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Cultivation, Yield, Income, and Tree Diversity in a Coffee Field in the Eastern Ghats of Andhra Pradesh, India

J. Ramalakshmana[1], S. B. Padal[2*]

[1]Department of Botany, Andhra University, Visakhapatnam, Andhra Pradesh, 530003, India
[2]Professor, Department of Botany, Andhra University, Visakhapatnam, Andhra Pradesh, 530003, India

***Corresponding author:** S. B. Padal
Professor, Department of Botany, Andhra University, Visakhapatnam, Andhra Pradesh, 530003, India

Abstract		Original Research Article

In this study we analyse coffee cultivation, yield, revenue and tree diversity in coffee forest regimes in Eastern Ghats of Andhra Pradesh. The coffee growing regions in India are mainly confined to the traditional South Indian states that are Karnataka, Kerala and Tamil Nadu and partly in non-traditional regions are Andhra Pradesh and Odisha. While to a smaller extent in North-Eastern states. The production of coffee has an impact on the national and international economies and is the second-most traded commodity in the world. Total area under coffee plantations in Andhra Pradesh was about 4010 ha. The Average yield of Andhra Pradesh coffee is roughly 363.9026MT per year and the average revenue is 629.158(in lakhs) per year. Deforestation and the loss of biodiversity are two effects of the expansion of coffee farming. However, shade-grown coffee has been hailed as a way to safeguard tropical biodiversity. If promoted, shade-grown coffee can help preserve some biodiversity, but it can't match a natural forest's whole range of ecological advantages. The coffee cultivated in Andhra Pradesh is mainly shade grown coffee. In this study we also focused on tree species diversity, we analysed data on tree species diversity from 20 field plots (0.1 ha) in coffee area of, Eastern Ghats, Andhra Pradesh, India. We also analyse diversity indices evenness indices species richness indices and Density, frequency, basal area and IVI also calculated. Forest ecosystems can be protected against rising levels of disruption by increasing the diversity of tree species. The variety of tree species may also be directly impacted by anthropogenic disturbance.

Keywords: Cultivation, Economy, Coffee, Non coffee, Biodiversity, Indices, Density, Frequency.

INTRODUCTION

Andhra Pradesh is non-traditional area for growing coffee. Coffee is grown in the agency areas of Chintapalli, Gudem, Paderu and Maredumilli of Visakhapatnam and East Godavari Districts in Andhra Pradesh. Visakhapatnam forest Circle, one of the circles with share comprises of three revenue districts of Visakhapatnam, Vizianagaram and Srikakulam. It has a geographical area of 23,53,700 ha of which nearly 28% (6,56,943 ha) is under forests. Most of the forest area of the Visakhapatnam Circle falls in Eastern Ghats ranges. The main source of livelihood for the people in this area was found to be agriculture and they follow shifting cultivation practices. Warm weather with high rainfall for a period of 6 months is congenial for coffee plantations The main objective to introduce coffee was to wean away the tribals from felling of forests for shifting cultivation (Podu) by providing them gainful employment round the year**.** The AP Forest Department

had raised coffee plantations over an area of 4010 ha, of coffee Plantations, APFDC is the single largest grower of coffee in Andhra Pradesh and also in the non-traditional areas for growing Coffee. APFDC Plantations is improve the yields from 600 - 800 kgs per hectare, (high yielding varieties of coffee i.e. S5, S9 and Chandragiri). Coffee plantations located in the agency areas are not only generating wage employment to the local tribals, protecting the forest area from encroachment, but also providing a coverage of insurance against soil erosion and helping in moisture conservation (A.P. Forest Development Corporation Ltd). Coffee growing regions in India have diverse climatic conditions, which are well suited for cultivation of different varieties of coffee. Some regions with high elevations are ideally suited for growing Arabicas of mild quality Coffee (Coffee arabica (de Jessieu) Linn) was introduced in India about 400 years ago in the Baba Budan hills in the Western Ghats, which presently a global biodiversity hotspot. While those with warm

