Agroforest Syst (2019) 93:1423–1438
https://doi.org/10.1007/s10457-018-0258-y

Butterfly diversity in agroforestry plantations of Eastern Ghats of southern Odisha, India

Anirban Mahata · Kranti Titikshya Samal · Sharat K. Palita

Received: 8 August 2017 / Accepted: 28 May 2018 / Published online: 1 June 2018

Abstract Agroforestry plays an important role in food security, sustainable development and biodiversity conservation. For understanding the role of agroforestry on biodiversity, a study was undertaken to access butterfly diversity in coffee, cashew and guava plantations in Eastern Ghats of southern Odisha during February–April 2016. A total of 1075 individuals of butterflies belonging to 60 species and 46 genera under five families were recorded during the study. Species richness (*S*) as well as Shannon diversity (*H*) were found to be higher in coffee ($S = 45$, $H = 3.051$) plantation, followed by cashew ($S = 31$, $H = 2.807$) and guava ($S = 20$, $H = 2.519$). However, though butterfly abundance was found to be maximum in coffee (43%), it was higher in guava (33%) followed by cashew (24%). Also, a significant difference was observed between butterfly abundance among three plantations. This shows coffee plantation was the best habitat for butterflies among the three agroforestry habitats studied. The reason for this was habitat heterogeneity in coffee plantation supporting maximum exclusive butterfly species and was least-human influenced with close canopy forest. Over all, family Nymphalidae was found to be the most abundant, and Lycaenidae was the least abundant. The findings of the present study are promising and may set new directions for management of agroforestry plantations in the region to support a rich biodiversity.

Keywords Butterfly · Agroforestry · Coffee · Cashew · Guava · Eastern Ghats · Koraput

A. Mahata · K. T. Samal · S. K. Palita (✉)
Department of Biodiversity and Conservation of Natural Resources, Central University of Orissa, Koraput, Odisha 764021, India
e-mail: skpalita@gmail.com

Introduction

Tropical forests are one of the most biodiversity-rich habitats on the Earth and have been suffering from exceptional rates of habitat degradation due to human activities (Morris 2010; Whitmore 1998). Such human-altered habitats are largely unknown in terms of their biodiversity status in changing scenario of land use and land cover (Schulze et al. 2004; Waltert et al. 2004). However, restoration of these habitats to their natural forested state is unlikely, and hence, agroforestry practices have been suggested as a land use alternative to maintain the land productivity with better ecosystem services and biodiversity status (Jose 2009; Schroth et al. 2004). Hence, assessment of biodiversity of any agroforestry ecosystem is important that ultimately helps in recommending conservation action plan for human-altered landscapes. Insects, being largest animal group, play a key role in overall biodiversity of any area, and among insects, butterflies are one of the important groups (Hill and Hamer 1998; Kremen 1994).

Butterflies play a vital role in ecosystem functioning such as pollinator, important components of food chain, bio-indicator and habitat restorer. The biodiversity of butterflies are linked to their ecosystem by influencing nutrient cycling, plant population dynamics and predator–prey population dynamics (Hammond and Miller 1998). They are highly sensitive to change in temperature, humidity and light levels and are typically affected by habitat disturbance (Murphy et al. 1990; Wood and Gillman 1998). Therefore, they have been identified as good indicators of environmental variation and quality (Erhardt 1985; Gilbert 1984; Kremen 1992). The advantage of using butterfly species as indicators or candidates for ecosystem monitoring is that their tremendous ecological diversity provides a wide choice for designing appropriate assessment programmes (Kremen et al. 1993) which can be applied for short-term and long-term monitoring (Oduro and Aduse-Poku 2005).

The role of agroforestry in species conservation depends on the presence of protected natural areas in the landscape and sustainable agricultural practices such as agroforestry would not be able to support forest-dependent species if remnant natural habitats were converted to agriculture, which would lead to the overall decline of species in the landscape (Francesconi et al. 2013). The studies on butterfly diversity in agroforestry reveal that forest distance was the most significant landscape driver followed by the proportion of semi-natural habitats and abundance, and species richness of butterflies declines linearly with increasing forest distance (Théodore Munyuli 2013).

A range of studies have been published about butterfly diversity in agricultural landscapes in different parts of the world, Rands and Sotherton (1986) in cereal fields of Hampshire, North East England; Aviron et al. (2007) in different landscapes of western France (meadows, plots of cultivated crops, high density of hedgerows and grassy field margins); Théodore Munyuli (2012) in the mixed coffee–banana mosaic (semi-natural, agricultural) landscapes of rural central Uganda; Francesconi et al. (2013) in different land-use practices and forest habitats in Sau Paulo, Brazil; and Remini and Moulaï (2015) in different agricultural landscapes (citrus orchard, market gardening plot, pear orchard, peach orchard and cereal plot) in the eastern part of Mitidja, Algeria. Some studies on butterfly diversity have also been carried out in Eastern Ghats of India—Krishnankutty et al. (2006) studied in tropical dry deciduous forest of Alagar Hills, Tamil Nadu; Prasanna Kumar et al. (2011) in southern Andhra Pradesh; Atluri et al. (2011) in *Anacardium* plantation at Visakhapatnam district of Andhra Pradesh; Ponraman et al. (2015) in three hills of southern Eastern Ghats in Tamil Nadu; and Gideon et al. (2016) in Pachamalai Hills, Tamil Nadu. Although southern Odisha region of Eastern Ghats, India, presents very good example agroforestry plantations, there is hardly any study on butterfly diversity in them. Koraput, a hilly region of Eastern Ghats of South Odisha has seen major landscape changes through conversion of natural forest habitats into agroforestry plantations, the main crop being cashew, although sisal, coffee and other plantation crops have also been promoted (Kumar et al. 2006). Keeping this in mind, the present study was undertaken to document butterfly diversity across three agroforestry plantations (coffee, cashew and guava) in Koraput so as to understand their assemblages in these habitats.

Methodology

Study area

The study was conducted in Koraput district (18°N and 19°N latitude and 82°E and 83°E longitude) (herein after ‘Koraput’) in Odisha, India (Fig. 1). A large portion of the district is mountainous terrains of the Eastern Ghats, which are rich in endemic flora (Misra et al. 2009, 2012) and fauna (Agarwal et al. 2012, 2013; Debata et al. 2015, 2017; Majumdar 1988; Mohapatra et al. 2009, 2016; Palita et al. 2016). Over time, Koraput has experienced large-scale deforestation and increase in agricultural practices due to rapid industrialisation and ‘Podu’ (shifting) cultivation practiced by tribal people along with increased human settlements (Reddy et al. 2012). Forest cover of Koraput is classified into tropical moist deciduous and tropical dry deciduous type (Champion and Seth 1968). Monsoon (July–October) is the most dominating season of the area, with an annual precipitation of 1521 mm. Winter is prolonged from November to March and summer is brief from April to June. The temperature varies from minimum 12 °C to maximum 38 °C. The elevation is between 500 and 1600 m a.s.l.

