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Research Article

Tree diversity at Payeh Maga Montane Forest, Sarawak, Borneo

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Abstract
Tree species composition and diversity were determined at 1,600 m Payeh Maga Highland in Lawas, Sarawak, Borneo. Five study plots (20 x 20 m) were established at five transect lines (1 ha). The study shows that the forest was represented by 40 families, 68 genera and 151 species. Fagaceae represented 26 % of the families recorded, followed by Myrtaceae (16 %) and Clusiaceae (12 %) which are a typical family of montane forest in this region. Important Value Index (IV) showed *Lithocarpus urceolaris* as the most important species (IV=294 %), followed by *Gymnostoma sumatranum* (IV=273 %) and *Tristaniopsis microcarpa* (IV=194 %). There are no significant differences among transects for number of species and diversity indices. This forest is important for biodiversity conservation as it is as rich as those reported for lowland forests elsewhere in this region. The continued accumulation of species is an indication that this highland could support and provide habitat for larger tree species communities.

Keywords: Highland, Payeh Maga, Montane forest,·Tree diversity, ·Sarawak

Introduction
Tree species in the tropical forest differs in terms of composition and diversity due to heterogeneity in the environment and biogeography (Whitmore, 1988). The important factors affecting are the communities' structure, composition that are biotic, abiotic, edaphic, and historical factors (Suratman et al., 2015). Altitudinal vegetation classifications in Malaysia are Lowland Dipterocarp Forests (0-300 m), Hill Dipterocarp Forests (300-750 m), Upper Dipterocarp Forests (750–1,200 m), Lower Montane Forests/Montane Oak Forests (1,200–1,500 m), Upper Montane Forests/Montane Ericaceous Forests (1,500-3,000 m) (Symington, 1943; Whitmore, 1993). The montane forest is represented by

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Fagaceae-Lauraceae and Ericaceae families with present of thick moss layer and bryophytes (Whitmore, 1984).

The highland forest ecosystems of Sarawak are unique as there are no distinct forest types with changes in altitude (Asthon, 1995; MNS, 1998; Pearce, 2006) as changes in floristic composition of the forests with altitude are gradual and continuous. Such uniqueness contributes to high plant endemism. In general, highland forests are important ecosystems due to their unique biological, hydrological aspects (Bruijnzeel et al., 2010) and carbon storage (Spracklen & Righelato, 2014). These forests are isolated due to the altitudinal factor and hence sensitive to changes in climate and land use. In addition, the steep mountain slopes are susceptible to erosion when forest canopies are removed. Among issues related to global highland ecosystems are fragmentations by road construction, logging and development associated with tourism, temperate agriculture as well as township and telecommunication facilities (Bruijnzeel et al., 2010).

The Heart of Borneo (HoB) initiative was initiated in 2007 across Malaysia, Brunei and Indonesia. The objective is to conserve the biodiversity for the benefit of the people through sustainable management practices and protected areas. The HoB in Sarawak covers an area of 2.1 million hectares (ha) stretching from Batang Ai in the SouthWest to Merapok in the NorthEast (FDS, 2014). The upland and montane forest ecosystems are important as these cover an area of 13.08 million ha out of 17.4 million ha of forest cover in the HoB area. It has been reported that between 2007 and 2012, approximately 600,000 ha of upland forests were deforested while 300,000 ha of montane forests were lost between 2007 and 2010 within the HoB area. These trends have resulted in about 26 % and 20 % of upland and montane forests respectively being fragmented (WWF, 2014).

The urgency to address the conservation initiative in these forest ecosystems is a priority to ensure that their functions in providing ecological products and services are maintained. This paper reports a study which was conducted to assess the tree diversity found in the montane forest in Sarawak. Payeh Maga Highland in Lawas, Sarawak has three peaks namely Gunung Doa (570 m-lower peak), Gunung Tuyo (1,752 m) and Gunung Matallan (1,828 m) (Ampeng et al., 2013). These highlands are part of the forest network of the HoB initiative site in Sarawak. Information gathered will provide the baseline data of this forest. This could help forest managers in developing conservation programmes towards more sustainable use of natural resources and protection of these highlands ecosystems.

Materials and methods

The study was conducted at Payeh Maga Highland (N 4°27'10.27" & E 115°33'34.1") in Lawas, Sarawak, Borneo. At an elevation of 1,600 m, five study plots (20 x 20 m) were established at an interval of 100 m at five transect lines (Figure 1) resulting in 25 plots covering a total area of 1-ha . This elevation was selected as there is access to the area via abandoned logging roads. All trees 10 cm ≥ dbh were tagged, measured and identified.

Figure 1. The location of the study plots

The stand data was analysed for species composition and diversity. Species composition was calculated based on the percentage of the individual species over the total species recorded. Importance Value (IV) index for each species was calculated by adding the relative frequency (RF), relative density (RD), and relative dominance (Rd) for that species. This value gives a reliable overall estimate on the importance of species in the community.

Stand species diversity analysis was based on Shannon-Wiener Diversity and Simpson's Diversity Indices. The Shannon-Wiener Diversity Index (H Index) assumes that individuals are randomly sampled from an indefinitely large population (Magurran, 1991). Simpson's Diversity Index (D Index) considers the number of species(s), the total number of individuals and also the proportion of the total that occurs in each species. It represents the probability that two randomly selected individuals in the habitat belong to the same species (Simpson, 1949). Jaccard Similarity Index (C_J) was based on presence or absence of species that are shared between study plots and species that are unique to each study plot (Magurran, 1991).

Analysis of Variance (ANOVA) was conducted to compare the means on number of species and diversity index values among transects. All significant differences means were grouped using Tukey's Range Test. Cluster analyses were conducted using SPSS on the species distribution among the study plots. The classification was based on Squared Euclidean Distance. Species-area curves were developed by plotting species number as a function of the sample plot size or area. This has been used in studies of community ecology which provides the fundamental component for conservation biology. This is also important in formulating recommendations on species preservation and extinction rates (Codit et al., 2002).

Results and discussion

The species composition of the 1-ha forest stand was represented by 40 families, 68 genera and 151 species. The list of species recorded in the study is as in Table 1. Fagaceae represented 26 % of the families recorded. The dominance of this family is expected as the distribution of this family is at 500-1,800 m (Soepadmo et al., 1995). In this study, *Castanopsis*, *Lithocarpus* and *Quercus* genera represented this family. *Castanopsis* was represented by eight species. This covers 38% of the total reported species for Sabah and Sarawak. Three species (*C. endertii*, *C. hypophoenicea* and *C. oviformis*) are endemic to Borneo and these represent 30 % of the total endemics species reported.