humid conditions are best suited for Robustas (Coffee Board, 2018). The dominance of Arabica has been falling down for the last 20–25 years with the preference over the Robusta variety-a sturdy, high yielding and sun-loving species. There has been a marked by a shift from Arabica to Robusta cultivation over the years, Now nearly 80% of the Coffee plantations in Karnataka and Kerala dominated by the Robusta variety. Another variety that is grown in the region, but not for commercial purpose is Liberian Coffee (Coffee liberica). Coffee is one of the most important plantation crops being cultivated in the hilly tracts of Visakhapatnam District in Andhra Pradesh These areas are mainly inhabited by the tribal community and they have an age old practice of podu/shifting cultivation which resulted in drastic reduction of the forest cover and has become an issue of serious environmental concern. Introduction of coffee in these areas preserved the biodiversity besides contributing significantly for the overall economy of this region by providing employment and lively hood to large number of tribals. Coffee is one of the important plantation crops of India, which is cultivated mainly in the hill tracts of South India especially in Karnataka, Kerala, and Tamil Nadu. The other important States of India in which coffee is grown on a limited scale are Andhra Pradesh, Maharashtra, West Bengal, Assam, Andaman and Nicobar Islands, and Madhya Pradesh (Joy 2004). From 1950 to 2014, the total area under coffee cultivation in India has increased from 92,523 hectares to over 409,690 hectares, (Coffee Board, 2020).Kerala is the second largest producer of coffee in India. It produces 23% of the total coffee output in the country. Wayanad produces 90% of the total coffee output in the State (Joy 2004). Coffee is a highly traded commodity in the world next only to oil in value. For some countries it is the most important source of foreign exchange (Rice and Ward 1997; Ambinakudige 2006). Today there are about 29 million coffee drinkers in the world (Ambinakudige 2006). Presence of this large number of coffee consumers encourages conservationists to this generates enormous pressure on growers to produce shade coffee with the goal of increased biodiversity conservation (Rappole *et al.*, 2003). The coffee plantations are spread along 13 Brazilian states It is estimated that there are around 300 thousand Brazil is not only the largest exporter of coffee worldwide, but it's also one of the largest consumers. Brazil itself is the second largest consumer of coffee according to the International Coffee Organization in London. Brazil is the world's largest exporter of instant coffee, Global coffee production in 2019/20 is estimated at 167.91 million bags, which could exceed consumption by 1.85 to 3.42 million bags, depending on impact of covid-19. In 2019/20, world coffee consumption is estimated at 166.06 million bags, 0.5% higher than in 2018/19. India's current share of world coffee production is around 3.67%, while its share in global exports is about 4.53%. The final crop estimate based on crop harvest data for the year 2017-18 is about 316,000 MT. Coffee cultivation was deregulated during 1996 and there is a sizable increase in the area under coffee cultivation in southern India (Coffee Board, 2018).Coffee cultivation, particularly when practiced with shade or traditional systems, has been recognized for its importance in promoting conservation of biodiversity. Shade trees in coffee system prevent soil erosion on a sloping terrain; they enrich the soil by recycling nutrients from deeper layers, protect the coffee plant from seasonal fluctuations in diverse flora and fauna (Perfecto *et al.*, 1996; Komar, 2006; Coffee Board, 2018). Shade trees in coffee plantations can improve soil fertility through various ways. These include an increase in nutrient supply through N-fixation, reduced leaching by checking runoff, more efficient nutrient cycling by way of decomposition and improvement of soil physical properties thereby enhancing root growth (Wilson, 1985, Buresh and Tian, 1997 and Khanna, 1997). Shaded soil had significantly higher soil pH, N, P, K, Ca and Mg contents than unshaded coffee (Aim, 2016).

The Hon'ble Chief Minister of Andhra Pradesh, on 17th October 2014 in connection with Hudhud Cyclone, has made an announcement that all efforts would be made by the Government of A.P for development of Coffee Plantation in Paderu Agency area including expansion of Coffee Plantation by 1.00 lakh acres more (40468 hectares). (Go AP, 2015), indicating that the coffee grown area in the Visakhapatnam district may expand by eight to ten times by the year 2025. Therefore it is necessary that the impacts of Coffee cultivation in the forested area needed an understanding and the present review is contemplated. Globally, the coffee industry employs around 25 million farmers – mostly small holders in over 50 developing countries (Ricketts, 2004). Studies in Karnataka divulged that labour force in coffee farms constitutes indigenous tribal communities and contribute to above 60% of women workers residing in or near surrounding forest areas. As per data released by the Coffee Board of India, average daily number of workers employed on coffee estates has increased from 4,23,451 in 2003-2004 to 4,79,453in 2009-2010 (United Nations COP-11 CBD edition, 2012). Despite the increase or decrease in coffee prices or productivity, shade trees will help farmers in generating income by providing additional products such as timber, firewood and fruits (Jeezer & Verweij, 2015).