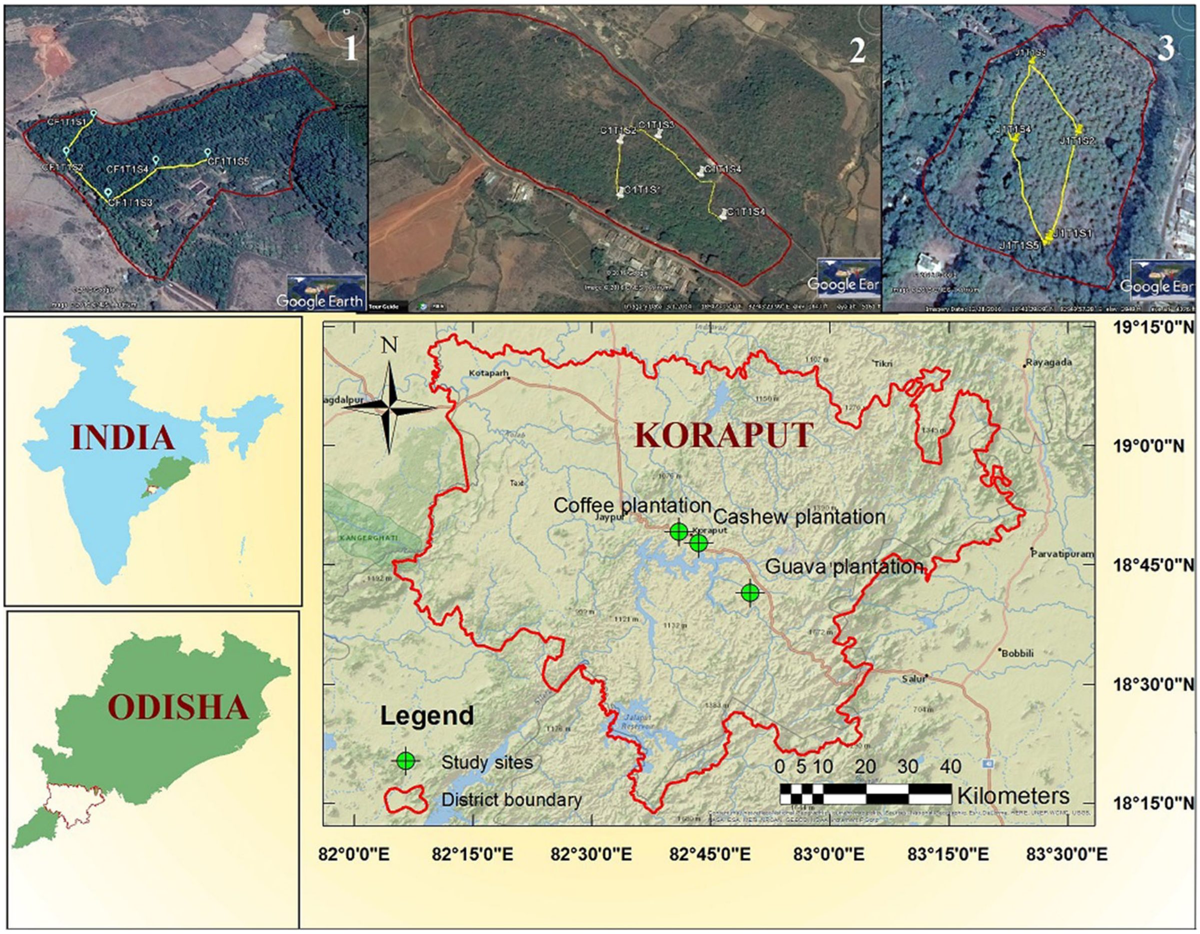

Fig. 1 Study area showing different sites (Google Earth images) in Koraput, Odisha, India, along with transect path (yellow colour) and plantation area (red colour) of coffee plantation (1), cashew plantation (2) and guava plantation (3). (Color figure online)

The present study was carried out in three different agroforestry plantations, i.e. cashew, coffee and guava in different locations in the district of Koraput, and details of sites are mentioned below (Fig. 1). Human impact and grazing activities in the study sites were also measured (Table 1).

Coffee

Coffee is polyculture in nature and was studied in a plot of 10.19 ha area, which merges with forest on the eastern side (Fig. 1). Fourteen varieties of coffee (13 varieties of *Coffea arabica* and 01 variety of *Coffea robusta*) are the main agroforestry plantation, whereas plants like Silky Oak (*Grevillea robusta*), Black Pepper (*Piper nigram*), Jackfruit (*Artocarpus heterophylla*), Mango (*Mangifera indica*), Coco Tamarind (*Albizia saman*), Jamun (*Syzigium cumini*) and Amaltas (*Cassia fistula*) provide shade to coffee. Microclimate of the area is shady and humid. Tree canopy cover (%) is 35.84 ± 1.9, coffee plant density is 38 ± 3.9 (no. of plants ± SE per 10 m^2 quadrate), and shade plant density is 8.8 ± 2.1. The entire plantation area represents almost a closed type environment. The area is well protected without any outside interference, and there is a definite management protocol for coffee plantation with periodic rotational mowing and manuring (Table 1).

Cashew

Cashew (*Anacardium oxcidentale*) is mainly monoculture in nature and was studied in a plot of 15 ha area surrounded by semi-natural area. It is surrounded by

Table 1 Study site location, major plant association, management practices and disturbance index

Parameters	Agroforestry plantations		
	Coffee	Cashew	Guava
GPS location	18°49′09.3″N 82°40′58.0″E	18°47′44.77″N 82°43′28.69″E	18°41′26.60″N 82°50′0.35″E
Altitude (m)	912	858	835
Area (ha)	10.19	15.0	3.70
Microclimate	Shady and humid	Dry	Dry
Plant types			
Major plant	*Coffea arabica* (13 varieties) and *Coffea robusta* (1 variety)	*Anacardium oxcidentale* (1 variety)	*Psidium gujava* (1 variety)
Shade plant	*Grevillea robusta*, *Artocarpus heterophyllus*, *Mangifera indica*, *Piper nigrum*, *Albizia saman*, *Cassia fistula*, *Syzygium cumini*	Nil	Nil
Shrub	The main plant coffee is a shrub	*Lantana camara*, *Chromolema odorata, Clerodendrum infortunatum, Ageratum conyzoides*	*Lantana camara*, *Chromolema odorata, Clerodendrum infortunatum*
Herb	*Cynodon dactylon*, *Tridex procumbens*	*Mimosa pudica*, *Eleusine indica*, *Eragrostis spp*, *Dactyloctenium aegyptium*, *Sida rhombifolia*, *Tridex procumbens*, *Chrysopogon aciculatus*	*Mimosa pudica*, *Parthenium hysterophorus*, *Cynodon dactylon*, *Ocimum sanctum*, *Laportea interrupta*
Plant density			
Major plant density (no of plant ± SE)	38 ± 3.9	6.8 ± 0.86	3.8 ± 0.2
Shade plant density	8.8 ± 2.1	NA	NA
Shrub density	–	27.2 ± 5.5	16.4 ± 3.9
Herb density	4.5 ± 1.1	34.1 ± 3.4	36 ± 2.0
Tree canopy cover (%)	35.84 ± 1.9	29.71 ± 4.6	35.87 ± 3.4
Management practices			
Rotational mowing	Every 3 years	Nil	Nil
Watering	Dependent on rainwater. Artificially watering provided during summer.	Dependent on rainwater	Dependent on rainwater
Pesticides	2 rounds of Bordeaux mix and one round of Hexaconazole-based pesticides are used.	No	No
Manure	NPK-based chemical fertilizer as well as organic fertilizer also used	No	No
Disturbance	Least HI, No G	Moderately HI, Least G	Highly HI, moderately G

Anthropogenic Activity Scale based on number of human encounter and grazing seen during study

Least HI: 0–1 time, moderately HI: 3–4 times, highly HI: 8–10 times encounter

HI human interference, *G* grazing of cattle shrubs like *Lantana camara, Chromolema odorata, Clerodendrum infortunatum, Ageratum conyzoides* and represents an open environment. Cashew plant density is 6.8 ± 0.86, whereas surrounding shrub density is 27.2 ± 5.5. Tree canopy cover (%) is 29.71 ± 4.6 and microclimate is dry. There is no specific management practice here, and moderate human activity and least grazing have been noticed (Table 1).

Guava

Guava (*Psidium gujava*) is orchard in nature and was studied over an area of 3.70 ha close to agricultural fields in a rural set-up (Fig. 1). It is surrounded by shrubs like *Lantana camara*, *Chromolema odorata, Clerodendrum infortunatum* and represents a semi-open environment. Guava plant density is 3.8 ± 0.2, whereas surrounding shrub density is 16.4 ± 3.9. Tree canopy cover (%) is 35.87 ± 3.4 and microclimate is dry. There is no specific management practice adopted here. Increased human activity along with grazing has been noticed in this orchard (Table 1).

Data collection

Data on butterfly diversity were collected from February to April of 2016. Survey was repeated with 15-day gap, for 6 times in each plantation. Sampling of butterflies were carried out in a total of 18 numbers of 400 m modified Pollard transect walks with a constant space of 60 min for each transect in three plantations. Butterflies were counted within an imaginary box of 2.5 m on each side of the path and 5 m in front and above the observer (Van Swaay et al. 2012). Butterflies were counted from 0900 to 1300 h by transect-walk method (Pollard and Yates 1993). A 100-m transect was set up by GPS (Garmin eTrex10, Kansas city, KS, USA), and temperature was recorded through digital thermometer (ST9269, Mextech, India). Temperature varied from 29 to 38 °C (February—29.76 °C, March—33.77 °C, April—37.36 °C).

