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A Comparative study on Biodiversity of Plant species between Natural forest and Coffee agro forest in Eastern Ghats of Andhra Pradesh, India

J. Ramalakshmana, Y.T. Rajesh Babu and S.B. Padal

Department of Botany Andhra University Viskhapatnam, Visakhapatnam, Andhra Pradesh, India

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ABSTRACT

We studied plant biodiversity (trees, shrubs and herbs) in two kinds of forests, natural and coffee agro forests and comparing diversity of plant species between them. The natural forest contained 63 plant species in total, of which 44 were trees, 5 were shrubs, and 14 were herbs. The planted forest, on the other hand, contained 42 species of flora, including 35 trees, 1 shrub, and 6 herbs. In the natural forest, the Shannon-Wiener diversity indices for trees, shrubs, and herbs were 3.26, 1.53, and 2.57, respectively. In the coffee agro forest, it was 2.91 for tree species, 0.00 for shrub species, and 1.77 for herb species. Simpson diversity index were 0.95, 0.77 and 0.91 for trees, shrubs and herbs respectively in the natural forest. However, it was 0.92 for tree species, 0.00 for shrub species and 0.82 for herb species in the coffee agro forest. Jaccard's similarity index showed that 72% species of trees, 20% species of shrubs and 33% species of herbs were same in natural and coffee agro forest.

Key words : *Comparative study, Biodiversity, Forests, Diversity indices, Eastern Ghats, Andhra Pradesh*

Introduction

Forests cover approximately 25% (Hirakuri, 2003) to 31% (Adams, 2012) of the world's landmass and are critical in meeting human needs for water, food, shelter, medicine, fuelwood, fodder, and timber (Adams, 2012; Mohammad *et al*., 2016).Global change increases the pressure on forest ecosystems through changed environmental conditions, which, in turn, alter ecological processes substantially (Trumbore *et al*., 2015). One of the most climate-sensitive processes in forest ecosystems is disturbance (Seidl *et al*., 2020; Sommerfeld *et al*., 2018; Sebald *et al*., 2021). India is a tropical country with the geographical area of 2.4 % of the world, but it houses 8% of the biodiversity of the world (Yadav *et al*., 2020). Tropical forests cover 7% of the earth's land surface, but harbor more than half of the world's species (Wilson 1988) and are currently disappearing at an overall rate of 0.8-2% per annum (May and Stumpf, 2000; Sagar *et al*., 2003). Biodiversity is defined as the kinds and numbers of organism and their patterns of distribution (Barnes *et al*., 1998; Eshaghi Rad *et al*., 2009). Tropical forests are regarded as world's most diversity rich ecosystem (Sanders, 2006; Sayer and Whitmore, 1991; Pratap *et al*., 2013; Reddy *et al*., 2008). As is evident (Arya *et al*., 2017) known, India being a tropical country, has tropical vegetation mostly dominated by angiospermic trees and shrubs which play an important role in providing shade and shelter to herbaceous and others flora in the particular region (Bora