Widespread agricultural development is one of the major causes of deforestation and biodiversity loss particularly in coffee agro-ecosystems (Bhagwat 2002; Perfecto and Vandermeere 2002; Perfecto *et al.*, 1996, 2007; Moguel and Toledo 1999; Philpott et al. 2007, 2008). Coffee can be grown under sun or under shade. Shade grown coffee may more closely resemble the natural environment (Geist and Lambin 2001; Jime´nez-Avila and Martı´nez 1979; Perfecto *et al.*, 2005; Moguel and Toledo 1999; Soto-Pinto *et al.*, 2001). India is the only country that grows all its coffee under shade, Shade grown coffee helps in conserving biological diversity by providing several ecosystem

services such as erosion control and water recharge, thereby preventing the degradation and loss of surrounding habitat. Certain modern as well as traditional systems of coffee production may play an important conservation role, not only for favouring species conservation and providing numerous environmental services, but also because coffee is usually grown on an elevation gradient that represents key biological transition zones (Moguel and Toledo, 1999). Trees in agroforestry are an essential part of natural ecosystems, and provide a range of benefits to the soil, other plant species and overall biodiversity (Murthy *et al*., 2016). Recent studies in traditional shaded coffee plantations have demonstrated this agroecosystem's potential as a refuge for biodiversity (Perfecto *et al*., 1996; Moguel and Toledo 1999; Perfecto *et al*., 2003). Shade grown coffee plantation has diverse, complex structure and that has a high potential to retain biodiversity in the changing climate scenarios. However, researches in coffee systems have allowed for an improved understanding of habitat management and biodiversity, a closer examination of the relationships between biodiversity and ecosystem services (Jha *et al*., 2014), and a greater understanding of the linkage between climate change and biodiversity.

MATERIALS AND METHODS
Study area
This study was conducted in Visakhapatnam district of Andhra Pradesh state in Eastern Ghats of the Southern India (Fig 1). Coffee is grown in the agency areas of Chintapalli, Gudem, Paderu and Maredumilli of Visakhapatnam and East Godavari Districts in Andhra Pradesh. Andhra Pradesh is a tribal belt at an altitude of 3650 feet MSL.
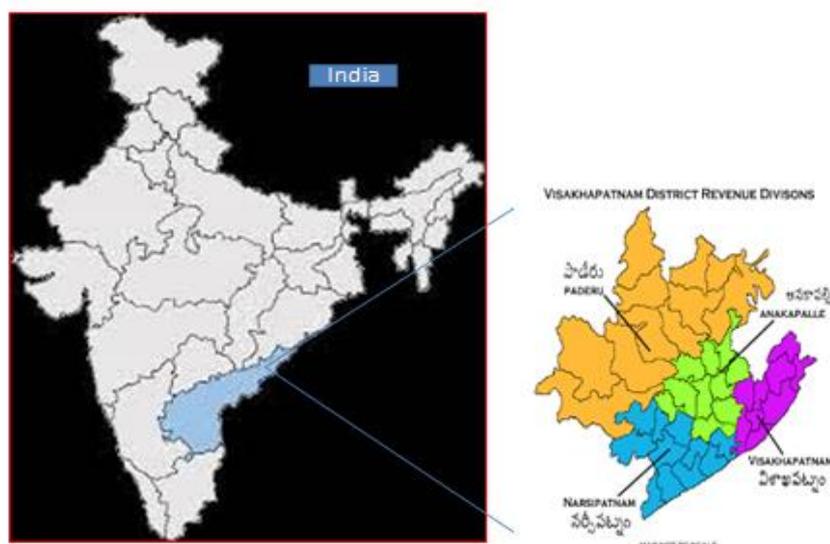
Fig 1: The Map of Study area