Butterflies were identified according to Wynter-Blyth (1957), Kunte (2000) and Kehimkar (2008). Species identification was based on visual observation and photo-documentation (Camera: Nikon D5300 with 18–140 mm Nikkon lens, Nikon Corporation, USA). Individual butterfly that could not be identified through visual study during transect flight was caught through butterfly net, identified and released. However, most 'Swift' and 'Dart' group of butterflies under Hesperiidae family could not be identified to the genus level were not included in calculation of abundance.

Habitat analysis

Habitat of three plantations was quantified by stratified random sampling. For tree density, the 400 m pollard transect was divided into 4 equal sections, and at the end of each section, a 10 m^2 quadrate was established. For quantifying shrub density, a 5 m^2 quadrate was placed at the end of each section. For herb density, two random 1 m^2 quadrate was placed inside the 5 m^2 quadrate. Within each plot, major plant density and shade plant density were quantified. Disturbance such as human impact (HI) and grazing of cattle (G) was also measured in and around 5-m visual distance in both side of the whole transect.

Canopy cover was measured with GLAMA app (Gap Light Analysis Mobile App, v.3; Masaryk University, Brno, Czech Republic) available through Google Play. The application was installed in smartphone and the picture of the vegetation was taken by 16 mega pixel rear inbuilt camera of the smartphone at the breast height and canopy cover index and CaCo was calculated through the application (Navarro-Martínez et al. 2017).

Data analysis

Family-wise species richness was analysed in three different plantation areas. Diversity indices were calculated using PAST software Version 3.15 (Natural History Museum, University of Oslo, Norway) (Hammer et al. 2001) and rank-abundance plot using Biodiversity Pro software version 2 (The Scottish Association for Marine Science and the Natural History Museum, London) (McAleece et al. 1997). Statistical analysis for habitat dependency on butterfly assemblage was examined by one-way ANOVA.

For each site, the overall species accumulation curve was generated using the EstimateS Program, version 9.1.0 (Colwell 2016). The number of samples was used as the index of sampling effort. EstimateS was also used to compute richness estimates based on a variety of nonparametric estimators such as Chao 1, Chao 2, ICE (Incidence-based Coverage Estimator), ACE (Abundance-based Coverage Estimator), Jackknife 1 and Jackknife 2 (Nganso et al. 2012) for coffee, cashew and guava plantations.

Shannon–Wiener index (H') is a widely used abundance-based diversity index assuming all species are represented in the sample.

$$H' = -\sum_{i=1}^{s} p_i \ln p_i$$

H′ is the species diversity index, s is the number of species, and p_i is the proportion of individuals of each species belonging to the ith species of the total number of individuals and *ln* is the natural logarithm.

Pielou's evenness index (equitability) or J' deals with species evenness, which is the relative abundance or proportion of individuals among the species. Evenness of species reveals how their relative abundance is distributed in a particular sample or site (Magurran 2004).

$$J' = H' / \ln S$$

where S is the number of species present in the site. The value of J' ranges from 0 to 1. The less the variation in communities between the species, the higher the value of J'.

Bray–Curtis is a popular similarity index based on abundance data among sites and was calculated using PAST software Version 3.15.

Results

Species richness

Table 2 summarises butterfly species diversity and abundance data in three agroforestry plantations (coffee, cashew and guava). A total of 1075 butterflies belonging to 60 species under 45 genera and five families were recorded from study sites. The family Nymphalidae with 26 species (43%) was found to be richest in species, followed by Lycaenidae with 12 species (20%), Hesperiidae with nine species (15%), Pieridae with seven species (12%) and Papilionidae with six species (10%), respectively (Table 2).

Among the study sites, species harvested varied between 20 and 45. The coffee plantation possesses maximum species richness with 45 species (75%), followed by cashew with 31 species (51.6%) and guava with 20 Species (33.3%), respectively (Fig. 2).

Among the recorded butterflies, 10 species are common in three plantations. There are four species under Nymphalidae (*Euploea core*, *Symphaedra nais*, *Tirumala limniace* and *Ypthima huebneri*), three species under Pieridae (Catopsilia pomona, *Catopsilia pyranthe* and *Delias hyparete*), two species under Hesperiidae (*Baoris farri* and *Iambrix salsala*), one in Papilionidae (*Pachliopta aristolochiae*) (Table 2).

The numbers of exclusive species restricted to a single habitat are more in coffee, followed by cashew and guava, respectively, while coffee plantation recorded 25 exclusive species (08 each under Lycaenidae, Nymphalidae, 07 under Hesperiidae and 02 under Pieridae), in cashew seven species (04 under Nymphalidae, 02 under Lycaenidae, and 01 under Pieridae) and in guava only two species (one each under Nymphalidae and Papilionidae), respectively (Table 2).

There is a good representation of forest species (forest-dependent and forest-edge species) among the studied butterflies in three plantations, with maximum of 57.77% in coffee (s = 26), 54.83% in cashew (s = 17) and 35% in guava (s = 7) (Table 2). Among the forest species, members of the family Nymphalidae were represented more in coffee (higher in sub-family Limentidinae and Satyrinae) and cashew (higher in sub-family Limentidinae). Cashew also has a good representation of forest-dependent species under family Papilionidae (sub-family Papilioninae) (Table 2).

The study revealed the occurrence of six species under Schedule category of Indian Wildlife Act. 1972, i.e. four species under Schedule I (*Castalius rosimon*, *Euploea midamus*, *Lethe europa and Chilasa clytia*), three species under Schedule II (*Cynitia lepidea*, *Neptis ananta*, *Rapala varuna*) and two species under Schedule IV (*Boaris farri* and *Euploea core*) (Table 2). IUCN Red List status (IUCN 2017) of butterflies indicate that only five species are under least concern (LC) category (*Euploea core*, *Euploea midamus*, *Hypolimnas bolina*, *Junonia almana* and *Eurema brigitta*) and rest 55 species are under not evaluated (NE) category (Table 2).

Estimated species richness

Species richness estimators showed that the observed species richness (S_{ob}) underestimates true species richness at three agroforestry plantations. The

Table 2 Species abundance data of three agroforestry plantations (coffee, cashew and guava) in Koraput, Odisha

Sl no	Scientific name	Common name	E-cat	Average abundance of butterflies (mean ± SE)			IUCN/WPA status
				Coffee	Cashew	Guava	
Family—Hesperiidae (9 species), sub-family—Coeliadinae							
1.	*Hasora chromus* Cramer, 1780	Common Banded Awl	WSS	1.33 ± 0.61	0	0	NE
Sub-family—Hesperiine							
2.	*Baoris farri* Moore, 1878	Paintbrush Swift	FDS	0.33 ± 0.33	0.16 ± 0.16	0.16 ± 0.16	NE/Sch IV
3.	*Gangara thyrsis* Fabricius, 1775	Giant Redeye	FDS	0.5 ± 0.34	0	0	NE
4.	*Iambrix salsala* Moore, 1866	Chestnut Bob	FDS	10.83 ± 3.73	0.16 ± 0.16	0.33 ± 0.21	NE
5.	*Notocrypta curvifascia* (Felder &Felder, 1862)	Restricted Demon	FDS	0.16 ± 0.16	0	0	NE
6.	*Suastus gremius* Fabricius, 1798	Indian Palm Bob	WSS	0.16 ± 0.16	0	0	NE
7.	*Telicota augias* (Linnaeus, 1763)	Pale Palm Dart	OHPS	0.66 ± 0.49	0	0	
Sub-family—Pyrginae							
8.	*Sarangesa dasahara* (Moore, [1866])	Common Small Flat	FES	7.5 ± 2.82	0	0	NE
9.	*Tagiades litigiosa* Moeschler, 1878	Water Snow Flat	FDS	1.83 ± 0.79	0	0	NE
Family—Lycaenidae (12 species), sub-family—Nemeiobiinae							
10.	*Abisara echeria* (Stoll, [1790])	Plum Judy	FDS	0.83 ± 0.40	0	0	NE
Sub-family—Polyommatinae							
11.	*Castalius rosimon* (Fabricius, 1775)	Common Pierrot	OHPS	0.5 ± 0.22	0	0	NE/Sch I
12.	*Catochrysops strabo* (Fabricius, 1793)	Forgetmenot	OHPS	0	0.33 ± 0.21	0.66 ± 0.21	NE
13.	*Freyeria trochylus* (Freyer, 1845)	Grass Jewel	OHPS	0.33 ± 0.21	0.66 ± 0.21	0	
14.	*Jamides celeno* (Cramer, [1775])	Common Cerulean	FDS	0	0.16 ± 0.16	0	NE
15.	*Petrelaea dana* (de Niceville, [1884])	Dingy Line blue	FDS	0.66 ± 0.49	0	0	NE
16.	*Pseudozizeeria maha* (Kollar, [1844])	Pale Grass Blue	OHPS	0	0.16 ± 0.16	0	NE
17.	*Zizula hylax* (Fabricius, 1775)	Tiny Grass Blue	OHPS	1.33 ± 0.49	0	0	NE
Sub-family—Theclinae							
18.	*Rapala pheretima* (Hewitson, 1863)	Copper Flash	FDS	0.16 ± 0.16	0	0	NE
19.	*Rapala varuna* (Horsfield, 1829)	Indigo Flash	OHPS	0.16 ± 0.16	0	0	NE/Sch II
20.	*Spindasis syama* (Horsfield, 1829)	Club Silverline	FDS	0.16 ± 0.16	0	0	NE
21.	*Spindasis vulcanus* (Fabricius, 1775)	Common Silverline	OHPS	0.16 ± 0.16	0	0	NE
Family—Nymphalidae (26 species), sub-family—Biblidinae							
22.	*Ariadne merione* Cramer, 1779	Common Castor	WSS	0.5 ± 0.22	0	0	NE
Sub-family—Cyrestinae							
23.	*Cyrestis thyodamas* Boisduval, 1836	Common Map	FDS	0.5 ± 0.34	1.66 ± 0.49	0	NE