and Bhattacharya, 2017; Yadav *et al*., 2020). The floral diversity of the state varies due to differences in sunlight intensity, temperature, humidity as well as other factors such as geology, climate and topography. Mostert (2014) discribed that at the local scale, the terrestrial plant diversity is driven by height, slope, soil condition, human and animals in a particular area (Yadav *et al*., 2020). However, most of these forests are under immense anthropogenic disturbances andrequire careful management intervention to maintain overall biodiversity and sustainability (Kumar *et al.,* 2006; (Reddy *et al*., 2008). Plant species diversity in any particular area is a key feature to know the community like trees and shrubs which are correlated with environmental conditions (Nabi *et al*., 2016; Yadav *et al*., 2020). Due to the rapid rise of human population and their consequent increased demands for more utilization of forest resources, the natural forests in india as well as in many other countries are shrinking at an alarming rate (Subrata Nandy *et al*., 2013). The conversion of forests has led to habitat loss, which is the greatest threat to biodiversity (Wong, 2011). The preservation of biodiversity is now a central issue of world conservation strategies (Norul-Alam *et al*., 2011). Agriculture is a major livelihood for millions of people in the world. At the same time widespread agricultural development is one of the major causes of deforestation and biodiversity loss (Ehrlich, 1988; Gorenflo and Brandon 2003; Chichilnisky 1994; Benhin 2006; Ambinakudige *et al*., 2009; Ramalakshmana *et al*., 2022). Old-growth tropical forest is threatened by increasing pressure from human population growth and land-use change, which generally results in biodiversity loss (Achard *et al*., 2002; Foley *et al*., 2005; Gibson *et al*., 2011). In tropical regions the extent of agricultural land is increasing rapidly at the expense of natural forest, with associated losses of biodiversity and ecosystem services (Mertens *et al*., 2020). Recently, much attention has been focused on measuring tree, ants and bird biodiversity loss due to agricultural intensification, 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. Highly shaded farms provide important habitat refuges for biodiversity in some regions (Perfecto *et al*., 1996, 2007). Compared to non-shaded or partially shaded plantations, shade-grown coffee stores significant amounts of carbon in both the aboveground woody biomass of shade trees and the litter layer and soil organic matter (Anil Kumar *et al.,* 2018). Shade grown coffee systems have been recognized as viable afforestation and reforestation (A&R) strategies under the Clean Development Mechanism (CDM) of the Kyoto Protocol (IPCC, 2000; UNFCCC, 2006; Schmitt-Harsh *et al*., 2012). Beyond that natural forests produce a much wider range of goods (Norul-Alam *et al*., 2011). Shade grown coffee may more closely resemble the natural environment (Geist and Lambin, 2001; Jime´nez-Avila and Martý´nez, 1979; Perfecto *et al.,* 2005; Moguel and Toledo 1999; Soto-Pinto *et al*., 2001). Furthermore, type and management of shade strongly affect species richness (Perfecto and Snelling, 1995; Perfecto *et al*., 1996; Moguel and Toledo, 1999; Blackman *et al*., 2005). Furthermore, researchers have also argued that species composition in shade-grown coffee farms is not identical to that of natural forest (Soto-Pinto *et al*., 2001; Rappole *et al*., 2003; Ambinakudige *et al*., 2009). Yields of the wild and semi-wild coffee in the forest habitats are extremely low due to low light levels, resulting in a growth form with few bearing shoots (Aerts *et al*., 2011; Schmitt *et al*., 2010). This leads the smallholder farmers to improve light conditions by thinning lower canopy shade trees and removing small shrubs and lianas, an activity that aims for coffee stems with larger crowns and a higher number of productive shoots (Aerts *et al.,* 2011; Senbeta and Denich, 2006). (Zewdie *et al*., 2022). Today there are about 29 million coffee drinkers in the world (Ambinakudige 2006). Presence of this large number of coffee consumers increase pressure on natural forest diversity. Species richness of woody plants, herbaceous plants and bryophytes display a monotonic negative relationship with coffee yield and Species composition of woody plants, herbaceous plants and bryophytes change monotonically with coffee yield (Zewdie *et al*., 2022).

In peninsular India, quantitative phytodiversity inventories are available from the forests of the Western Ghats (Reddy *et al*., 2008a), however Eastern Ghats remains as a neglected area for studies (Kadavul and Parthasarathy, 2000; Jayakumar *et al*., 2002; Natarajan *et al*., 2004; Reddy *et al*., 2007; Reddy *et al*., 2008b). Eastern Ghats is rich in plant diversity due to geographic factors, high seasonality and variations in elevation, affected by heavy anthropogenic pressures (Naidu *et al*., 2015). This hill range is home for wide array of flowering plants and these

forests are rich in medicinal and economically important plants (Panayatou and Ashton, 1992; Sobuj *et al*., 2011). There are over 4000 flowering plant species (Krishnamurthy *et al*., 2014). A total of 166 flowering plant taxa are exclusively endemic to the Eastern Ghats (Singh *et al*., 2015) At present, there are 61 species of invasive exotic plants, 149 liana species representing 31 families and 90 genera are present in the Eastern Ghats. (*Source:* Proc. National Seminar on Conservation of Eastern Ghats).

A pattern of a negative relationship between regulating ecosystem services (e.g. biodiversity) and provisioning ecosystem services (e.g. yield) among a group of sites could be an indication that management for one property will trade off against the other property (Elmqvist *et al.,* 2010). My research also reveals that species richness and composition effected in coffee agro forest compare with natural forest. The objective of this paper is comparing the diversity of plant species (trees, shrubs, herbs) of natural forest and Coffee agro forest of Eastern Ghats of the Andhra Pradesh.

