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Tree Species Diversity of Various Vegetation Types at the Alliance Level in Submontane Forest of Mount Salak, Bogor, West Java

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The submontane zone on Mount Salak is part of the tropical montane forest ecosystem on West Java. It is important to conserve the biodiversity of Mount Salak, especially the endemic and rare species found only on this mountain. The aims of this research were to determine the structure and composition of the tree species, including species diversity, for all stands in vegetation types classified at the alliance level in the submontane zone of Mount Salak, Bogor, West Java. Vegetation was surveyed in alliance 1, alliance 2, and alliance 3. We counted each tree, measured its basal area, and identified it to the species level. Tree data were used to determine an importance value index of every species from all stands. We also examined the species diversity of each stand using three indexes: the Shannon-Wiener diversity index (H'), Pilou's evenness index (e), and Menhinick's richness index (R). There were 72 tree species found in alliance 1. *Schima wallichii* was the species with the largest number of individuals, whereas *Pinanga javana*, *Dysoxylum excelsum*, and *Antidesma tetrandrum* were represented by only one individual. There were 71 tree species found in alliance 2. *Pinus merkusii* had the largest number of individuals, and *Glochidion rubrum*, *Goniothalamus macrophyllus*, *Schefflera scandens*, *Gluta renghas*, *Antidesma tetrandrum*, *Dissochaeta gracilis*, and *Polygala venenosa* were represented by one individual. There were 56 tree species in alliance 3. *Pinus merkusii* had the largest number of individuals, and *Pithecellobium montanum*, *Calliandra tetragona*, *Polygala venenosa*, *Dipterocarpus hasseltii*, and *Symplocos spicata* were represented by one individual. The H' values in stands of alliance 1 (mixed forest) ranged from 2.666 to 3.391, stands of alliance 2 (bamboo forest) from 1.163 to 3.233, and stands of alliance 3 (forest plantation) from 1.683 to 3.498. The ranges of e values for alliances 1, 2, and 3 were 1.136−1.403, 0.551−1.331, and 0.770−1.434, respectively. The ranges of R values for alliances 1, 2, and 3 were 1.691−2.662, 0.621−2.829, and 1.051−2.588, respectively.

Key words: Alliance, Pilou's evenness index, Menhinick's richness index, Mount Salak, Shannon-Wiener diversity index, submontane zone.

Introduction

Mount Salak, which ranges in elevation from 400 to 2210 m asl, is home to one of the tropical montane ecosystems on West Java (Sandy, 1997). It is important to conserve the biodiversity of this mountain, especially the endemic and rare species that can be found only on Mount Salak (Vivien, 2002).

The submontane zone of Mount Salak's ecosystem is susceptible to human interference because it is located very close to human settlement. According to Yusuf *et al.* (2003), most of Mount Salak's forest is still primary forest in relatively good condition, although it has been disturbed in some places. The disturbance comes in the form of land-use change from primary forest to paddy fields, agricultural fields, and gardens. When such lands are abandoned, they become scrub and brush or secondary forest.

Considering its topographical features, including high-elevation steep slopes, and its relatively high rainfall (up to 3000 mm year^{-1}), the submontane zone of Mount Salak is also susceptible to natural distur-

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bance that results in changes in the distribution, composition, and structure of various vegetation types in the ecosystem. The loss of vegetation types results in the reduction of habitat diversity, which may threaten many species with extinction (Ehrlich, 1997). A previous study of the area by Wiharto (2009) revealed that the submontane zone of Mount Salak has three vegetation types: (1) *Schima walichii-Pandanus punctatus/Cinchona officinalis* forest alliance (alliance 1); (2) *Gigantochloa apus-Mallotus blumeanus/C. officinalis* forest alliance (alliance 2); and (3) *Pinus merkusii-Athyrium dilatatum/Dicranopteris dichotoma* forest alliance (alliance 3).