Table 2 continued

Sl no	Scientific name	Common name	E-cat	Average abundance of butterflies (mean ± SE)			IUCN/WPA status
				Coffee	Cashew	Guava	
Sub-family—Daninae							
24.	*Danaus chrysippus* Linnaeus, 1758	Plain Tiger	WSS	0.33 ± 0.21	0	0	NE
25.	*Danaus genutia* (Cramer, [1779])	Common Tiger	WSS	0	0.83 ± 0.30	4.66 ± 0.49	NE
26.	*Euploea core* Cramer, 1780	Common Crow	WSS	8.5 ± 0.67	8.66 ± 1.60	10.83 ± 0.30	LC/Sch IV
27.	*Euploea midamus* Linnaeus, 1758	Spotted Blue Crow	FES	0	0.33 ± 0.21	0	LC/Sch I
28.	*Parantica aglea* Stoll, 1782	Glassy Tiger	FDS	1.66 ± 0.42	0	1.66 ± 0.49	NE
29.	*Tirumala limniace* Cramer, 1775	Blue Tiger	WSS	0.83 ± 0.30	3.5 ± 0.84	6.83 ± 1.04	NE
30.	*Tirumala septentrionis* Butler, 1874	Dark Blue Tiger	FDS	0	0.5 ± 0.22	0	NE
Sub-family—Heliconiinae							
31.	*Phalanta phalantha* Drury, 1773	Common Leopard	WSS	0.33 ± 0.21	0	0.83 ± 0.47	NE
Sub-family—Limentidinae							
32.	*Athyma perius* Linnaeus, 1758	Common Sergeant	FES	1.16 ± 0.60	0	0	NE
33.	*Cynitia lepidia* (Butler, 1868)	Grey Count	FDS	0.16 ± 0.16	0	0	NE/Sch II
34.	*Moduza procris* (Cramer,[1777])	Commander	FDS	0	0.33 ± 0.21	0	NE
35.	*Neptis ananta* Moore, 1857	Yellow Sailer	FDS	0	0.33 ± 0.21	0	NE/Sch II
36.	*Neptis hylas* (Linnaeus, 1758)	Common Sailer	FDS	9.5 ± 1.60	2.33 ± 0.42	0	NE
37.	*Pantoporia hordonia* (Stoll, [1790])	Common Lascar	FDS	0.33 ± 0.21	0	0	NE
38.	*Symphaedra nais* (Forster, 1771)	Baronet	OHPS	0.33 ± 0.21	0.33 ± 0.21	0.83 ± 0.30	NE
Sub-family—Nymphalinae							
39.	*Hypolimnas bolina* Linnaeus, 1758	Great Eggfly	FDS	1.33 ± 0.42	0	0	LC
40.	*Junonia almana* (Linnaeus, 1758)	Peacock Pansy	SWSS	0	0	1.33 ± 0.42	LC
41.	*Junonia iphita* (Cramer, [1779])	Chocolate Pansy	FDS	0.83 ± 0.54	2.83 ± 0.74	0	NE
42.	*Junonia lemonias* (Linnaeus, 1758)	Lemon Pansy	OHPS	0	0.33 ± 0.21	2.5 ± 0.22	NE
Sub-family—Satyrinae							
43.	*Elymnias hypermnestra* Linnaeus, 1763	Common Palmfly	FDS	0.33 ± 0.21	0	0	NE
44.	*Lethe europa* (Fabricius, 1775)	Bamboo Treebrown	FDS	0.5 ± 0.22	0	0	NE/Sch I
45.	*Melanitis leda* (Linnaeus, 1758)	Common Evening Brown	WSS	5.33 ± 1.28	1.83 ± 0.87	0	NE
46.	*Mycalesis perseus* (Fabricius, 1775)	Common Bushbrown	FDS	4.33 ± 0.95	3.16 ± 1.13	0	NE
47.	*Ypthima huebneri* Kirby, 1871	Common Four-ring	FDS	2.5 ± 0.71	1.66 ± 0.42	5.16 ± 0.30	NE
Family—Papilionidae (6 species), sub-family—Papilioninae							
48.	*Chilasa clytia* (Linnaeus, 1758)	Common Mime	FDS	0	0.83 ± 0.47	0.66 ± 0.21	NE/Sch I
49.	*Graphium agamemnon* (Linnaeus, 1758)	Tailed Jay	FDS	2.5 ± 0.5	0.16 ± 0.16	0	NE
50.	*Graphium nomius* (Esper, 1798)	Spot Swordtail	FDS	0	0.16 ± 0.16	0.33 ± 0.21	NE

Table 2 continued

Sl no	Scientific name	Common name	E-cat	Average abundance of butterflies (mean ± SE)			IUCN/WPA status
				Coffee	Cashew	Guava	
51.	*Pachliopta aristolochiae* (Fabricius, 1775)	Common Rose	OHPS	0.16 ± 0.16	0.5 ± 0.22	0.16 ± 0.16	NE
52.	*Papilio demoleus* Linnaeus, 1758	Lime Swallowtail	OHPS	0	0	5.66 ± 0.49	NE
53.	*Papilio polymnestor* Cramer, [1775]	Blue Mormon	FDS	0.16 ± 0.16	0.16 ± 0.16	0	NE
Family—Pieridae (7 species), sub-family—Colladinae							
54.	*Catopsilia pomona* (Fabricius, 1775)	Common Emigrant	OHPS	1.5 ± 0.71	6 ± 0.63	8.83 ± 0.47	NE
55.	*Catopsilia pyranthe* (Linnaeus, 1758)	Mottled Emigrant	OHPS	0.33 ± 0.21	0.83 ± 0.47	2.16 ± 0.65	NE
56.	*Eurema blanda* (Boisduval, 1836)	Three-spot Grass Yellow	FDS	2.5 ± 0.56	0	0	NE
57.	*Eurema brigitta* (Stoll, [1780])	Small Grass Yellow	OHPS	1.16 ± 0.65	0	0	LC
58.	*Eurema hecabe* (Linnaeus, 1758)	Common Grass Yellow	SWSS	0	1.33 ± 0.42	0	NE
Sub-family-Pierinae							
59.	*Delias hyparete* (Linnaeus, 1758)	Painted Jezabel	FDS	1.33 ± 0.49	2 ± 0.36	3.83 ± 0.47	NE
60.	*Pareronia valeria* (Cramer, [1776])	Common Wanderer	OHPS	0	0.66 ± 0.33	2 ± 0.96	NE

FDS forest-dependent species, *FES* forest-edge/woodland species, *OHPS* open habitat specialist species, *WSS* widespread species, *SWSS* swamp/wetland specialist species, *NE* not evaluated, *LC* least concern, *Sch* schedule, *WPA* Wildlife (Protection) Act of India, 1972