Materials and Methods

Study area

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. R.V. Nagar Range is situated between 17º 48' to 18º 00' N and 82º 02' to 82º 16' E in Visakhapatnam district, Andhra Pradesh and covers an area of 312 km^2 (Reddy *et al*., 2008; Naidu *et al*., 2015).

Eastern Ghats encompasses several hills of different elevations and the low-laying valleys. The highest peak of the hills is about 1615 m. The hill range consists chiefly of charnokites and kondalites and varied metamorphic rocks; and the main soil types are loamy, black, lateritic and alluvial. Lateritic soils are the common type along the deciduous forests of the area (Subrahmanyam, 1982; Naidu *et al*., 2015). The temperature ranges from 28–46 ºC during summer and 13–27 ºC during winter. Maximum rain fall occurs between July and September with 1300mm per annum during the south-west monsoon period and the relative humidity is quite high throughout the year: 70–88 % (Naidu *et al*., 2014). There are five major forest types in the Eastern Ghats of northern Andhra Pradesh which are tropical semi-evergreen, tropical moist-deciduous, tropical dry-deciduous, tropical thorny-scrub vegetation and tropical dry-evergreen forest types (Champion and Seth, 1968). The study was carried out through stratified random quadrate method. Data were collected from both the natural and coffee agro forest. The vegetation analysis was carried out by total 40, 30.6 m × 30.6 m sample plots placed randomly from both forest. From each forest 20 sample plots were taken. For herb 1x1 and shrub species 10 × 10 m sample plots

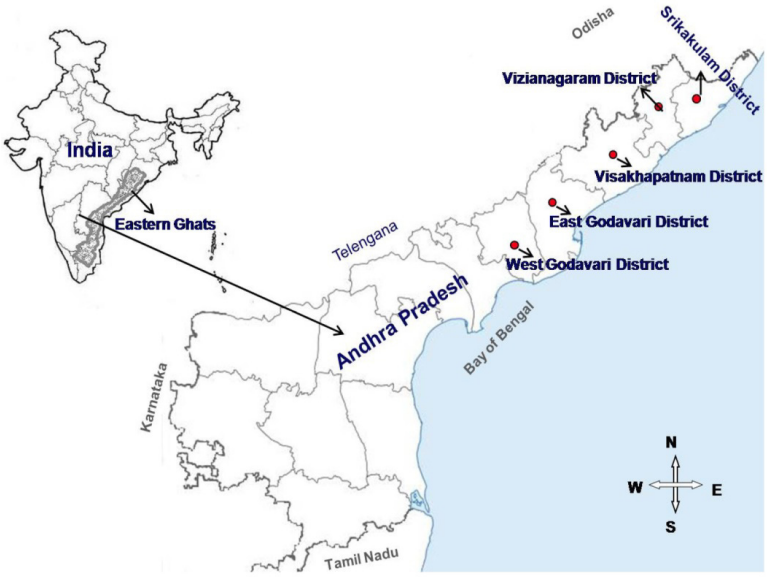

Fig. 1. Location map of the study area
Source: (Naidu *et al*., 2015).

were nested within each plot of tree layer. After collection of field data, they were analyzed for richness, Shannon-Wiener diversity index, Simpson index and Jaccard's similarity index. The simplest definition of diversity is the species richness, or the number of species present in a community. Following Whittaker (1976), species richness was calculated by counting the number of tree, shrub, and herb species in the research area's natural and coffee agroforest.

One of the most commonly used measures of species diversity is the Shannon- Wiener diversity index. It combines two quantifiable measures; 1. the species richness (the number of species in the community) and 2. species equitability (how even are the numbers of individuals of each species). The higher the number, the higher is the species diversity. The index equals zero when there is only a single species, increases with richness and evenness, and commonly has a value between 1.5 and 3.5 for many sampled ecological communities (Legendre and Legendre, 1998). The Shannon- wiener index for diversity was calculated according to Michael (1990) and Norul-alam *et al.* (2011) it is as follows:

$H = - \Sigma PiLnPi$

Where, H = Index of species diversity Pi = Number of individuals of one species / Total number of individuals in the samples

The Simpson Index is an index of dominance whose maximum value is 1, which is obtained in the case of a single species (complete dominance) and the near values are obtained when numerous species are present (no dominance), each species representing a small fraction of the total value. The Simpson index is weighed in favour of dominant species and Shannon-Weiner Index in favour of rare species. The formula for calculating Simpson index (Concentration of Dominance) is

$$CD = \sum_{i=1}^{s} (n1/N)2$$

Where n1 and N were the same as for the Shannon–Weiner information function.