Mount Salak is part of the Gunung Halimun Salak National Park. In order to properly manage this montane ecosystem, it is necessary to improve our understanding of the vegetation ecology of Mount Salak. Among those ecological conditions that need to be better understood are vegetation structure and composition, including the tree species diversity of every stand in all the alliances in the submontane zone.

Methods

Study Site

Mount Salak is located within the Bogor and Sukabumi regencies of West Java, Indonesia. The geographical position of this mountain is 6°42′32″–6°43′32″S and 106°37′41″–106°40′50″E, and it has an area of 31,327 ha. The monthly average precipitation throughout the year is 300 mm. Climatologically, the rainy season on the mountain extends year-round. The average temperature with little variation is 25.7℃ (Hadiyanto, 1997).

Mount Salak is one of more than 40 volcanic mountains on Java Island. Although it is essentially inactive, some volcanic activity still occurs at Ratu crater, Hirup crater, Paeh crater, and Perbakti crater. The mountain's stone consists of lava and pyroclastic materials with a basaltic andesite composition (Putro, 1997).

The soils of Mount Salak largely consist of Andosols. The solum is moderate to deep, with depths from 60 to 120 cm. The soil's upper layer is rich with organic matter, and the color ranges from reddish to black. The soil texture ranges from silt to sandy clay silt, and the granular structure is coarse, with moderate consistency. The lower layer ranges in color from reddish yellow to reddish brown. Its texture is silt to sandy silt, and it has the same granular structure as the layer above it (Vivien, 2002).

Most of the Mount Salak area is comprised of slopes with a grade of more than 40%. The other areas have undulating hills with slopes around 15–40% (Putro, 1997). Most land used for agricultural activities is located in this hilly area, and the activities include dry field farming (locally called *Tegalan*) and agroforestry. Much of the land areas have been opened for commercial agricultural enterprises (Sastrowihardjo, 1997).

Data Collection

The research was done in the submontane forest zone of Mount Salak. The study sites were accessed by climbing from Gunung Bunder Dua village (6°41′48.40″S, 106°42′23.40″E) and Gunung Sari village (Kawah Ratu) (6°41′78.60″S, 106°42′00.06″E).

Vegetation data were collected from 36 stands of trees of alliance 1, 17 stands of alliance 2, and 7 stands of alliance 3. All the stands were randomly distributed in the areas where the alliances were situated. In each stand we placed 10 quadrats, each measuring 20×20 m. In each quadrat, we counted all the trees with a diameter at breast height (130 cm from the soil surface) of more than 20 cm and measured the basal area of those trees. Data of soil nutrient status and topography from each stand were taken from Wiharto (2009).

Data Analysis

We identified each tree to the species level in the field based on Balgooy (2001); voucher specimens were collected for those trees that could not be identified in the field, and we identified them at The Indonesian Academy of Science, Cibinong, Indonesia. The importance value index (IVI) for each species was calculated according to the method of Mueller-Dombois and Ellenberg (1974) as fallow :
IVI=relative dominance+relative frequency+relative density. Using the IVI, we calculated the Shannon-Wiener diversity index (H') as follows:

$$H' = -\sum p_i \ln p_i,$$

where $p_i = n_i/N$, n_i is the IVI of species i, and N is total IVI (Michael, 1984). The evenness index (e) was calculated by using Pilou's formula:

$$e = H'/\ln S,$$

where Shannon-Wiener diversity index of each stand and S is the total number of species in the stand (Odum, 1993). Menhinick's richness index (R) was

calculated as follows:

$$R = S/\sqrt{N},$$

where S is the total number of species and N is the total number of individuals sampled (Ludwig and Reynolds, 1988).

Descriptive statistics (mean, standard error, and coefficient of variation) were calculated to explain the species diversity index for each alliance. The Mann-Whitney U-test was used to determine differences in the number of species, species diversity index, evenness index, and richness index among the alliances (Daniel, 1987).