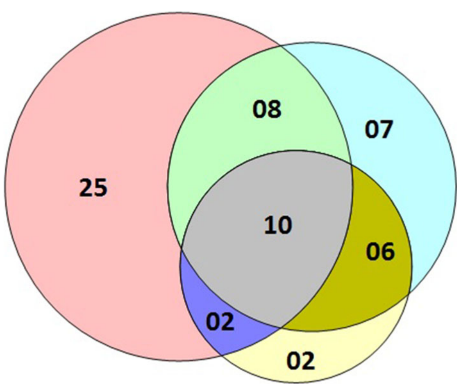

Fig. 2 Venn diagram showing habitat-wise species richness in three agroforestry plantations in Koraput (circles on the basis of decreasing size belongs to coffee, cashew and guava, respectively)

incidence-based richness estimator (ICE and Chao 2), abundance-based richness estimator (ACE and Chao 1), Jack 1 and Jack 2 tended to level with increasing sample size and produced stable and broadly accurate estimates at small number of samples (Table 3; Fig. 3). In all three plantations, observed species richness underestimates true species richness, when unique species are either more or equal to singletons in assemblages sampled. In case of coffee, all six estimators showed that S_{ob} underestimates true species, in which unique species are more than singletons/doubletons. In case of cashew, S_{ob} underestimates true species richness, in which unique species number are same as that of singletons/doubletons. In case of guava, while Chao 1/Chao 2 estimators indicate that S_{ob} is equal with true species richness, ACE/ICE and Jack 1/Jack 2 estimators indicate that S_{ob} underestimates true species richness, and the number of unique species is equal with singletons/doubletons (Table 3).

Among the three agroforestry plantations of the present study, the observed species richness of butterflies in coffee was higher in comparison with cashew and guava (Table 3). An analysis of the species accumulation curves (Fig. 3) shows that in all three cases (coffee, cashew and guava) asymptote has

Table 3 Butterfly species diversity data for three agroforestry plantations in Koraput

Sites	Observed species richness	Singletons/doubletons	Uniques/ Duplicates	Estimate of total richness ACE/ICE	Additional species prediction Chao 1/Chao 2	Diversity indices Jack 1/Jack 2	Evenness indices	Shannon (H')	Pielou (J')
Coffee	45	9/8	10/12	51/52	49/48	53/54	3–9	3.051	0.4698
Cashew	31	7/6	7/6	37/36	34/34	37/38	3–7	2.807	0.5341
Guava	20	2/2	2/2	21/21	20/20	22/22	0–2	2.519	0.6206

Singletons and doubletons are the number of species represented by one or two individuals, respectively; uniques and duplicates are the number of species occurring in only one or two samples, respectively; nonparametric richness estimators were used to estimate total species richness at a site; ACE and Chao 1 are abundance-based richness estimators. All others (ICE, Chao 2, Jack 1 and Jack 2) are incidence-based estimators (Nganso et al. 2012)

been reached, which indicates that species saturation had been reached and sampling effort was adequate (Nganso et al. 2012).

Species diversity and abundance

Among the sampled butterflies, maximum of 460 were recorded in coffee (43%), followed by 357 in guava (33%) and 258 in cashew (24%), respectively. The most abundant butterflies were recorded from coffee plantation, *Iambrix salsala* is the most abundant species (65 individuals), followed by *Neptis hylas* (57 individuals) and *Euploea core* (51 individuals), respectively. Coffee plantation exhibited maximum species richness as well as abundance whereas guava plantation has lowest species diversity but second-most abundant species population. Among the butterfly families, Nymphalidae is the most abundant family accounting for 57.3% of the recorded specimens, followed by family Pieridae with 19.26% and family Hesperiidae with 13.49%. Family Papilionidae with 6.42% and Lycaenidae with 3.53% abundance are the least abundant families with the least number of individuals (Table 4).

Higher species diversity in terms of butterfly species was observed in coffee plantation with the Shannon–Wiener index value $H'= 3.05$, followed by cashew plantation with $H'= 2.80$. The guava plantation exhibits the lowest species diversity with $H'= 2.51$ (Table 3). The rank-abundance curve shows maximum species richness in coffee plantation (Fig. 4). Very few species dominated in three plantations and exclusive species are more in coffee plantation. Coffee plantation possesses lowest evenness whereas guava plantation possesses greater species evenness. Bray–Curtis cluster analysis shows that guava and cashew plantations have more species similarity than coffee plantation (Fig. 4).

One-way ANOVA indicated that there is a significant difference in total species abundance among three plantations [$F = 8.915$, $p = 0.002$ (< 0.05)]. However, on comparing family-wise abundance data in three plantations, it was revealed that species under family Nymphalidae only shows similarity in abundance [$F = 1.804$, $p = 0.198$ (> 0.05)] (Table 4).

Discussion

In the present study, among three agroforestry plantations, coffee plantation shows highest butterfly species richness, maximum abundance and higher species diversity in comparison with cashew and guava plantations, which may be due to habitat heterogeneity supporting maximum exclusive butterfly species along with higher plant density, humid condition as well as closed system with good canopy cover. Based on the result, the presence of forest species in coffee plantation was higher compared to cashew and guava, which may be due to its proximity to natural forest. The study is consistent with the earlier finding of Francesconi et al. (2013). In addition, tree density was relatively higher in shaded coffee compared to the other land-use practices, which may be identified as a predictor of butterfly species richness (Bobo et al. 2006). Francesconi et al. (2013) is of the opinion that shaded coffee resembles an open canopy forest patch in the agricultural landscape, which would explain a more similar butterfly species composition to that of the forest habitats.

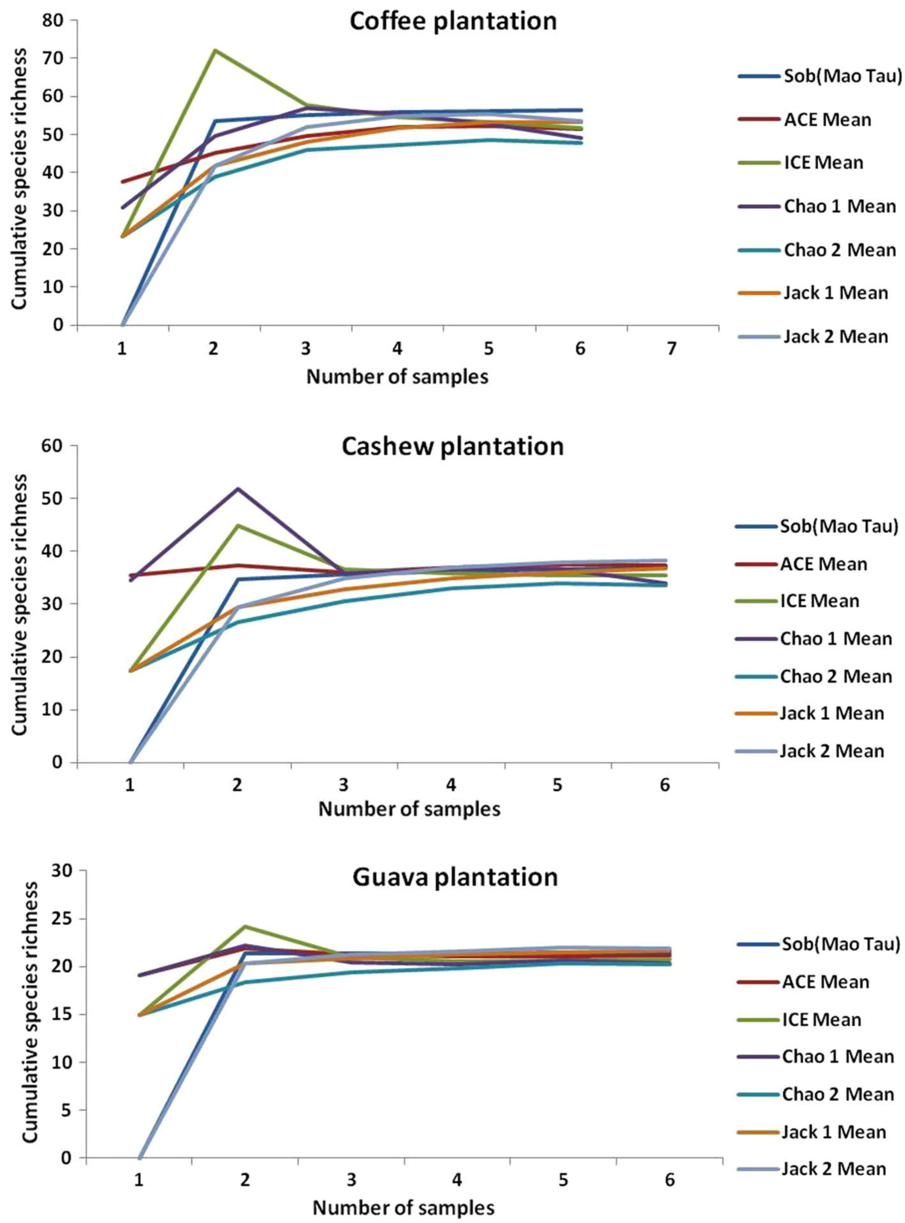

Fig. 3 Randomised species accumulation curves for butterflies in three agroforestry plantations at Koraput, Odisha. Number of observed and estimated species at each site as a function of increasing numbers of samples. Chao 1, Chao 2, ACE, ICE, Jack 1 and Jack 2 = nonparametric estimates of species richness; Sobs = actual species observed in samples