Castanopsis is distributed from sea level up to 2,500 m. The genus is important as Borneo has the largest number of species. *Lithocarpus* was represented by 10 species, representing 16 % total recorded for Sabah and Sarawak. It is distributed from sea level up to 3,000 m. Only two species (*L. bullantus* and *L. echinifer*) were reported and endemic to Borneo. *Quercus* was represented by two species (*Q. gemelliflora* and *Q. subsericea*) and these cover 12 % of the total recorded species. The low occurrence could be due to their common distribution being at 600-1,500 m (Soepadmo et al., 1995).

Myrtaceae represented by S*yzygium* and *Tristaniopsis* genera contributed about 16 % of the families recorded. They are found in every type of habitat in Borneo (Ashton, 2011). *Syzygium* was represented by six species with *Syzygium multibracteolatum* being endemic to Borneo. Their dominance on the montane forest is not unusual as they are more dominant than *Shorea* at this altitude (Ashton, 2011). It is also found to be abundant in kerangas, peat swamp and upper montane forests (Whitmore, 1984). *Tristaniopsis* was represented by five species which covers 45 % of the total species reported for Sabah and Sarawak. This genus is important in Borneo and New Caledonia as it is the centre of diversity for this genus (Ashton, 2011). Two species under this genus namely *T. beccarii* and *T. microcarpa* are endemic to Borneo and are recorded in this study.

Clusiaceae represented by *Garcinia* and *Calophyllum* genera comprised about 12 % of the families recorded. It is commonly found in all forests except mangroves but most abundant on acidic soils and kerangas forest at low and high altitudes (Ashton, 1988). Two species were recorded but only one was identified as *Calophyllum buxifolium* which is common on mountain ridges up to as high as 2,000 m. *Garcinia* was represented by four species in this study. This genus is found in most of the habitats including the montane area.

The dominance of Fagaceae, Myrtaceae, Clusiaceae, Lauraceae and Casuarinaceae in this study is expected as they are typical families of the montane forest. The main floristic zone in the lower montane forest is called oak-laurel forest and is dominated by Fagaceae and Lauraceae while the upper montane forest is represented by Myrtaceae (Cranbook 1988).The montane forest in Borneo was reported to be represented by the family Araucariaceae, Clethraceae, Ericaceae, Fagaceae, Lauraceae, Myrtaceae, Podocarpaceae, Symplocaceae, Theaceae (WWF, 2014), Elaeocarpaceae, Hamamelidaceae, Flacourtiaceae, Magnoliaceae and Moraceae (Ohsawa, 1991). In relation to this, Fagaceae, Myrtaceae, Clusiaceae, Euphorbiaceae are important families in Borneo being the centre of plant distribution and diversity in the world (Soepadmo, 1995). This finding reflects the importance of montane forest as seed and gene banks for various species. This information supports its potential as a site for developing a conservation area for highland species.

Importance Value Index (IV) analysis among the plots showed that *Lithocarpus urceolaris* (Fagaceae) represented 36 % of the 25 study plots, followed by *Gymnostoma sumatranum* (12 %) (Casuarinaceae) and *Tristaniopsis microcarpa* (12 %) (Myrtaceae). The ranking of IV among plots are shown in Table 2. Analysis based on 1-ha showed similar pattern where *L. urceolaris* are the most important species (IV=294 %). This is followed by *G. sumatranum* (IV=273 %), *T. microcarpa* (IV=194 %), *L. bennettii* (IV=174 %) and *Calophyllum* sp. (IV=117 %). As expected *L. urceolaris* also has the highest IV index in this study. *L. urceolaris* is reported to be widespread in Sabah and Sarawak (Soepadmo et al., 1995). Another dominant species in this study is *G. sumatranum* representing some 50 % of the recorded species in Sabah and Sarawak. This species is confined to hill, ridge and lower montane forests at altitude 600-1,800 m (Pungga, 1995) which can explain its dominance in the area. *T. microcarpa* is commonly found in mixed dipterocarp forests up to an altitude of 1000 m (Ashton, 2011). These represent the common species found in the lower montane forest such as *Lithocarpus* and *Castanopsis* and *Syzygium*, while *Tristaniopsis* and *Rhodamnia* in the upper montane forest. The dominance of these species is an indication of a lower montane forest. In the lower montane forest, oak (*Quercus* spp. and *Lithocarpus* spp.) and chestnut (*Castanopsis* spp.) forests are dominant (WWF, 2014).

Table 1 The list of species recorded in this study.