Results

Structure and Species Composition at the Alliance Level

There were 72 tree species identified in alliance 1, with a total of 9046 individual trees sampled in 36 stands over 14.4 ha (Table 1). *Schima wallichii* was the species with the largest number of individuals (1258 trees), whereas *Pinanga javana*, *Dysoxylum excelsum*, and *Antidesma tetrandrum* were each represented by only 1 individual.

In alliance 2, a total of 3124 individual trees representing 71 species were sampled in 17 stands over 6.8 ha (Table 2). The species with the largest number of individuals was *Pinus merkusii* (373 trees). *Glochidion rubrum*, *Goniothalamus macrophyllus*, *Schefflera scandens*, *Glutta renghas*, *Antidesma tetrandrum*, *Dissochaeta gracilis*, and *Polygala venenosa* were each represented by 1 individual.

We identified 56 tree species in alliance 3, with a total of 1527 individual trees sampled in 7 stands on 2.8 ha (Table 3). *Pinus merkusii* had the largest number of individuals (311 trees). *Pithecellobium montanum*, *Calliandra tetragona*, *Polygala venenosa*, *Dipterocarpus hasseltii*, and *Symplocos spicata* were each represented by 1 individual.

Tree species that were found only in alliance 1 were *Ficus involucrata*, *Knema cinerea*, *Ficus lepicarpa*, *Antidesma bunius*, *Medinela axima*, *Ficus elastica*, and *Ficus variegata*. Eight tree species were found only in alliance 2: *Glochidon rubrum*, *Goniothalamus macrophyllus*, *Schefflera scandens*, *Gluta renghas*, *Dendrocalamus asper*, *Gigantochloa pseudoarundinacea*, *Schizostachyum iraten*, and *Gigantochloa apus* (Tables 1–3). The bamboo species *S. iraten* and *G. apus* were the most dominant species in alliance 2. All the species in alliance 3 could be found in alliance 1, alliance 2, or both.

Some of the species were found at a density of ≤ 1 individual ha^{-1}: 20 of the 72 species (27.8%) in alliance 1, 25 of the 71 species (35.2%) in alliance 2, and 7 of the 56 species (12.5%) in alliance 3. In all three alliances, the number of tree species with few individuals was much higher than the number of species with numerous individuals. There were no tree species with a density greater than 100 individuals ha^{-1} (Table 4).

No tree species had the highest IVI in one or more of stands in all three alliances, although *P. merkusii*, *Schizostachyum brachycladum*, and *Dysoxylum arborescens* had the highest IVI in one or two stands in two alliances (Tables 1–3). This finding indicates that no single tree species dominates the submontane zone of Mount Salak.

All the tree species with the highest IVI at one or more stands in alliance 1, except *S. brachycladum*, had a density of more than 300 individuals ha^{-1}. There were five species included in this category, accounting for 6.94% of the species in alliance 1 (Table 1). We identified 2750 individuals of these five species across 14.4 ha, accounting for 29.96% of the total number of individuals in alliance 1. Six species (8.45%) had the highest IVI in alliance 2, and 1204 individuals belonging to these six species were identified across 6.8 ha, accounting for 38.70% of the total individuals in alliance 2. Five species (8.93%) had the highest IVI in alliance 3. We identified 493 individuals of these five species across 2.8 ha, accounting for 32.28% of the total individuals in alliance 3.

We identified 83 tree species in the submontane zone of Mount Salak, with a total of 13,697 trees sampled. The total number of individuals in alliance 1 significantly differed from that in alliance 2, but no other differences between alliances were significant (Table 5). The tree density (individuals ha^{-1}) in alliance 1 was the highest, followed by alliance 3 and alliance 2. This suggested that the number of trees in mixed forest (natural forest, alliance 1) is the highest, followed by forest plantation (alliance 3) and bamboo forest (natural forest, alliance 2).