It lies between latitudes of 18o 18' to 17o 56' and the longitudes of 82o 32' to 82o 53'. Chintapalli and Gudem kottaveedhi mandal is located on the north eastern part of Visakhapatnam district in Andhra Pradesh State of India. Chintapalli lies between latitude of 17o 44' 22" to 18o 04' 29" N and Longitude of 820 16' 00" to 82o 38' 04" E and Gudem kottaveedhi is located at17.8667°N 82.2000°E. The State supported and nourished the Indian coffee sector for many years by providing subsidies and extension services. When the Coffee Board of India allowed an open market for coffee in early 1990s, growers received higher prices (Ambinakudige 2006). Andhra Pradesh is non-traditional area for growing coffee. Coffee is grown in the agency areas of Chintapalli, Paderu and Maredumilli of Visakhapatnam and East Godavari Districts in Andhra Pradesh. The main objective to introduce coffee was to wean away the tribals from felling of forests for shifting cultivation (Podu) by providing them gainful employment round the year**.** Coffee is one of the most important plantation crops being cultivated in the hilly tracts of Visakhapatnam District in Andhra Pradesh These areas are mainly inhabited by the tribal community and they have an age old practice of podu/shifting cultivation which resulted in drastic reduction of the forest cover and has become an issue of serious environmental concern. Coffee is a highly traded commodity in the world next only to oil in value. For some countries it is the most important source of foreign exchange (Rice and Ward 1997; Ambinakudige 2006). Today there are about 29 million coffee drinkers in the world (Ambinakudige 2006). The AP Forest Department had raised coffee plantations over an area of 4010 ha, of coffee Plantations.

Table 1: This information of table obtained from APFDC

Division	Area in ha.
Paderu	623
Chintapalli	1484
RV Nagar	1903
Total	4010

APFDC is the single largest grower of coffee in Andhra Pradesh and also in the non-traditional areas for growing Coffee. APFDC Plantations is improve the yields from 600 - 800 kgs per hectare, (A.P. Forest Development Corporation Ltd). The following are the details of Coffee yields and revenues realized during the past five years.

Table 2: This table obtained from A.P. Forest Development Corporation Ltd

Year	Yield (in MT)	Revenue (Rs.inlakhs)
2015-16	322.6940	502.83
2016-17	543.4990	1047.40
2017-18	333.6300	540.90
2018-19	384.8400	577.18
2019-20	234.8500	477.48

Coffee has good domestic and international markets. The price of coffee in the domestic market is dependent to a large extent on the prevailing price in the international market.

The French Institute of Pondicherry found that the increase in the area under coffee cultivation between 1977 and 1997 resulted in a net loss of forest habitat. Although shaded coffee plantations resemble the original forest they have a relatively high biodiversity (Moguel and Toledo 1999; Perfecto *et al*., 1996).

Tree Diversity in Coffee field
In this study in addition to economy of coffee we also examine the Tree diversity in the coffee field through Phytosociological studies. The purpose of Phytosociological analysis is to understand vegetation characteristics and to estimate the species richness and species diversity existing in the study area. Phytosociology is the quantitative study, We carried out by quadrat sampling method as per Mishra (1968), Kershaw (1973). Randomly selected 20 square plots 31.6x31.6(0.1 ha), The major Phytosociological attributes such as species density, frequency, basal area and importance value index; and important biodiversity indices such as Shannon diversity index (Shannon & Weiner 1949); Simpson dominance index (Simpson 1949), Species Richness Index (Margalef Index, 1958) Evenness index (Pielou 1969) (Mohammad *et al*., 2016), were calculated using the formula as given in the reference cited above.

Table 3: Specifications of Phytosociological parameters and diversity indices for species available at study site

Biodiversity attributes	Formula and their Source
Density	$\dfrac{\textit{Total number of individuals of species in all quadrates}}{\textit{Total quadrats studied}}$ Ref: (Shukla and Chandel, 2000)
Frequency	$\dfrac{\text{Total number of quadrats in which species occur}}{\text{Total number of quadrats studied}}$ Ref: (Shukla and Chandel, 2000)
Basal area	$= \dfrac{C2}{4\,\pi}$ (Reddy *et al*.,)
IVI	RD + RF + RDO Source: (Dallmeier *et al*., 1992, Shukla and Chandel, 2000)
Shannon-wiener Index	$= \sum_{i=1}^{N} Pi \,(\text{lnpi})$ (Krebs, 1999; Michael, 1990)
Simpson Index	$= \sum_{i=1}^{s} (n1/N)2$ (Colwell, 2009; Magurran, 1988; Simpson, 1949)
Species Richness Index (Margalef Index, 1958)	s-1/log n (Margalef Index, 1958)
Species evenness Index or Pielou Index	$\dfrac{H}{\log(S)}$ (Pielou, 1966)