Adoption of specific management practices in coffee plantation of the present study through rotational mowing in every three years, manuring and watering provides a better environmental condition. In addition, least anthropogenic disturbance makes the coffee plantation protected. Further, mixed culture in coffee plantations may provide favourable environment for butterflies. In contrast, Dolia et al. (2008) view that coffee plantations may not provide sufficient food resources for adult butterflies and their larvae. However, these plantations may provide butterflies with non-consumable resources (e.g. roosting, resting, basking and mate location), which are also important for their survival. By providing such additional resources, coffee plantations may enhance landscape supplementation (Dunning et al. 1992). Although large areas of relatively undisturbed forests are essential for preserving biodiversity, opportunities for conservation in human-dominated landscapes must not be overlooked. Agroforestry systems such as

Table 4 Butterfly species abundance of three agroforestry plantations in Koraput

Family	Coffee Abundance (%)	Cashew	Guava	Total	F value (*df* = 2.15)	*p*-probability
Hesperiidae	140	2	3	145 (13.49%)	11.333	0.001 (< 0.05)
Lycaenidae	26	8	4	38 (3.53%)	5.919	0.012 (< 0.05)
Nymphalidae	236	172	208	616 (57.3%)	1.804	0.198 (> 0.05)
Papilionidae	17	11	41	69		
(6.42%)	14.823	0.000 (< 0.001)				
Pieridae	41	65	101	207		
(19.26%)	14.384	0.000 (< 0.001)				
Total individual	460 (43%)	258 (24%)	357 (33%)	1075 (100%)	8.915	0.002 (< 0.05)

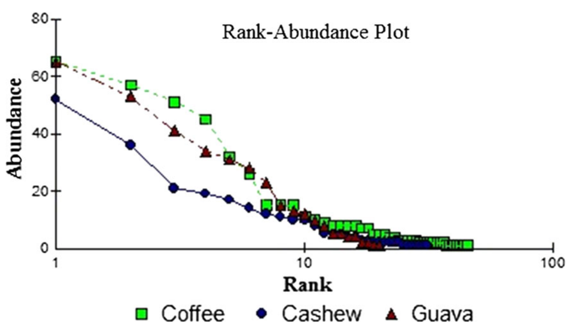

Fig. 4 Rank-abundance plot of butterflies three agroforestry plantations in Koraput

shaded coffee plantations are known to be more compatible with biodiversity conservation than other, more drastic, land transformations (Dolia et al. 2008).

Though cashew plantation in the present study records a lower density of cultivated plants, density of shrub and herbs in this plantation is quite high, thereby providing very good ground cover, which may be suitable for butterflies. However, lack of specific management practices, dry microclimate and moderate level of disturbance are causes of concern for this agroforestry plantation. Investigation on the impacts of cashew cultivation on biodiversity using butterfly assemblages in Guinea-Bissau (West Africa) indicated slightly lower overall species richness and abundance of butterflies in cashew orchards than in native woodland habitats, whereas the former were dominated by generalist species, the latter showed a much higher richness and abundance of trophic and habitat specialists (Vasconcelos et al. 2015). In the present study, cashew recorded 31 species of butterfly, next to its richness in coffee plantation along with quite a good number of exclusive and forest species of butterflies, which may be due to good ground cover with shrub and herbs. Further, the plantation area being largest (15 ha) among three plantations may also be responsible for quite a good species richness of butterflies in cashew.

In case of guava, least number of species was recorded, which may be due to low density of cultivated plants, ground cover was dominated by exotic plants and microclimate being dry (Table 1). Further, lack of specific management practices along with high anthropogenic disturbance, grazing pressure and comparatively smaller plantation area (3.7 ha) may also be responsible for lower butterfly species richness in guava. This finding in guava is consistent with theoretical expectation of species–area relationship, whereby small areas tend to support fewer species (May and Stumpf 2000; Purvis and Hector 2000).

In the present study, significant difference in species abundance ($p < 0.05$) in three plantations was observed along with species richness. Rank-abundance curve indicates the presence of less number of abundant species and large number of unique species during sampling. Cashew and guava showed maximum similarity (50.69%) (Fig. 5) in butterfly species, in comparison with coffee, which may be due to a combination of several factors, viz. openness of the agrosystems, dry microclimate and near similarity in ground cover (herbs and shrubs) (Table 1). However, more sampling is required for three plantations for understanding complete habitat dependency of butterflies.

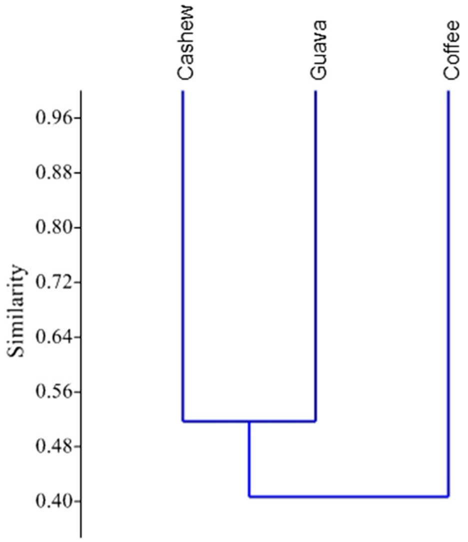

Fig. 5 Bray–Curtis cluster analysis among three agroforestry plantations in Koraput

Among the butterfly families recorded, the family Nymphalidae with maximum abundance and highest species richness are the most successful family among the studied three agroforestry plantations with a good representation of forest species. Similarly, Fermon et al. (2005) report higher diversity and abundance of Nymphalidae in a disturbed forest in comparison with natural forests site. Nymphalidae has a strong association with the highly disturbed site, and therefore, it appears to be disturbance tolerant (Khan and Rastogi 2015). Monitoring butterflies could guide management on a smaller scale and over shorter periods, and baited nymphalid butterflies seem to provide a good indicator tool (Fermon et al. 2000). Findings of Bobo et al. (2006) confirmed that species richness and diversity do not represent powerful indicators of forest disturbance on smaller scale, but that the abundance of butterfly species, particularly of the Nymphalidae family, with smallest geographic ranges is of a much more indicative value in the present study (Fermon et al. 2000, 2005).

In recent years, conservationists have placed increasing emphasis on the importance of conserving biodiversity and ecosystem services outside of protected areas, including in agricultural landscapes (Harvey et al. 2008; Gardner et al. 2009). Such efforts are recognised as critical for buffering and connecting nature reserves, maintaining populations of native species, and increasing the resilience of rural regions to climate change and other disturbances (Bennett 2003; Fischer and Lindenmayer 2007). Bhagwat et al. (2008), Philpott et al. (2008), and Scales and Marsden (2008) examined the results of various biodiversity studies comparing species richness values in agroforestry and forest habitats. These as well as many other authors have come to the conclusion that agroforestry can play an important role in biodiversity conservation (Estrada et al. 2000; Harvey et al. 2006; Harvey and Villalobos 2007; Perfecto et al. 2005; Wezel and Bender 2003). Francesconi et al. (2013) are of the view that agroforestry plots cannot replace natural habitats. The role of agroforestry in species conservation depends on the presence of protected natural areas in the landscape. Further, they are of the view that sustainable agricultural practices such as agroforestry would not be able to support forest-dependent species if remnant natural habitats were converted to agriculture, which would lead to the overall decline of species in the landscape. The present study at Koraput in Eastern Ghats showed that coffee plantation close to natural forest and cashew surrounded by semi-natural area had higher species richness and abundance of butterflies in comparison with guava. Similar findings have been reported by Dolia et al. (2008) around a protected area in Western Ghats of India and Théodore Munyuli (2013) from Central Uganda, in which both the abundance and species richness of butterflies declined linearly with increasing forest distance. Further, it is suggested that the ability of different agricultural land uses (human-dominated landscapes) to support Lepidoptera communities can be enhanced if tree plantations/crop fields are established in proximity to surrounding primary forests (Hawes et al. 2009; Théodore Munyuli 2013).