The Jaccard's (1912) index is a valuable tool because it allows one to determine whether two communities are composed of similar species. The Jaccard's Index is calculated as

Jaccard's Index = A/ (A+B+C)

Where, A = total number of species present in both communities

B = the number of species present in community 1 but not 2

C = the number of species present in community 2 but not 1

If the Jaccard's Index is equal to one (B=0 & C=0), all species are shared between the two communities. If the Jaccard's Index is near 0, few if any species are shared.

Results

Tree species in study area

A total of 44 species of trees ≥ 30 cm (DBH) distributed into 24 families were recorded in natural forests of the study site. The dominant families were Fabaceae and Moraceae containing 4 species each. followed by Combretaceae and malvaceae each with 3 species. 7 families Anacardiaceae, Ebenaceae, Euphorbiaceae, Lauraceae, Myrtaceae, Rubiaceae and Rutaceae represented by two species.The remaining families were represented by single species. On the contrary, there were 35 tree species belonged to 23 families found in the coffee forest of the study area. It was found that family Fabaceae, Combretaceae and Rubiaceae comprised the highest number of species (3 species each) followed by Ebenaceae, Euphorbiaceae, Malvaceae, Moraceae, Phyllanthaceae and Rutaceae each with 2 species. Rest of the families occupied one species each. In the present study, 32 species were common occurred both in the natural forest and coffee agro forest. However there were 9 species namely *Bombax ceiba, Caryota urens, Eucalyptus globulus, Ficus auriculata, Ficus benghalensis, Litsea glutinosa, Premna latifolia, Semecarpus anacardium, Tamarindus indica* were recorded only from natural forest, On the other hand, three species namely *Cleistanthus collinus*, *Morinda* species, *Ziziphus xylopyrus* were confined to coffee agro forest site only (Table 1).

Shrub species in study area

During the present study, 5 species of shrubs under 4 families were identified in the natural forest. The highest number of species were belonged to Malvaceae contain 2 species. Rest of the families contained one species each. In contrast, only single family (Lamiaceae) represented with single species (*Colebrookea oppositifolia)* were recorded from the coffee agro forest sites. Thereby among 5 species of herbs, 4 confined only in natural forest and one species common in both natural and coffee agro forest. No herb species uniquely found in coffee agro forest

Table 1. Tree species in natural forests and coffee forests of study area

Local Name	Scientific Name	Family	Natural Forest	Coffee agro forest
Maredu	*Aegle marmelos*	Rutaceae	P	P
Peddamanu	*Ailanthus excelsa*	Simaroubaceae	P	P
Panasa	*Artocarpus heterophyllus*	Moraceae	P	P
Samudraphala	*Barringtonia acutangula*	Lecithidaceae	P	P
Buruga	*Bombax ceiba*	Malvaceae	P	A
Jeelugu	*Caryota urens*	Arecaceae	P	A
Golden shower	*Cassia fistula*	Fabaceae	P	P
Bella	*Chloroxylon swietenia*	Rutaceae	P	P
Hill Neem	*Cipadessa baccifera*	Meliaceae	P	P
Wodesha	*Cleistanthus collinus*	Phyllanthaceae	A	P
Chinna kalinga	*Dillenia pentagyna*	Dilleniaceae	P	P
Beedi aku	*Diospyros melanoxylon*	Ebenaceae	P	P
Gatha	*Diospyros sylvatica*	Ebenaceae	P	P
Neelagiri Chettu	*Eucalyptus globulus*	Myrtaceae	P	A
Racha bodda	*Ficus auriculata*	Moraceae	P	A
Marri chettu	*Ficus benghalensis*	Moraceae	P	A
Ravi chettu	*Ficus religiosa*	Moraceae	P	P
Garuga	*Garuga pinnata*	Burseraceae	P	P
Silver oak	*Grevillea robusta*	Proteaceae	P	P
Tada chettu	*Grewia tiliifolia*	Malvaceae	P	P
Kamba	*Haldina cordifolia*	Rubiaceae	P	P
Tella chettu	*Homalium nepalense*	Flacourtaceae	P	P
Eruku toda	*Kydia calycina*	Malvaceae	P	P
Nara chettu	*Litsea glutinosa*	Lauraceae	P	A
Boddu	*Macaranga peltata*	Euphorbiaceae	P	P
Champakamu	*Magnolia champaca*	Magnoliaceae	P	P
Kunkum	*Mallotus philippines*	Euphorbiaceae	P	P
Mamidi	*Mangifera indica*	Anacardiaceae	P	P
Noni	*Morinda species*	Rubiaceae	A	P
Nees	*Neolitsea foliosa*	Lauraceae	P	P
Usiri	*Phyllanthus emblica*	Phyllanthaceae	P	P
Nelli	*Premna latifolia*	Verbenaceae	P	A
Yegisa	*Pterocarpus marsupium*	Fabaceae	P	P
Manda chettu	*Randia aculeata*	Rubiaceae	P	P
Kosangi	*Schleichera oleosa*	Sapindaceae	P	P
jiduchettu	*Semecarpus anacardium*	Anacardiaceae	P	A
Neredu chettu	*Syzygium cumini*	Myrtaceae	P	P
Chintachettu	*Tamarindus indica*	Fabaceae	P	A
Nallamaddi	*Terminalia alata*	Combretaceae	P	P
Thellamaddi	*Terminalia arjuna*	Combretaceae	P	P
Tandrachettu	*Terminalia bellirica*	Combretaceae	P	P
Adaviankudu	*Wrightia arborea*	Apocyanaceae	P	P
Kondatangedu	*Xylia xylocarpa*	Fabaceae	P	P
Gotti	*Ziziphus xylopyrus*	Rhamnaceae	A	P