Species Diversity in All Alliances on Mount Salak

Among the stands of alliance 1 the H' values ranged from 2.666 to 3.391, those of alliance 2 ranged from 1.163 to 3.233, and those of alliance 3 ranged from

Table 1. Number of individual tree species at alliance 1

No	Species	No. of Individuals	No	Species	No. of Individuals	No	Species	No. of Individuals
1	*Pinanga javana*	1	25	*Cinchona officinalis*	21	49	*Tarenna laxiflora*	114
2	*Dysoxylum Excelsum*	1	26	*Caryota mitis*	23	50	*Lithocarpus elegans*	121
3	*Antidesma Tetrandrum*	1	27	*Macaranga cf. rhizimoides*	25	51	*Phoebe grandis*	134
4	*Dissochaeta gracilis*	2	28	*Ficus ribes*	27	52	*Ficus grossulariodes*	141
5	*Ficus Involucrate*	2	29	*Archydeudron clypearia*	28	53	*Macaranga rhizimoides*	142
6	*Knema cinera*	2	30	*Ficus deltoidea*	31	54	*Altingia excelsa*	185
7	*Symplocos Spicata*	2	31	*Ficus padana*	35	55	*Notaphoebe umbelliflora*	214
8	*Ficus Lepicarpa*	3	32	*Urophyllum arboreum*	37	56	*Glochidion hypoleucum*	220
9	*Ficus globosa*	3	33	*Litsea tomentosa*	38	57	*Polyosma interifolia*	221
10	*Antidesma Bunius*	4	34	*Aporosa octandra*	38	58	*Litsea macrophylla*	224
11	*Schizostachum brachycladum* *(37)	5	35	*Litsea cubeba*	45	59	*Euodia latifolia*	227
12	*Medinilla Axima*	5	36	*Litsea brachystachia*	46	60	*Prunus arboreum*	248
13	*Polygala Venenosa*	5	37	*Lasiathus sp.*	47	61	*Mallotus blumeanus*	266
14	*Maesa latifolia*	7	38	*Ficus fistulosa*	48	62	*Athyrium dilatatum*	268
15	*Mangifera cf. indica*	8	39	*Peperomia laevifolia*	52	63	*Hoersfieldia glabra*	310
16	*Cleistocalyx Opperculata*	9	40	*Michelia montana*	52	64	*Clustocalyx opperculata*	316
17	*Pinus Merkusii*	11	41	*Castanopsis argentea*	52	65	*Castanopsis acuminatissima*	332
18	*Ficus elastic*	12	42	*Homalanthus populnes*	57	66	*Quercus gemelliflora*	342
19	*Lannea coromandelica*	14	43	*Schefflera longifolia*	61	67	*Quercus gemelliflora*	379
20	*Cinnamomum javanicum*	14	44	*Manglietia glauca*	68	68	*Symplocos fasciculata*	443
21	*Saurauria cauliflora*	16	45	*Cyathea contaminants*	74	69	*Pandanus punctatus* *(45)	478
22	*Sapium Virgatuns*	16	46	*Elaocarpus sp.*	75	70	*Cyathea contaminans*	497
23	*Ficus Variegate*	16	47	*Maesopsis eminii*	77	71	*Dysoxylum arborescens* *(30,39,40)	653
24	*Helicia Robusta*	17	48	*Plectocomia elongata*	80	72	*Schima wallichii* *(3,4,5,8,10,13, 14,15,20,24,25, 31,33,38,42,43,44, 46,49,50,51,52,53,54, 55,56,57,58,59,60)	1258

Note: The number of individual trees in 36 stands (14.4 ha). *Dominant species are the species with the highest value of IVI. Numbers in parentheses are the stands where the dominant species have the highest IVI in alliance 1. A total of 36 stands were sampled in the study.