No	Scientific Name	No	Scientific Name	No	Scientific Name
1	*Acronychia* sp.	29	*Castanopsis* sp. (no. 2)[3]	57	*Elaeocarpus valentonii*
2	*Actinodaphne obovata*	30	*Cinnamomum* sp.	58	*Endiandra* sp.
3	*Actinodaphne* sp.	31	*Conocarpus* sp.	59	*Engelhardia serrata*[3]
4	*Adinandra dumosa*	32	*Cordia* sp.	60	*Engelhardia roxburghiana*[3]
5	*Adinandra* sp.	33	*Cotylelobium melanoxylum*[2]	61	*Euonymus* sp.
6	*Agathis* sp.	34	*Cratoxylum formosum*[2]	62	*Eurya acuminata*
7	*Alangium* sp.	35	*Cryptocarya ferrea*[3]	63	*Fagraea* sp.
8	*Alseodaphne bancana*	36	*Cryptocarya strictifolia*	64	*Ganua* sp.
9	*Alseodaphne* sp. (no. 1)	37	*Dacrycarpus elatus*	65	*Garcinia bancana*[2]
10	*Alseodaphne* sp. (no.2)	38	*Dacrycarpus imbricatus*[2, 3]	66	*Garcinia nitida*
11	*Ardisia* sp.	39	*Dacrydium elatum*[3]	67	*Garcinia parvifolia*[2, 3]
12	*Austrobuxus nitidus*[2, 3]	40	*Dacrydium gracilis*[2]	68	*Garcinia* sp.
13	*Beilschmiedia dictyoneura*	41	*Dehaasia firma*[3]	69	*Glochidion ellipticum*
14	*Beilschmiedia kunstleri*	42	*Dehaasia* sp.	70	*Glochidion littorale*
15	*Beilschmiedia madang*	43	*Diospyros elliptifolia*	71	*Glochidion sericeum*
16	*Beilschmiedia* sp.	44	*Diospyros* sp.	72	*Glochidion* sp.
17	*Bhesa paniculata*[2, 3]	45	*Diospyros subrhomboidea*[2]	73	*Gomphia serrata*
18	*Calophyllum buxifolium*	46	*Elaeocarpus angustifolius*[3]	74	*Gonystylus augescens*
19	*Calophyllum* sp.	47	*Elaeocarpus floribundus*[2]	75	*Gonystylus borneensis*
20	*Campnosperma squamatum*[2]	48	*Elaeocarpus glaber*	76	*Gordonia* sp.
21	*Carallia brachiata*[2, 3]	49	*Elaeocarpus mastersii*[2]	77	*Gymnacranthera* sp.
22	*Castanopsis acuminatissima*[3]	50	*Elaeocarpus pedunculatus*[2]	78	*Gymnostoma sumatranum*[1, 3]
23	*Castanopsis endertii*[1, 3]	51	*Elaeocarpus serratus*	79	*Horsfieldia carnosa*[1, 2]
24	*Castanopsis evansii*	52	*Elaeocarpus* sp. (no. 1)	80	*Horsfieldia laticostata*[1, 2]
25	*Castanopsis hypophoenicea*[1]	53	*Elaeocarpus* sp. (no. 2)	81	*Knema latifolia*
26	*Castanopsis oviformis*[1, 2]	54	*Elaeocarpus* sp. (no. 3)	82	*Knema* sp. (no. 1)
27	*Castanopsis psilophylla*[3]	55	*Elaeocarpus stipularis*[3]	83	*Knema* sp. (no. 2)
28	*Castanopsis* sp. (no. 1)	56	*Elaeocarpus submonoceras*	84	*Kokoona littoralis*[2,3]

Table 1 Continue

85	*Kokoona ochracea*	115	*Phobe opaca*	145	*Tristaniopsis microcarpa*[1,3]
86	*Kokoona* sp.[3]	116	*Phoebe* sp.	146	*Tristaniopsis* sp.[2, 3]
87	*Lithocarpus bennettii*[2, 3]	117	*Phyllocladus hypoplyllus*[2]	147	*Tristaniopsis whiteana*[2,3]
88	*Lithocarpus blumeanus*[3]	118	*Podocarpus imbricatus*	148	Unknown (no. 1)
89	*Lithocarpus bullantus*[1, 3]	119	*Podocarpus neriifolius*[2, 3]	149	Unknown (no. 2)
90	*Lithocarpus echinifer*[1, 3]	120	*Polyosma latifolia*[2]	150	*Vernonia arborea*[2]
91	*Lithocarpus elegans*[3]	121	*Quercus gemelliflora*[3]	151	*Xanthophyllum* sp.
92	*Lithocarpus garcilis*[3]	122	*Quercus subsericea*[3]		
93	*Lithocarpus lampadarius*[3]	123	*Saurauia amoena*[3]		
94	*Lithocarpus lucidus*[3]	124	*Saurauia glabra*[2]		
95	*Lithocarpus* sp.	125	*Saurauia* sp.		
96	*Lithocarpus sundaicus*[2, 3]	126	*Stemonurus umbellatus*[2, 3]		
97	*Lithocarpus urceolaris*[2, 3]	127	*Symplocos odoratissima*		
98	*Litsea accedens*[2, 3]	128	*Syzygium multibracteolatum*[1,2]		
99	*Litsea castanea*[2, 3]	129	*Syzygium scortechinii*[3]		
100	*Litsea elliptica*[2]	130	*Syzygium* sp. (no. 1)		
101	*Litsea ferruginea*	131	*Syzygium* sp. (no. 2)		
102	*Litseama chilifolia*[2]	132	*Syzygium* sp. (no. 3)		
103	*Litsea* sp. (no. 1)	133	*Syzygium* sp. (no. 4)		
104	*Litsea* sp. (no. 2)	134	*Talauma* sp.		
105	*Macaranga pachyphylla*	135	*Teijsmanniodendron* sp.		
106	*Macaranga* sp.	136	*Terminalia* sp.		
107	*Mangifera griffithii*	137	*Ternstroemia coriacea*		
108	*Memecylon* sp. (no. 1)	138	*Ternstroemia hosei*		
109	*Memecylon* sp. (no.2)	139	*Ternstroemia sp.* (no 1)		
110	*Palaquium oxleyanum*	140	*Ternstroemia* sp. (no. 2)		
111	*Palaquium* sp. (no. 1)	141	*Tetramerista glabra*[1]		
112	*Palaquium* sp. (no.2)	142	*Timonius flavescens*		
113	*Parastemon* sp.	143	*Tristaniopsis beccarii*[1,2,3]		
114	*Parkia* sp.	144	*Tristaniopsis merguensis*[2,3]		

Note: 1 indicates endemic to Borneo, 2 indicates species found in kerangas forest, 3 indicates species found in montane forest

Table 2 Species composition and diversity among transects in the study area

	Transect									
	1	2		3		4		5		
No of tree	36-53	18-42		29-39		25-39		26-53		
No of species	13-23	10-16		16-21		13-25		6-25		
Shannon-Wiener Diversity Index	1.91-2.64	1.79-2.36		2.05-2.85		2.37-3.01		1.05-3.07		
Simpson's Diversity Index	0.79-0.93	0.76-0.93		0.84-0.96		0.93-0.97		0.50-0.97		
	IV (%)		IV (%)		IV (%)		IV (%)		IV (%)	
Tristaniopsis microcarpa	480	*Lithocarpus urceolaris*	307	*Dacrydium elatum*	300	*Calophyllum* sp.	123	*G. sumatranum*	188	
Garcinia sp.	114	*Engelhardtia roxburghiana*	67	*Lithocarpus urceolaris*	288	*Lithocarpus bennettii*	94	*Agathis* sp.	125	
Gonystylus sp.	83	*Tristaniopsis microcarpa*	37	*Calophyllum buxifolium*	199	*Lithocarpus echinifer*	93	*Dacrydium elatum*	100	
Calophyllum buxifolium	65	*Knema* sp. (no 2)	37	*Lithocarpus* sp. (no. 1)	194	*Talauma* sp.	68	*Quercus gemelliflora*	68	
Stremonurus umbellatus	63	*Alseodaphne* sp. (no 1)	36	*Garcinia* sp. (n.o 1)	113	*Kokoona ochracea*	64	*Adinandra dumosa*	62	