RESULTS AND DISCUSSION

Tribal farmers develop coffee mixed crops using traditional methods in the Visakhapatnam agency areas. It aids in biodiversity preservation, reduces soil erosion issues, and offers a backup source of revenue in the event that there are ongoing issues with coffee plantation profits. Annual Income from coffee mixed plantations cultivated by small tribal farmers in Visakhapatnam district was found to be around Rs.35,000 to 50,000 per hectare. From 1950 to 2014, the total area under coffee cultivation in India has increased from 92,523 hectares to over 409,690 hectares, with Karnataka accounting for around 229,658 hectares (56.1 per cent) of the total area and 226,335 million tons (70.7 per cent) of total national production (Coffee Board, 2014). On an average about 200-300 kilos of coffee beans and 8 to 12 kilos of pepper were produced from one hectare of land by the private farmers every year. (Nisha *et al.*, 2018). From the survey it was conclude that coffee cultivation requires plenty of cheap and skilled labour for various operations including sowing, transplanting, pruning, plucking, drying, grading and packing of coffee. Tribal women were more keen in taking up this plantation activity compared to men. Wages for labours working in coffee board plantations in Visakhapatnam district was Rs.222 per day in 2016-17 (Nisha *et al*., 2018). Amount of land covered by forest in Visakhapatnam is 3692 sq. km, or roughly 33.08 percent of the district's overall geographic area, according to the India State Forest Report 2017 assessment. The majority of the district's forestland is connected to coffee plantations. The coffee board in maintains the area of coffee crops.

When the cover density of the woods in the Visakhapatnam district was analysed in comparison to the non-coffee areas, it was found that the coffee-growing areas had much higher cover densities. Even in coffee-growing regions, the percentage of non-coffee lands with trees was less than moderate (10–40%). As per Centre's for people forestry survey in 2014 &2015(http://cpf.in/whatsnew/IFR-%20Policy%20Brief.pdf), Individual Forest Rights (IFR) titles under Forest Rights Act (FRA) 2006 were issued to 81,800 across the state of Andhra Pradesh for an extent of 170,731 acres. Of the 13 districts, Vishakhapatnam and Srikakulam districts recorded maximum recognition of Individual titles. In Visakhapatnam IFR titles were issued to 28808 for an extent of 54061 acres. In this IFR titles conferred lands, tribal could be encouraged to grow coffee for the sake of wean out shifting cultivation as well to maintain forest cover along with conserving biodiversity. Perhaps, 30% of this IFR title conferred lands could be promoted more for coffee cultivation.

We obtained an average daily capital expenditure of INR 9,515 per ha per day using the data reported in 2012 on coffee yield and quality, maintenance and purchase of machinery, maintenance of infrastructure and machinery and diesel use. Average yield of each estate in our sample was less in high yielding (9.66 tonnes per ha) as compared to medium (9.95 tonnes per ha) and low yielding estates (9.48 tonnes per ha).Wage rates of coffee workers have risen steadily over the years, increasing from INR 27 per day in 1994 to INR 140 per day in 2014 (Coffee Board, 2014).

Density of Tree Species

The population density of the 34 tree species were identified in randomly collected 20 ha (0.1) area of Coffee forest studied in Gudem, Chintapalli and paderu mandel of Visakhapatnam district. Tree Species Richness and Abundance in this study revealed that considerable number of tree species are being managed and conserved in coffee forest. Accordingly, a total of 538 trees belonging to 34 species and 22families were encountered in coffee forest. Based on the population density, the top five species of Coffee forest were *Grevillea robusta* (9.08%, 89) was the most abundant species in the study plots, followed by *Diospyros melanoxylon* (6.83%, 67), *Mallotus philippines* (4.89%, 48), *Syzygium cumini* (4.08%, 40), *Mangifera indica* (3.77%, 37).