Table 2. Number of individual tree species at alliance 2

No	Species	No. of Individuals	No	Species	No. of Individuals	No	Species	No. of Individuals
1	*Glochidon rubrum*	1	25	*Castanopsis argentea*	6	49	*Lithocarpus elegans*	29
2	*Goniothalamus macrophyllus*	1	26	*Helicia robusta*	7	50	*Castanopsis acuminatissima*	32
3	*Schefflera scanden*	1	27	*Peperomia laevifolia*	7	51	*Plectocomia elongata*	39
4	*Gluta renghas*	1	28	*Michelia montana*	7	52	*Quercus gemelliflora*	46
5	*Antidesma tetrandrum*	1	29	*Homalanthus populneus*	7	53	*Giganthocloa pseudoarundina-cea*	49
6	*Dissochaeta gracilis*	1	30	*Cinnamomum javanicum*	8	54	*Glochidion hypoleucum*	52
7	*Polygala venenosa*	1	31	*Ficus ribes*	10	55	*Clustocalyx opperculata*	65
8	*Dipterocarpus haseltii*	2	32	*Prunus arboreum*	10	56	*Cyathea cf. javanica*	66
9	*Dysoxylum excelsum*	2	33	*Maesa latifolia*	12	57	*Notaphoebe umbelliflora*	66
10	*Lannea coromandelica*	2	34	*Aporosa octandra*	12	58	*Cinchona officinalis*	67
11	*Ficus padana*	2	35	*Archydeudron clypearia*	14	59	*Athyrium dilatatum*	71
12	*Lasianthus sp.*	2	36	*Litsea cubeba*	14	60	*Maesopsis eminii*	76
13	*Ficus fistulosa*	2	37	*Elaeocarpus sp.*	14	61	*Euodia latifolia*	94
14	*Mangifera cf. indica*	3	38	*Schizostachyum iraten* *(2, 32)	18	62	*Horsfieldia glabra*	95
15	*Macaranga cf. Rhizimoides*	3	39	*Polyosma interifolia*	18	63	*Schefflera aromatica*	96
16	*Ficus deltoidea*	3	40	*Dendrocalamus asper*	19	64	*Cyathea contaminans*	107
17	*Calliandra tetragoma*	4	41	*Schefflera longifolia*	19	65	*Dysoxylum arborescens*	141
18	*Clustocalyx opperculata*	4	42	*Litsea tomentosa*	20	66	*Schima wallichii*	149
19	*Urophyllum arboreum*	4	43	*Tarenna laxiflora*	20	67	*Pandanus punctatus* *(34)	159
20	*Ficus globosa*	5	44	*Phoebe grandis*	20	68	*Symplocos fasciculata*	182
21	*Schizostachyum Brachycladum* *(36)	5	45	*Antidesma tetrandum*	20	69	*Gigantochloa apus* *(7, 16,17,18,19,21,22,23, 26,28,29)	322
22	*Saurauia cauliflora*	6	46	*Ficus grossulariodes*	22	70	*Mallotus blumeanus* *(27)	326
23	*Caryota mitis*	6	47	*Altingia excelsa*	22	71	*Pinus Merkusii* *(6)	374
24	*Litsea brachystachya*	6	48	*Macaranga rhizinoides*	27			

Note: The number of individual trees in 17 stands (6.8 ha). *Dominant species are the species with the highest value of IVI. Numbers in parentheses are the stands where the dominant species have the highest IVI in alliance 2. A total of 60 stands were sampled in the study.

Table 3. Number of individual tree species at alliance 3.