In conclusion, the present study represents the first survey of butterfly diversity in agroforestry plantations of Koraput, Odisha. The butterfly diversity in the present study varied with different agroforestry plantations in Koraput. The variation in species richness and abundance may be due to nature of agroforestry plantations or due to management practices adopted along with distance of the plantations from the natural forest. As butterfly acts as umbrella species (New 1997), the findings of the present study are promising and may set new directions for management of agroforestry plantations in the region to support a rich biodiversity. Further, the degraded lands require agroforestry plantations, which may increase butterfly diversity as well as increase in the socio-economic level of tribal people.

Acknowledgements The authors are grateful to University Grant Commission, New Delhi, for providing NON-NET fellowship to the first author (Reference No: CUO/ACA/NNF-PHD/135). We are also thankful to the Senior Liaison Officer, Coffee Board, Koraput and Koraput Forest Division, Koraput for necessary support to carry out our study. Special thanks to the Editor and reviewers for their valuable suggestions in improvising the manuscript.

References

Agarwal I, Datta-Roy A, Bauer AM, Giri VB (2012) Rediscovery of *Geckoella jeyporensis* (Squamata: Gekkonidae), with notes on morphology, coloration and habitat. Hamadryad 36(1):17–24

Agarwal I, Wilkinson M, Mohapatra PP, Dutta SK, Giri VB, Gower DJ (2013) The first teresomatan caecilian (Amphibia: Gymnophiona) from the Eastern Ghats of India—a new species of *Gegeneophis* Peters, 1880. Zootaxa 3696(4):534–546

Atluri JB, Chinna Rao K, Sandhya Deepika D, Bhupathirayalu M (2011) Butterfly species richness and seasonality in the Anacardium Plantation. The Ecoscan 6(2):249–254

Aviron S, Jeanneret P, Schüpbach B, Herzog F (2007) Effects of agri-environmental measures, site and landscape conditions on butterfly diversity of Swiss Grassland. Agric Ecosyst Environ 122(3):295–304

Bennett AF (2003) Linkages in the landscape: the role of corridors and connectivity in wildlife conservation. IUCN, Gland

Bhagwat SA, Willis KJ, Birks HJB, Whittaker RJ (2008) Agroforestry: a refuge for tropical biodiversity? Trends Ecol Evol 23:261–267

Bobo KS, Waltert M, Sainge NM, Njokagbor J, Fermon H, Muhlenberg M (2006) From forest to farmland: species richness patterns of trees and understorey plants along a gradient of forest conversion in southwestern Cameroon. Biodivers Conserv 15:4097–4117

Champion HG, Seth SK (1968) A revised survey of forest types of India. Govt. of India Press, New Delhi

Colwell RK (2016) EstimateS: statistical estimation of species richness and shared species from samples, Version 9.0.1. User's guide and application published. http://viceroy.eeb.uconn.edu/estimates/EstimateSPages/EstSUsersGuide/EstimateSUsersGuide.htm

Debata S, Palei HS, Mohapatra PP, Palita SK (2015) Additional records of Cantor's Leaf-Nosed Bat *Hipposideros galeritus* Cantor, 1846 (Mammalia: Chiroptera: Hipposideridae) in eastern India: Odisha. J Threat Taxa 7(8):7477–7479. https://doi.org/10.11609/JoTT.o4247.7477-9

Debata S, Palita SK, Nayak AK (2017) Lesser False Vampire—additional record of the Lesser False Vampire from Odisha, India. Zoos' Print J XXXII 1:21–25

Dolia J, Devy MS, Aravind NA, Kumar A (2008) Adult butterfly communities in coffee plantations around a protected area in the Western Ghats, India. Anim Conserv 11(1):26–34

Dunning JB, Danielson BJ, Pulliam HR (1992) Ecological processes that affect populations in complex landscapes. Oikos 65(1):169–175

Erhardt A (1985) Diurnal Lepidoptera: sensitive indicator of cultivated and abandoned Grassland. J Appl Ecol 22(3):849–861

Estrada A, Cammarano P, Coates-Estrada R (2000) Bird species richness in vegetation fences and in strips of residual rain forest vegetation at Los Tuxtlas, Mexico. Biodivers Conserv 9:1399–1416

Fermon H, Waltert M, Larsen TB, Dall'Asta U, Mühlenberg M (2000) Effects of forest management on diversity and abundance of fruit-feeding nymphalid butterflies in south-eastern Côte d'Ivoire. J Insect Conserv 4:173–189

Fermon H, Waltert M, Vane-Wright RI, Muhlenberg M (2005) Forest use and vertical stratification in fruit-feeding butterflies of Sulawesi, Indonesia: impacts for conservation. Biodivers Conserv 14:333–350

Fischer J, Lindenmayer DB (2007) Landscape modification and habitat fragmentation: a synthesis. Glob Ecol Biogeogr 16:265–280

Francesconi W, Nair PKR, Levey DJ, Daniels J, Cullen L Jr (2013) Butterfly distribution in fragmented landscapes containing agroforestry practices in Southeastern Brazil. Agroforest Syst 87:1321–1338

Gardner TA, Barlow J, Chazdon R, Ewers RM, Harvey CA, Peres CA, Sodhi NS (2009) Prospects for tropical forest biodiversity in a human-modified world. Ecol Lett 12:561–582

Gideon VA, Rufus KC, Vivekraj P (2016) A study on nectar host plants of butterflies of Pachamalai Hills of Eastern Ghats in Tamil Nadu, India. Ann Biol Res 7(9):9–12

Gilbert LE (1984) The biology of butterfly communities: the biological butterflies. Academic Press, Landon

Hammer Ø, Harper DAT, Ryan PD (2001) Paleontological statistics software package for education and data analysis. Paleontol Electron 4:19

Hammond PC, Miller JC (1998) Comparison of the biodiversity of Lepidoptera within three forested ecosystems. Ann Entomol Soc Am 91(3):323–328

Harvey CA, Villalobos JAG (2007) Agroforestry systems conserve species-rich but modified assemblages of tropical birds and bats. Biodivers Conserv 16:2257–2292

Harvey CA, Gonzalez J, Somarriba E (2006) Dung beetle and terrestrial mammal diversity in forests, indigenous agroforestry systems and plantain monocultures in Talamanca, Costa Rica. Biodivers Conserv 15:555–585

Harvey CA, Komar O, Chazdon R, Ferguson BG, Finegan B, Griffith DM, Martínez-Ramos M, Morales H, Nigh R, Soto-Pinto L, Breugel MV, Wishnie M (2008) Integrating agricultural landscapes with biodiversity conservation in the Mesoamerican Hotspot. Conserv Biol 22:8–15

Hawes J, Motta CDS, Overal WL, Barlow J, Gardner TA, Peres CA (2009) Diversity and composition of Amazonian moths in primary, secondary and plantation forests. J Trop Ecol 25(3):281–300

Hill JK, Hamer KC (1998) Using species abundance model as indicators of habitat disturbance in tropical forest. J Appl Ecol 35(3):458–460

IUCN (2017) The IUCN red list of threatened species, Version 2017-23. http://www.iucnredlist.org. Accessed 20 Sept 2017

Jose S (2009) Agroforestry for ecosystem services and environmental benefits: an overview. Agrofor Syst 76(1):1–10

Kehimkar I (2008) The book of Indian butterflies. Bombay Natural History Society. Oxford University Press, New York

Khan SR, Rastogi N (2015) Impact of mining activity on butterfly diversity and community composition. J Entomol Zool Stud 3(4):178–185