Frequency of Tree Species

The vegetation attribute known as frequency describes the likelihood of finding a particular species in a given location. The probability is based on the presence of that species in a number of sample units. The overall frequency of occurrence of shade tree species ranged from 10 to 90% of the plot surveyed. The five most frequent tree species in the coffee forest of the study area were *Grevillea robusta* (90%), *Mangifera indica* (80%), *Syzygium cumini* (80%), *Mallotus philippines* (70%), *Diospyros melanoxylon* (70%).

Basal Area

It is an area occupied by the base of a tree. It is considered as a good indicator of the size, volume, or weight of a tree. Basal area provides information on the proportion or dominance of larger and smaller trees in an ecosystem. It is one of the most important parameters in estimating the standing biomass in an area that in turn is used as a measure of productivity. The basal area was calculated by dividing 4π with the square of DBH (Diameter at Breast Height). The total basal area for 20 plots (0.1 ha) of coffee forest was 65.26 ha with the mean basal value of 32.63. (standard deviation 3.200844). Basal area and density relationship among plots in study area is represented in Fig 2.
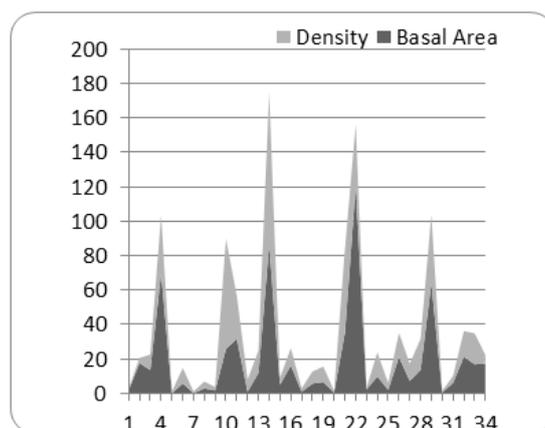
Fig 2: Relationship between Density and Basal area
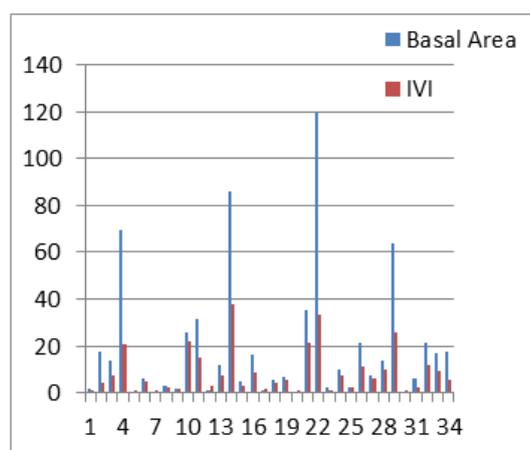
Fig 3: Relation between Basal area and IVI

Important Value Index (IVI)

IVI is a statistical quantity, which gives an overall picture of the importance of the species in the plant community. Since the above relative parameters give clues individually, all the parameters are summed up in order to provide the total picture of sociological structure of a species in a community, and called as IVI. It thus incorporates three important parameters that are measures of diversity and productivity of every species. IVI is the sum of quantities of relative frequency, relative density and relative dominance expressed per 300. IVI = Relative frequency + Relative dominance (basal area) +

Relative density. The IVI depict the sociological structure of a species in its totality in community. The important value index (IVI) of the 34species varied considerably (Table 4). The IVI value of the top five predominant species in among 20 plots were *Grevillea robusta (*37.6180841*), Mangifera indica (*33.3537695*), Syzygium cumini (*25.93519452*), Diospyros melanoxylon (*21.83352233*), Mallotus philippines (*21.33915615*)* are predominant tree species with greater values in the study area. Quantitative values encountered in all sampling study plots are given in Table-5.