Table 2 continue

L. bennettii	525	*T. microcarpa*	143	*L. urceolaris*	173	*Calophyllum* sp.	149	*G. sumatranum*	612
Endiandra sp. (no. 1).	151	*Calophyllum buxifolium*	115	*L. lampadarius*	157	*G. sumatranum*	132	*T. merguensis*	101
Syzygium sp. (no. 1)	149	*Ternstroemia hosei*	98	*Tristaniopsis microcarpa*	120	*Syzygium* sp. (no. 2)	129	*Calophyllum* sp.	63
Glochidion sp. (no. 1)	85	*Syzygium* sp. (no. 3)	94	*Calophyllum buxifolium*	76	*Macaranga* sp.	90	*Garcinia* sp.	38
Adinandra dumosa	85	*Lithocarpus* sp.	78	*Garcinia bancana*	60	*Ternstroemia hosei*	62	*Dacrydium elatum*	33
L. sundaicus	400	*T. microcarpa*	283	*L. lampadarius*	150	*Palaquim oxleyanum*	150	*Palaqium oxleyanum*	119
L. bennettii	275	*L. urceolaris*	129	*Calophyllum* sp.	133	*Calophyllum* sp.	108	*Syzygium* sp. (no. 4)	93
Castanopsis sp. (no. 1)	75	*Adinandra* sp.	94	*T. merguensis*	66	*Syzygium* sp. (no. 4)	105	*Beilschmiedia madang*	63
Garcinia bancana	50	*C. buxifolium*	92	*Litsea castanea*	60	*L. lampadaius*	59	*Castanopsis endertii*	53
Ternstroemia sp. (no. 1)	50	*Syzygium* sp (no. 2).	58	*Syzygium* sp. (no. 2)	66	*Macaranga* sp.	59	*Agathis* sp.	41

Table 2 continue

L. urceolaris	511	*L. urceolaris*	376	*Adinandra* sp.	344	*Lithocarpus bullantus*	205	*G. sumatranum*	855
Syzygium sp. (no. 2)	145	*T. microcarpa*	160	*L. urceolaris*	181	*L. lampadarius*	144	*Podocarpus neriifolius*	240
Castanopsis sp. (no. 1)	118	*C. buxifolium*	115	*C. buxifolium*	66	*Elaeocarpus mastersii*	87	*T. merguensis*	89
Elaeocarpus angustifolius	114	*Syzygium* sp. (no. 2)	87	*Elaeocarpus angustifolius*	61	*Calaphyllum* sp.	71	*Calophyllum* sp.	31
L. bennettii	59	*Cordia* sp.	64	*Syzygium* sp. (no. 1)	60	*Podocarpus imbricatus*	67	*Lithocarpus garcilis*	30
Adinandra dumosa	186	*Alseodaphne* sp. (no. 1)	272	*Syzygium* sp.	186	*L. blumeanus*	221	*Dacrydium elatum*	141
E. serratus	148	*Gymnostoma sumatranum*	163	*Alseodaphne* sp. (no. 1)	176	*Syzygium* sp. (no. 4)	99	*Syzygium* sp. (no. 4)	119
E. angustifolius	121	*Garcinia bancana*	126	*L. urceolaris*	152	*Elaeocarpus* sp.	67	*L. blumeanus*	88
L. urceolaris	94	*T. microcarpa*	96	*E. angustifolius*	91	*L. lucidulus*	63	*Calophyllum* sp.	62
Saurairia sp.	91	*Dacrydium elatum*	65	*L. lampadarius*	89	*P. oxleyanum*	63	*Garcinia* sp.	61

Table 3 Species composition of selected forest types

No.	Forest type	Altitude (m)	Plot size (ha)	Min dbh (cm)	Species (no.)	Genus (no.)	Family (no.)	References
1	Tropical forest	n.a.	n.a.	n.a.	52-141	n.a.	n.a.	Swaine et al. (1987)
2	Danum Valley Conservation Area, Sabah, Malaysia	n.a.	1.00	10.0	114	n.a.	n.a.	Jumaat and Kamarudin (1992)
3	23-year old lowland secondary forest, Bintulu, Malaysia	50	0.04	10.0	120	80	38	Kueh et al. (2013)
4	Lowland primary forest, Pasoh Forest Reserve, Negeri Sembilan, Malaysia	80	50.00	1.0	822	298	77	Okuda et al. (2003)
5	Lowland regenerating forest, Pasoh Forest Reserve, Negeri Sembilan, Malaysia	80	36.00	1.0	672	254	76	Okuda et al. (2003)
6	Lowland secondary forest Ayer Hitam Forest Reserve, Selangor, Malaysia	500	1.00	10	146	82	39	Kueh (2000)
7	Lambir Hills National Park, Miri, Malaysia	465	52.00	1.0	1173	286	81	Lee et al. (2002)
8	Gunung Silam, Sabah, Malaysia	700-870	0.04-0.24	19-91				Proctor et al. (1988)

Table 3 Continue

9	Ba Vi National Park, Vietnam	>1,000	0.20	10.0	45			Van Do et al. (2015)
10	Payeh Maga Highland, Lawas, Malaysia	1,600	1.00	10.0	151 (12-25)	68	40	This study
11	Gunung Kinabalu, Sabah, Malaysia	1,700	0.20-0.50	10.0	32-84	29-51	22-31	Aiba and Kitayama (1999)
12	Gunung Kinabalu, Sabah, Malaysia	2,700	0.2-0.25	10.0	15	13-14	11-13	Aiba and Kitayama (1999)
13	Gunung Kinabalu, Sabah, Malaysia	3,000	0.06-0.20	10.0	4-17	4-14	3-10	Aiba and Kitayama (1999)
14	Middle montane forest zone, Yunnan, China	1,650-1,780	0.25	5.0	62-70	n.a.	n.a.	Zhu et al. (2015)

Note: The number of species per plot (0.04ha) in hypen; n.a. denotes not available