Kremen C (1992) Assessing the indicator properties of species assemblages for natural area monitoring. Ecol Appl 2(2):203–217

Kremen C (1994) Biological inventory using target taxa: a case study of the butterflies of Madagascar. Ecol Appl 4(3):407–422

Kremen C, Colwell RK, Erwin TC, Murphy DD, Noss RF, Sanjayan MA (1993) Terrestrial arthropod assemblages: their use in conservation planning. Conserv Biol 7(4):796–808

Krishnankutty N, Chandrasekaran S, Jeyakumar G (2006) Evaluation of disturbance in a tropical dry deciduous forest of Alagar hill (Eastern Ghats), South India. Trop Ecol 47(1):47–55

Kumar K, Soumendra, Giri Rao Y (2006) Livelihoods, security and conflict—Orissa, India. In: Patricia M (eds), Resource rights, sustainable livelihoods, environmental security and conflict mitigation in South Asia. IUCN, Asia Regional Office, Bangkok; IUCN, USA Multilateral Office, Washington, DC, US

Kunte K (2000) Butterflies of Peninsular India. Universities Press and Bengaluru/Indian Academy of Sciences, Hyderabad

Magurran AE (2004) Measuring biological diversity. Wiley/Blackwell, NJ

Majumdar N (1988) On a collection of birds from Koraput district, Orissa, India. Rec. Zoological Survey of India, Miscellaneous Publication Occasional Paper 108, pp 1–56

May RM, Stumpf MPH (2000) Species-area relations in tropical forests. Science 290:2084

McAleece N, Gage JDG, Lambshead PJD, Paterson GLJ (1997) BioDiversity professional statistics analysis software. Jointly developed by the Scottish Association for Marine Science and the Natural History Museum, London

Misra MK, Das PK, Dash SS (2009) Phytodiversity and useful plants of eastern Ghats India (A special reference to the Koraput region). International Book Distributors, Dehra Dun

Misra MK, Panda A, Sahu D (2012) Survey of useful wetland plants of South Odisha, India. Indian J Tradit Knowl 11(4):658–666

Mohapatra PP, Dash PK, Mishra SN (2009) Biodiversity assessment in some selected Hill Forests of South Orissa, India. Downloaded from www.indiaenvironmentportal.org.in/reports-documents/biodiversity-assessment-some-selected-hill-forests-south-orissa-india. Downloaded on 25 Jan 2016

Mohapatra PP, Schulz K, Helfenberger N, Hofmann S, Dutta SK (2016) A Contribution to the Indian Trinket Snake, *Coelognathus helena* (Daudin, 1803), with the description of a new subspecies. Prussian J Herpet 23(2):115–144

Morris RJ (2010) Anthropogenic impacts on tropical forest biodiversity: a network structure and ecosystem functioning perspective. Phil Trans R Soc B 365:3709–3718

Murphy DD, Freas KE, Weiss SB (1990) An environment-metapopulation approach to population viability analysis for a threatened invertebrate. Conserv Biol 4(1):41–51

Navarro-Martínez A, Palmas S, Ellis EA, IBlanco-Reyes P, Vargas-Godínez C, Iuit-Jiménez AC, Hernández-Gómez IU, Ellis P, Álvarez-Ugalde A, Carrera-Quirino YG, Armenta-Montero S, Putz FE (2017) Remnant trees in enrichment planted gaps in Quintana Roo, Mexico: reasons for retention and effects on seedlings. Forests 8:1–11. https://doi.org/10.3390/f8080272

New TR (1997) Are Lepidoptera an effective 'umbrella group' for biodiversity conservation? J Insect Conserv 1(1):5–12

Nganso BT, Kyerematen R, Obeng-Ofor D (2012) Diversity and abundance of butterfly species in the Abiriw and Odumante sacred groves in the Eastern Region of Ghana. Res Zool 2(5):38–46. https://doi.org/10.5923/j.zoology.20120205.01

Oduro W, Aduse-Poku K (2005) Preliminary assessment of fruit-feeding butterfly communities in the Owebi Wildlife Sanctuary. Ghana J. Forestry 17 & 18:9–19

Palita SK, Jena S, Debata S (2016) Odonate diversity along different habitats of Koraput, Odisha, India. J Entomol Zool Stud 4(3):40–47

Perfecto I, Vandermeer J, Mas A, Pinto LS (2005) Biodiversity, yield, and Shade Coffee certification. Ecol Econ 54:435–446

Philpott SM, Arendt WJ, Armbrecht I, Bicier P, Diestch TV, Gordon C, Greenberg R, Perfecto I, Reynoso-Santos R, Soto-Pinto L, Tejeda-Cruz C, Williams-Linera G, Valenzuela J, Zolotoff M (2008) Biodiversity loss in Latin American coffee landscapes: review of the evidence on ants, birds, and trees. Conserv Biol 22(5):1093–1105

Pollard E, Yates TJ (1993) Monitoring butterflies for ecology and conservation. Chapman and Hall, London

Ponraman G, Dinakaran S, Anbalagan S, Balachandran C (2015) Diversity and distributional pattern of butterflies (Lepidoptera: Papilionoidae) in stream corridors of Southern Eastern Ghats. Int J Environ Biol 5(3):53–56

Prasanna Kumar V, Reddy PH, Venkata Ramana SP (2011) Climate effects and habitat destruction on butterfly diversity in the Eastern Ghats of southern Andhra Pradesh. Ecoscan Spec Issue 1:139–143

Purvis A, Hector A (2000) Getting the measure of biodiversity. Nature 405:212–219

Rands MRW, Sotherton NW (1986) Pesticide use on cereal crops and changes in the abundance of butterflies on Arable Farmland in England. Biol Cons 36(1):71–82

Reddy CS, Jha CS, Dadhwal VK (2012) Assessment and monitoring of long-term forest cover changes in Odisha, India using remote sensing and GIS. Environ Monit Assess. https://doi.org/10.1007/s10661-012-2877-5

Remini L, Moulaï R (2015) Diversity and structure of butterfly populations in agro ecosystems of Mitidja (Algeria). Zool Ecol 25:355–364

Scales BR, Marsden SJ (2008) Biodiversity in small-scale tropical agroforest: a review of species richness and abundance shifts and the factors influencing them. Environ Conserv 35(2):160–172

Schroth G, da Fonseca GAB, Harvey CA, Gascon C, Vasconcelos HL, Izac AMN (2004) Agroforestry and biodiversity conservation in tropical landscapes. Island Press, Washington, DC

Schulze CH, Steffan-Dewenter I, Tscharntke T (2004) Effects of land use on butterfly communities at the ran forest margin: a case study from Central Sulawesi. In: Gerold G, Fremerey M, Guhardja E (eds) Land use, nature conservation and the stability of rainforest margins in Southeast Asia. Springer, Berlin, pp 281–297

Théodore Munyuli MB (2012) Butterfly diversity from Farmlands of Central Uganda. Psyche 2012:1–23

Théodore Munyuli MB (2013) Drivers of species richness and abundance of butterflies in coffee–banana agroforests in Uganda. Int J Biodivers Sci Ecosyst Serv Manag 9(4):298–310. https://doi.org/10.1080/21513732.2012.709539

Van Swaay CAM, Brereton T, Kirkland P, Warren MS (2012) Manual for butterfly monitoring. Report VS2012.010. De Vlinderstichting/Dutch Butterfly Conservation, Butterfly Conservation UK & Butterfly Conservation Europe, Wageningen

Vasconcelos S, Rodrigues P, Palma L, Mendes LF, Palminha A, Catarino L, Beja P (2015) Through the eye of a butterfly: assessing biodiversity impacts of cashew expansion in West Africa. Biol Cons 191:779–786

Waltert M, Mardiastuti A, Mühlenberg M (2004) Effects of land use on bird species richness in Sulawesi, Indonesia. Conserv Biol 18:1339–1346

Wezel A, Bender S (2003) Plant species diversity of Homegardens of Cuba and its significance for household food supply. Agrofor Syst 57:37–47

Whitmore TC (1998) An introduction to tropical rain forests. Oxford University Press, Oxford

Wood B, Gillman MP (1998) The effects of disturbance on Forest butterflies using two methods of sampling in Trinidad. Biodivers Conserv 7(5):597–616

Wynter-Blyth MA (1957) Butterflies of Indian region. Bombay Natural History Society, Bombay