Note: P = Present, A = Absent

(Table 2).

Herb species in study area

Herb species inventory of the natural forest of the study area yielded a total of 14 species belonged to 9 families. It was found that the familys Asteraceaeand Malvaceaeoccupied the highest number of species (3 species) followed by Rubiaceae (2 species each). The remaining families contained one species each. On the other hand, 6 species of

Table 2. Shrub species of natural and coffee agro forest of study area

Local name	Name of the Shrub	Family	Natural forest	Coffee agro forest
Jolidi	*Colebrookea oppositifolia*	Lamiaceae	P	P
kampurodda	*Eupatorium odoratum*	Asteraceae	P	A
Panipedunkikay	*Grewia oppositifolia*	Malvaceae	P	A
Nulitida	*Helicteres isora*	Malvaceae	P	A
Rasagadi	*Solanum erianthum*	Solanaceae	P	A

Note: P = Present, A = Absent

herbs of 5 families were identified in the coffee agro forest. The family Malvaceae dominated containing two species, whereas the remaining families were represented by single species each. Study revealed that 5 species such as *Asparagus racemosus*, *Barleria crystata*, *Phyllanthus rheedii*, *Sida acuta*and *Triumfetta rhomboidea* were common in both types of forests. But, 9 species namely, *Achyranthes aspera*, *Ageratum conyzoides*, *Alpinia galanga, Biophytum sensitivum, Spemacoce pusilla*, *Sida cordifolia, Spermacoce hispida, Synedrella nodiflora* and *Vernonia cinerea*, were reported only in natural forest. *Senna hirsuta* was identified in plantation forest only (Table 3).

Diversity Indices

Table 4 shows the Shannon-Wiener diversity index, Simpson dominance index and the Jaccard's similarity index of the study area's natural forest and coffee agro forest. The most often used indicator of species diversity is the Shannon-Wiener diversity index. The Shannon-Wiener diversity index (H), which measures ecosystem diversity, has a high value for a rich ecosystem with a high species variety and a low value for an ecosystem with low diversity. Therefore, natural forest of the study area was more diverse than coffee agro forest. Shannon-Wiener diversity index for natural forests was 3.26 in terms of tree species, compared to 2.91 for coffee agro forests. The Shannon-Wiener diversity index for shrub species was 1.53 in natural forests and 0.00 in coffee agro forests. In natural and coffee agro forests, respectively, the Shannon- Wiener diversity index for herb species was 2.57 and 1.77. The Shannon-Weiner Index in favour of rare species and Simpson index is weighed in favour of dominant species. Simpson index for natural forests was 0.95 in terms of tree species, compared to 0.92 for coffee agro forests. Simpson index for shrub species was 0.77 in natural forests and 0.00 in coffee agro forests. In natural and coffee agro forests, respectively, the Simpson index