Table 4 Species diversity of selected forest types

No.	Forest types	Shannon-Wiener Diversity Index	Simpson's Diversity Index	References
1	55 year-old secondary forest, Central Kalimantan	3.40	n.a.	Brearley et al. (2004)
2	Primary forest, Central Kalimantan	4.17	n.a.	Brearley et al. (2004)
3	23 year old secondary forest, Bintulu, Malaysia	4.23	0.98	Kueh et al. (2012)
4	Coastal forest/Pasir Tengkorak Forest Reserve, Langkawi (130m)	5.607	0.962	Abdul Hayat et al. (2010)
5	Payeh Maga Highland, Lawas, Malaysia	4.16 (1.05-3.08)	0.97 (0.5-0.97)	This study
6	Lower montane forest zone, Yunnan, China	3.55-3.56	0.95-0.96	Zhu et al. (2015)
7	Ba Vi National Park, Vietnam	3.51	0.92	Van Do et al. (2015)
8	Gunung Kinabalu (1,700m)	2.81-3.93	n.a.	Aiba & Kitayama (1999)
9	Gunung Kinabalu (2,700m)	2.02-2.21	n.a.	Aiba & Kitayama (1999)
10	Gunung Kinabalu (3,100m)	0.39-2.3	n.a.	Aiba &Kitayama (1999)

Note: n.a. denotes not available

The mean number of species among transects showed no significant differences despite Transects 4 and 5 being at a higher altitude compared to Transects 1 and 3 (Figure 2). In the case of this study, there were 151 species per hectare which is comparable to what was reported by other researchers in the range of 114-146 species per hectare (Jumaat & Kamarudin 1992; Kueh 2000). This forest is also comparable to those reported for montane forest which range from 4-87 species. The number of species found in the tropical forest can range from 52 to 1173 as reported by various researchers (Table 2). This forest is considered to be as comparatively as rich as those reported for lowland forests in the region, such as by Swaine et al. (1997), Jumaat & Kamarudin (1992) and Okuda et al. (2003). Species diversity analysis using the Shannon-Wiener Index (H index) recorded a range of 1.05 to 3.08. H Index is generally more sensitive to species evenness compared to richness (Colwell 2008). This is reflected in Plot 24 (Transect 5) where 15 species were recorded but with lower H=1.67 as it has lower evenness compared to other plots (Plot 2 and 4) of similar number of species. The highest H index was recorded in Plot 16 (Transect 4) which recorded high species richness but more evenness. The dominance of *Calophyllum* sp. was 11 % of the total species. The lowest H index was recorded in Plot 22 (Transect 5) with low richness and evenness. The low evenness was due to the prominent of *G. sumatranum* which covered 70 % of the total species. The reduction in the number of species with higher altitude remains unclear. The altitude above 1,690 m the H index was lower except for Plot 18 at 1,715 m. The other exception was the low H index for Plot 6 (Transect 2) due to the fact that *L. urceolaris* was only distributed half of the study plots. This could explain the low evenness this transect.

In the case for Simpson's Diversity Index (D Index), it recorded a range of 0.50-0.97 for species diversity. D index is more sensitive to richness in comparison to H index (Colwell 2008). These are reflected in the study plots where the lowest species richness corresponds with the lower D index. The lowest species richness was in Plot 22 (Transect 5) with D=0.50 while the highest in Plot 16 (Transect 4) and 25 (Transect 5) with D=0.97. The low D index is due to the dominance of *G. sumatranum* in the study plots. D index also did not indicate that the species diversity is decreasing due to change in altitude and this pattern remains unclear. This is true in the case for forests in Sabah and Sarawak. This is contrast to the traditional altitudinal sequence as found in Peninsular Malaysia is unrecognizable. The main contributing factors to the floristic communities are usually correlated to the soil types as reported by Ashton (1995) that a combination of sharply defined topography, diverse rock substrate and shallow low nutrient soils create the diversity of the forest covers.

Despite this, analysis of variance showed that there is no significant differences for both diversity indices among those transects (Figure 2), when analysed as 1-ha size, the H= 4.16 while D= 0.97. The diversity index in this study is comparable to those reported in the lowland forest with a range of H= 3.40-4.23. This shows a similar pattern with the species richness as discussed earlier. In relation, the study plots also show that it has similar species diversity to other montane forests in the region (such as by Aiba & Kitayama 1999; Van Do et al., 2015) (Table 3). The diversification promotes the uniqueness of the highlands in Sarawak especially in Payeh Maga Highland forest. The high species diversity and richness means that this montane forest has a wealth of forest products which can be beneficial to mankind, wildlife and the environment.

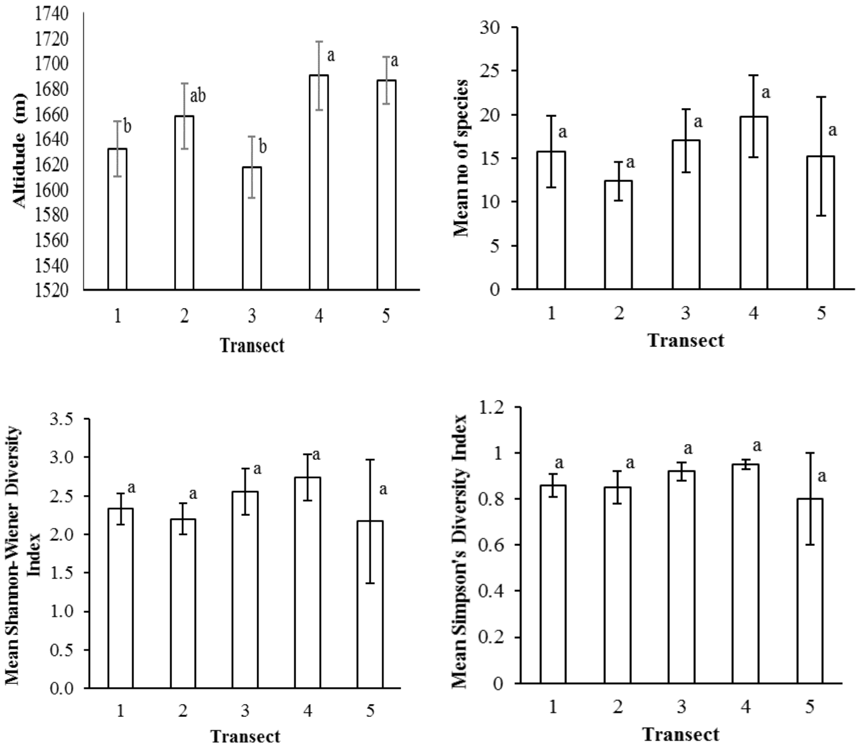
Cluster analysis in Transect 1 shows the prominent species community is *Lithocarpus bennettii* while another prominent species community is *L. urceolaris-Tristaniopsis microcarpa-L. sundaicus* (Figure 3). *L. bennettii* is dominant as the species that occurred in three plots with IV=59-525 %. *L.*

