多樣性的下降。本研究的研究樣區設立在此丘稜地區的兩個 100 公頃保留區中，Nrusinghanath (研究樣區-I) 以及 Harishankar (研究樣區-II)。在 17.5 公頃的調查範圍中，設置 441 的樣區，共記錄到 91 個木本植物種類，10,775 植株。最優市的物種為 *Diospyros melanoxylon, Madhuca indica, Cleistanthus collinus, Anogeissus latifolia,* 以及 *Lagerstroemia parviflora*。生物多樣性指數 (Shannon-Weiner index (H')) 為 3.92 (研究樣區-I) and 3.31 (研究樣區-II)，然而兩者的 Simpson's value 皆為 1.0 左右。平均植株密度為 671/平方公頃 (研究樣區-I) 以及 565 (研究樣區-II)。植株的密度集物種多樣性穩定的隨植株周長等級而減少。本研究所對於當地植物相以及相關研究對於當地自然資源利用的探討，將能提供熱帶潮濕落葉林生物多樣性保育永續經營參考。

關鍵詞：森林植物多樣性、東高止山、族群結構、永續保育、熱帶森林。