Table 3. Herb species in natural and coffee forests of study area

Local Name	Name of the Herb	Family	Natural forest	Coffee agro forest
Uttaraene	*Achyranthes aspera*	Amaranthaceae	P	A
Nelavemu	*Achyranthes bidentata*	Amaranthaceae	A	A
Pokabanti	*Ageratum conyzoides*	Asteraceae	P	A
Dumparaastramu	*Alpinia galanga*	Zingiberaceae	P	A
Shatavari	*Asparagus racemosus*	Asparagaceae	P	P
Nerugoranta	*Barleria crystata*	Acanthaceae	P	P
Atta Patti	*Biophytum sensitivum*	Oxalidaceae	P	A
Errausirika	*Phyllanthus rheedii*	Phyllanthaceae	P	P
Tsukkakada	*Spemacoce pusilla*	Rubiaceae	P	A
Nugutangedu	*Senna hirsuta*	Fabaceae	A	P
Nelabenda	*Sida acuta*	Malvaceae	P	P
Chirubenda	*Sida cordifolia*	Malvaceae	P	A
Madanaganti	*Spermacoce hispida*	Rubiaceae	P	A
Cinderella weed	*Synedrella nodiflora*	Asteraceae	P	A
Bankatuttara	*Triumfetta rhomboidea*	Malvaceae	P	P
Sahadevichettu	*Vernonia cinerea*	Asteraceae	P	A

Note: P = Present, A = Absent

Table 4. Diversity indices of plant species in natural and coffee forests of study area

Diversity indices	Tree		Shrub		Herb	
	Natural	Coffee	Natural	Coffee	Natural	Coffee
Shannon -wienner index	3.26	2.91	1.53	0	2.57	1.77
Simpson index	0.95	0.92	0.77	0	0.91	0.82
Jaccard similarity index	0.72	0.2	0.33			

for herb species was 0.91 and 0.82 the Jaccard's similarity index allows us to quantify the degree of overlap between the species in the two communities. The lower the values of the similarity index, the higher the heterogeneity. The study site's tree species had a Jaccard similarity value of 0.72, shrub species of 0.2, and herb species of 0.33. The results showed that 72% of the tree species in both Natural and coffee agro forests were similar. For shrubs, there were 20% species that were present in both coffee agro and natural forests. In terms of herb species, both types of forests shared 33% of them. As a result, the two forests had different plant species compositions.

Discussion

Distinguishing plant communities has been at the centre of plant science for centuries, with a traditional focus on the distribution, composition and classification of plant communities (Kashian *et al*., 2003; Norul *et al.,* 2011). Plant communities are differentiated from each other based on indicator species in combination with a distinctive floristic composition (Norul *et al*., 2011). Some species in the research region only appeared in natural forests or coffee forests making up differing species compositions. More unaltered than wild forest was the plantation forest at the research site. Illegal tree cutting and cow grazing have disrupted natural forests. These disturbances may play a role to the higher richness of natural forest than plantations (Norul *et al.,* 2011; Mishra *et al*., 2004) reported that moderately or slightly disturbed tropical forests tend to support more number of species in comparison with a forest which is dense and undisturbed. Though the diversity of trees was higher in natural forest but, density of tree species was higher in the plantation forest than natural forest (Norul *et al*., 2011). In natural forest plant species distributed irregularly by the way of seed dispersal through air, water or animals, whereas distribution pattern in coffee forest somehow regular pattern. Any forest's tree density is associated with its light intensity. Less trees allow for greater open space in the forest, which allows the ground to get more sunshine. The quantity and quality of understory vegetation depend on the amount of light that is accessible. The diversity of shrub and herb species was greater in the natural forest than in the plantation forest. The availability of greater light in natural settings than in plantations may be the cause of this. Uemura (1994) reported that the species diversity of understorey vegetation in different environments vary with light condition. Dense shade creates a photosynthetically inactive light regime at the ground level (Fetcher *et al*., 1983; Turton and Duff, 1992).

Conclusion

My study reveals that the natural forest shows higher biodiversity than the coffee agro forest because density of plant species low number in natural forest that lead to penetrate light to ground, help to herbaceous and shrub species thereby species richness of herbs, shrubs and trees are higher in natural forest than the coffee agro forest. In coffee agro forest coffee plants closely aggregate prevent light penetration to ground thereby prevent herbaceous species growth and coffee growers manually remove shrub species during cultivation of coffee, hence species richness of natural forest were higher than the coffee agro forest but density of species were low. Species richness varies with different habitat. My study area Eastern Ghats of Andhra Pradesh is one of the biodiversity richest area in India.

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