urceolaris with IV=510 % clustered with *T. microcarpa* (IV=480 %) and *L. sundaicus* (IV=400 %) and other species. The Fagaceae and Myrtaceae contributed 68 % of the total individuals in this transect. In the case of Transect 2, the main species community is *L. urecolaris* with another prominent species community *Tristaniopsis microcarpa-Alseodaphnae* sp. (no. 1). *L. urceolaris* is dominant as it occurred in three plots with high IV=129-306 %. *T. microcarpa* is present in all plots (IV=96-283 %) and clustered with *Alseodaphne* sp. (no. 1) (IV=271 %). Fagaceae contributed 21 % of the total individual while *Lauraceae* and *Myrtaceae* contributed 35 % of the total individuals in this transect. In Transect 3, the prominent species community is *Adinandra* sp. While another prominent species community *L. urceolaris-L. lampadarius-Alseodaphne* sp. (no. 1). *Adinandra* sp. (no. 1) is a prominent species in this transect as it has the highest IV=344 %, despite only being distributed in two plots. In comparison, *L. urceolaris* occured in four plots (IV=152-288 %) while *L. lampadarius* occurred in three plots (IV=89-157 %) and *Alseodaphne* sp. (no. 1) (IV=176%) in one plot. *Fagaceae* contributed 25 % of the total individuals while *Lauraceae* contributed 9 % of the total individuals in this transect.

In Transect 4, the prominent species community is *Lithocarpus blumeanus*. *L. blumeanus* is the most important species with highest IV=221 %. The *Calophyllum* sp. is clustered with *L. lampadarius-L. bullantus* and *Palaquium oxleyanum-Syzygium* sp. (no. 4). The other group is *Calophyllum* sp. which occurs in three plots (IV=107-123 %) while *L. lampadarius* occurs in three plots (IV=30-144 %) and *L. bullantus* occurs in one plot but has the highest IV=205 % in that particular plot. Another subgroup under this cluster is *P. oxleyanum* which has the highest IV=150 % in plot 17 while *Syzygium* sp. (no. 4) with IV=67-105 % which occurred in two plots. *Fagaceae* and *Clusiaceae* dominated this transect with a contribution of 35 % of the total individual. As for Transect 5, the prominent species community is *G. sumatranum-Podocarpus neriifolius*. *G. sumatranum* occurs in three plots with IV=188-855 % with *P. neriifolius* (IV=34-240 %). *Casuarinaceae* and *Podocarpaceae* contributed 47 % of the total individuals in this transect.

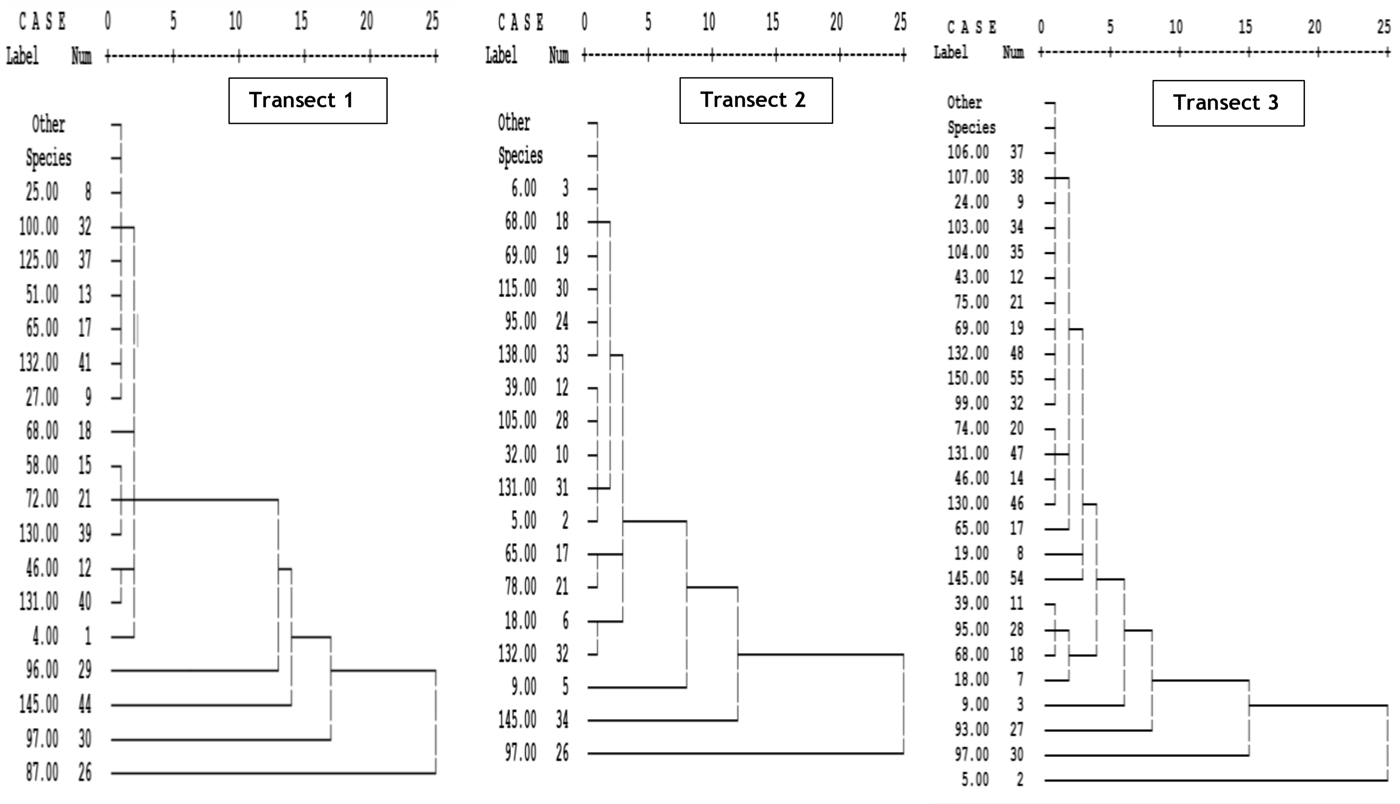
The analysis suggests that the species community is complex in the lower transect (1 to 3). Less complex species community is reflected in Transect 5. However, the less complex species community in relation to altitude remains unclear warranting study plots to be established also at higher elevation to validate this theory. Based on the cluster analysis for 1 ha, the prominent species is the *G. sumatranum* forest. This forest dominated 60 % of the plots in

Transect 5 with IV index of 188-855 %. The second forest community is the *L. urcelaris* which dominated 20-40 % is Transect 1, 2 and 3, while the third forest community is the *L. benentii* which is found in all the plots in Transect 1. The fourth forest community is *T. microcarpa* which is 20-40 % in Transect 1 and 2. Based on the IV index, the top 4 species are *G. sumatranum* (IV=611.7-855.0 %) are the dominant species with *L. bennettii* (IV=525.0 %), *L. urceolaris* (IV=510.7 %) and *Tristaniopsis microcarpa* (IV=480.4 %). With this information, the forest can be named as *Gymnostoma-Lithocarpus-Tristaniopsis* (Rhu-Mempening-Selunsur) montane forest.