Table 4: The IVI of 34 Tree species in study Area

Name of the Taxa	R D	RF	RDO	IVI
Aegle marmelos	0.191204589	0.555555556	0.275451471	1.022211616
Ailanthus excelsa	0.573613767	1.111111111	2.747169338	4.431894216
Artocarpus heterophyllus	1.7208413	3.333333333	2.110276568	7.164451201
Barringtonia acutangula	6.500956023	3.333333333	10.85718294	20.6914723
Cassia fistula	0.191204589	0.555555556	0.011018059	0.757778203
Chloroxylon swietenia	1.7208413	2.222222222	0.898118703	4.841182226
Cipadessa baccifera	0.191204589	0.555555556	0.01958766	0.766347805
Cleistanthus collinus	0.764818356	1.111111111	0.449598012	2.325527479
Dillenia pentagyna	0.382409178	1.111111111	0.265853518	1.759373807
Diospyros melanoxylon	12.23709369	5.555555556	4.040873081	21.83352233
Diospyros sylvatica	4.780114723	5	4.924631581	14.7047463

Name of the Taxa	R D	RF	RDO	IVI
Ficus religiosa	1.338432122	1.666666667	0.15910077	3.164199559
Garuga pinnata	2.485659656	2.777777778	1.861317407	7.124754841
Grevillea robusta	17.01720841	7.222222222	13.37865347	37.6180841
Grewia tiliifolia	0.764818356	1.666666667	0.784522517	3.216007539
Haldina cordifolia	1.912045889	3.888888889	2.539895167	8.340829945
Homalium nepalense	0.382409178	1.111111111	0.141043395	1.634563684
Kydia calycina	1.338432122	2.222222222	0.887296521	4.447950866
Macaranga peltata	1.7208413	2.777777778	1.020321218	5.518940296
Magnolia champaca	0.191204589	0.555555556	0.078350641	0.825110785
Mallotus philippines	9.177820268	6.666666667	5.494669218	21.33915615
Mangifera indica	6.883365201	7.777777778	18.69262652	33.3537695
Morinda species	0.191204589	0.555555556	0.353802112	1.100562256
Neolitsea foliosa	2.676864245	3.333333333	1.532709923	7.542907501
Phyllanthus emblica	0.764818356	1.111111111	0.317381306	2.193310773
Pterocarpus marsupium	2.676864245	5	3.294142506	10.97100675
Randia aculeata	1.912045889	2.777777778	1.135080422	5.824904089
Schleichera oleosa	3.4416826	4.444444444	2.129129691	10.01525674
Syzygium cumini	7.648183556	8.333333333	9.953677632	25.93519452
Terminalia aleta	0.191204589	0.555555556	0.082317142	0.829077286
Terminalia arjuna	0.764818356	0.555555556	0.949389404	2.269763315
Terminalia bellirica	2.868068834	5.555555556	3.302197931	11.72582232
Wrightia arborea	3.4416826	3.333333333	2.633144672	9.408160605
Xylia xylocarpa	0.956022945	1.666666667	2.679469488	5.302159099
	100	100	100	300

Diversity

Ecologists have proposed a number of indices for species diversity from time to time, but most commonly used indices are Shannon- Wiener Index for diversity, Simpson's Index for dominance, Margalef Index for Species Richeness, Pielou Index for Evenness.

The Shannon index ranges from 2.833 to 2.988, Simpson's index ranging from 0.9124 to 0.9308, Evenness index ranging from 0.4998 to 0.5838 and Margalef index ranging from 5.272 to 5.272. Different diversity indices are shown in Fig 4.
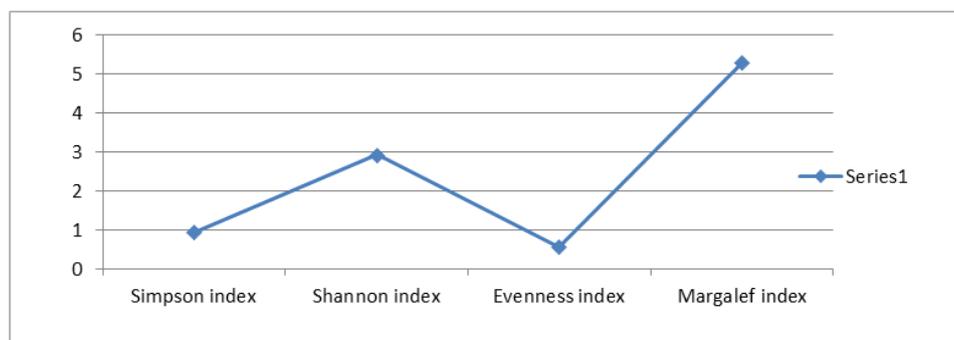
Fig 4: The graph represents different indices

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