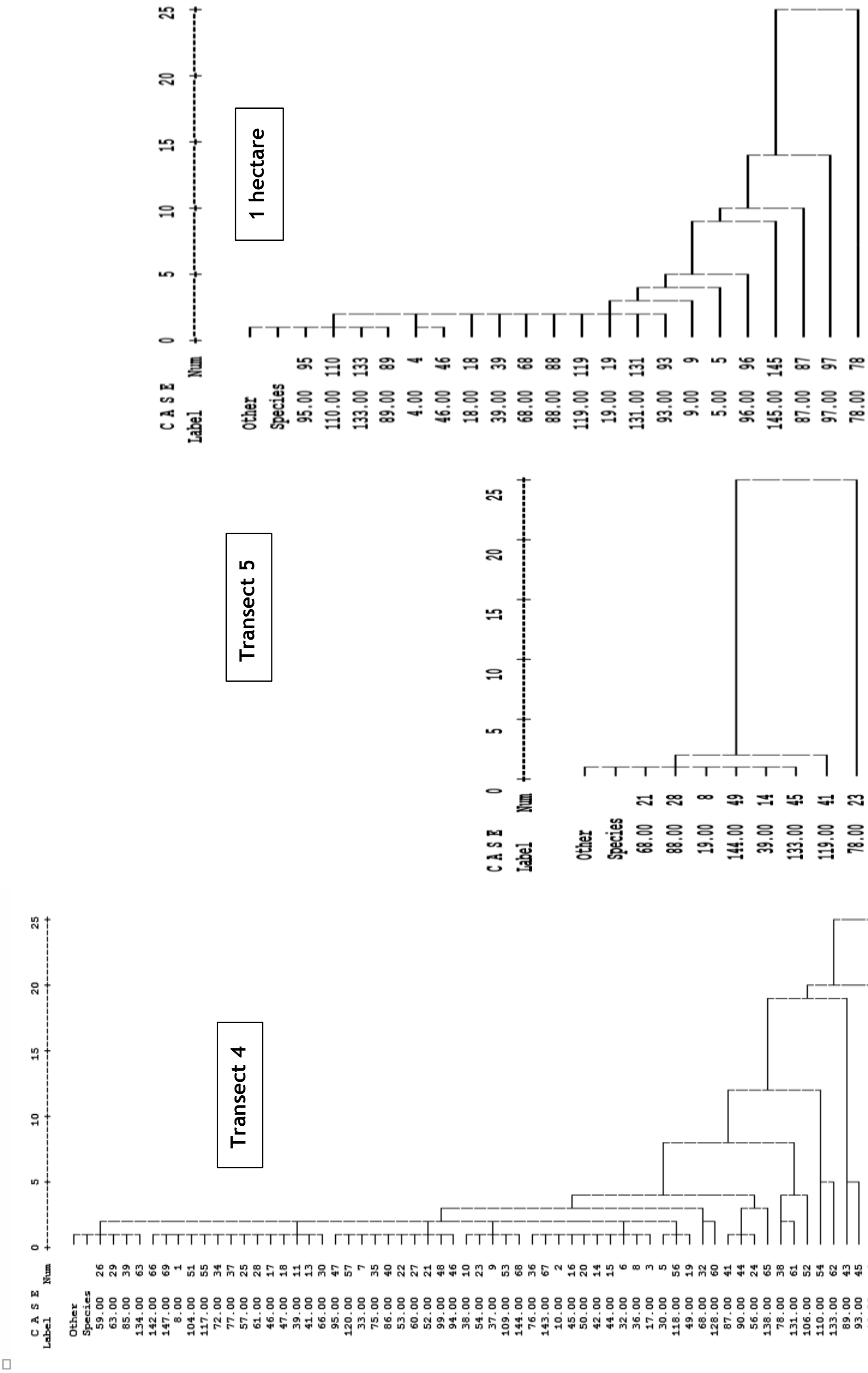
Note: Means with different alphabets indicate significant differences between transects by Tukey Range Test at p≤ 0.05

Figure 2. The mean distribution of altitude (m), number of species, Shannon-Wiener Diversity and Simpson's Diversity Indices among the transects



Note: The number in this analysis corresponds with the species number in Table 1

Figure 3. The cluster analyses for species community



Note: The number in this analysis corresponds with the species number in Table 1

Figure 4. The cluster analyses for species community

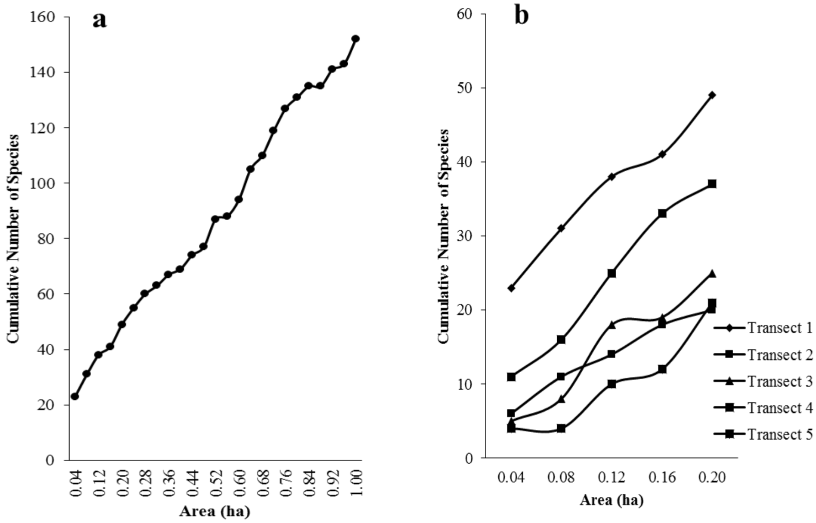


Figure 5. Species area curve (a) over 1 ha, (b) among transects

The cumulative species curve as in Figure 5 shows that the species-area curve is normally more steep in the early part of tree sampling. This is due to the fact that common species in the area are detected relatively quickly. Generally, the curve continues to rise as more tree species are sampled. Hence, the slope becomes more gentle progressively and eventually flattens when when the sampling area is homogenous where are all species are sampled (Gotelli & Choa, 2013). In this study, the plots are rather heterogeneous as Jaccard Similarity Index (C_J) showed about 38 % or less similarity (Table 5). The curve has yet to show any point of levelling off (Figure 5). This can be an indication that there are high chances that rare tree species can be detected if large sampling plots are considered.

In this case, if the species area curve is considered separately, Transect 2 species-area curve begins to flatten after 0.16 ha. This could be explained by the higher similarity among the study plots in Transect 2 where Jaccard Similarity Index (C_J) showed 20-38 % similarity. This is considered high when compared to other transects with only 35 % similarity to as low as null. Lower number of species (n=10-16 species) while smaller range of diversity indices were recorded (H=1.91-2.53; S=0.79-0.93) among the plots in Transect 2. This is in contrast with Transect 1 with H=1.79-2.36 and S=0.76-0.88 (n=13-23 species), Transect 3 with H=2.05-2.82, S=0.84-0.96 (n=12-21 species), Transect 4 with H=2.37-3.09, S=0.93-0.97 (n=13-23 species) and Transect 5 with H=1.05-3.07, S=0.50-0.97 (n=6-25 species).

The asymptotes were not expected in the other transects probably to the fact that in the tropical forest, expectation of the asymptote in species-area curve is unclear. Species-area curve reported for 50 ha plots in 3 different old forests namely Pasoh Forest Reserve (Malaysia), Barro Colorado Island (Panama Canal) and Mudumalai Game Reserve (Tamil Nadu) showed that species continues to accumulate beyond 50 ha (Condit et al., 2002). There are similar findings in Sungai Menyala and Bukit Lagong, Malaysia which may imply all inland tropical rainforests have a similar pattern. The expectation of an asymptote only comes from delimited communities defined by edaphic and climatic regimes (Cranbook, 1988).

The heterogeneity in the species is due to rare species where the species is represented by a single individual. This study recorded 44 % rare species. Similar patterns have been recorded in all transects (Figure 6). Hence, this contributes to the high degree of endemism (Cranbook, 1988). At 1,600 m, the climatic regimes could have limited the species distribution. The continued

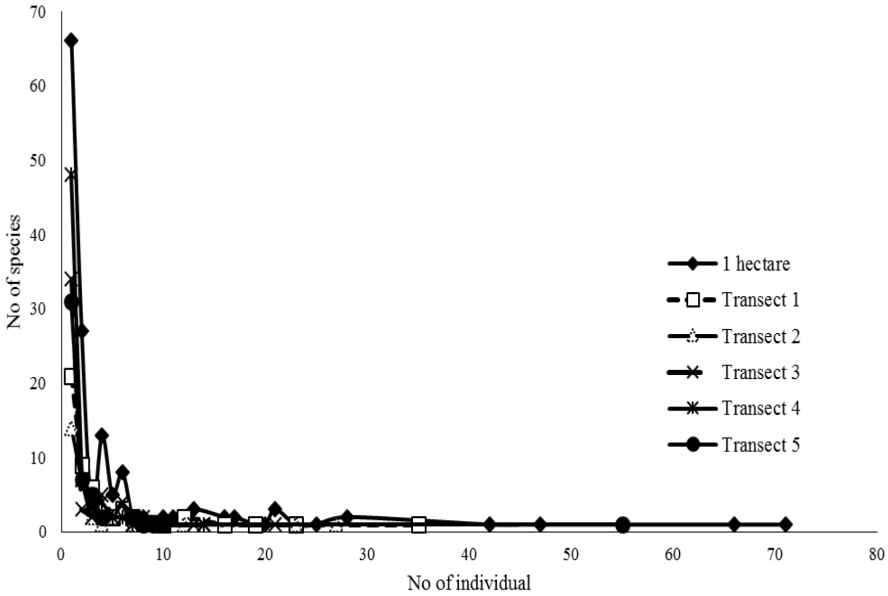


Figure 6. The species abundance in the study area

accumulation of species is an indication that this highland could support and provide habitat for larger tree species communities. With the theory of rare species, there are high possibilities that high endemism of species could be found in this area. This study recorded 8% of the total species which are endemic to Borneo.

The presence of white sand in the study sites with black water streams are main characteristics for a kerangas forest (Whitmore, 1984). 23 % species recorded in this study are found to be distributed in kerangas forest. The dominance of *Clusiaceae* and *Myrtaceae* in this study area can be attributed to these found abundantly on acid soils and in kerangas forest (Ashton, 1988; 2011). In montane forest, families such as Myrtaceae, Theaceae, Podocarpaceae, Ericaceae, Clusiaceae and Ebenaceae are also present in kerangas forest (Ashton, 1995). At this altitude, trees are covered with bryophytes which are termed as mossy forest. Therefore, the study forest area could be named as Rhu-Mempening-Selunsur kerangas-mossy montane forest.

Overall, the tree diversity in Payeh Maga Highland forest is rich when compared to lowland and montane forests such as reported by Aiba & Kitayama (1999), Brearley et al. (2004) and Zhu et al., (2015). This makes the area important as a source of seeds as well as a gene bank. This would facilitate in the securing planting materials to initiate any forest rehabilitation activities. The uniqueness of the area is reflected by the occurrence of rare and endemic species. The priority to conserve this area should be the interest of forest managers and policy makers.

Conclusions

The Payeh Maga Highland has a forest which is high in tree number and diversity. The assessment of the floristic composition provides base line information to manage conservation initiatives in the area. With such information, it would facilitate local authorities and policy makers to extend more conservation efforts in protecting the fragile and sensitive the highland ecosystems. This would ensure the sustainability of these highlands ecosystems to provide ecological products and services to mankind, wildlife and the environment. Long term monitoring is still required to understand the forest dynamics especially in relation to the climate change and other environmental issues.

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