No	Species	No. of Individuals	No	Species	No. of Individuals	No	Species	No. of Individuals
1	*Calliandra tetragoma*	1	20	*Ficus fistulosa*	7	39	*Plectocomia elongate*	26
2	*Dipterocarpus haseltii*	1	21	*Saurauia cauliflora*	8	40	*Nothaphoebe umbeliflora*	26
3	*Symplocos spicata*	1	22	*Macaranga rhizinoides*	10	41	*Schefflera aromatica*	30
4	*Polygala venenosa*	1	23	*Phoebe grandis*	11	42	*Ficus grossulariodes*	37
5	*Pithecellobium montanum*	1	24	*Antidesma tetrandrum*	12	43	*Maesopsis eminii* *(12)	40
6	*Aporosa octandra*	2	25	*Mangifera cf. indica*	12	44	*Cyathea cf. Javanica*	42
7	*Litsea brachystachya*	2	26	*Lasianthus sp.*	12	45	*Altingia excelsa**(48)	46
8	*Ficus padana*	3	27	*Maesa latifolia*	13	46	*Castanopsis acuminatissima*	50
9	*Manglietia glauca*	3	28	*Litsea cubeba*	13	47	*Schefflera longifolia*	52
10	*Sapium virgatuns*	4	29	*Tarenna laxiflora*	14	48	*Schima Wallichii*	52
11	*Peperomia laevifolia*	4	30	*Cinchona officinalis*	15	49	*Horsfieldia glabra*	53
12	*Homalanthus populneus*	4	31	*Ficus deltoidea*	15	50	*Pandanus punctatus*	55
13	*Polyosma interifolia*	4	32	*Prunus arboreum*	15	51	*Cyathea contaminans*	64
14	*Pinanga javana*	5	33	*Glochidion hypoleucum*	17	52	*Symplocos fasciculate*	68
15	*Elaeocarpus sp.*	5	34	*Litsea macrophylla*	20	53	*Quercus gemelliflora* *(9)	72
16	*Macaranga cf. rhizimoides*	6	35	*Euodia latifolia*	22	54	*Athyrium dilatatum* *(47)	74
17	*Ficus ribes*	6	36	*Dysoxylum arborescens*	22	55	*Mallotus blumeanus*	76
18	*Actinorhytis calapparia*	7	37	*Lithocarpus elegans*	24	56	*Pinus Merkusii* *(1, 11, 41)	311
19	*Litsea Tomentosa*	7	38	*Clustocalyx opperculata*	24			

Note: The number of individual trees in 7 stands (2.8 ha). *Dominant species are the species with the highest value of IVI. Numbers in parentheses are the stands where the dominant species have the highest IVI in alliance 3. A total of 60 stands were sampled in the study.

1.683 to 3.498 (Table 6). Only the H' values of alliances 1 and 2 were significantly different, but the mean H' values showed a trend of alliance 1 > alliance 2 > alliance 3 (Table 7). In alliance 1, 72.22% of the stands had an H' value > 3 (Table 8), whereas this was the case for only 11.76% of the stands in alliance 2 and 42.86% of those in alliance 3 (Table 9).

The range of e values in the stands of alliance 1 was 1.136−1.403, that of alliance 2 was 0.551−1.331, and that of alliance 3 was 0.770−1.434 (Table 6). Only the e values of alliances 1 and 2 were significantly different (Table 7), and the mean e value showed the following trend: alliance 1 > alliance 3 > alliance 2 (Table 8).

The range of R values in the stands of alliance 1 was 1.691−2.662, that of alliance 2 was 0.621−2.829 , and that of alliance 3 was 1.051−2.588 (Table 6) . We found a significant difference only between the R values of alliances 1 and 2 (Table 7), and the trend of mean R values was as follows: alliance 1 > alliance 2 > alliance 3 (Table 8).

Table 4. Number of species in various density classes among the alliances

Alliance	Number of species in each density class (individuals ha^{-1})				
	1–10	11–30	31–100	>100	Total
1	53	14	5	0	72
2	59	9	3	0	71
3	41	15	0	0	56

Table 5. Comparisons of the number of individual trees between alliances

Statistical test	Alliance comparison		
	1 vs. 2	1 vs. 3	2 vs. 3
Mann-Whitney *U*	90**	68.5	30

** $P<0.01$

Discussion

The tree communities of tropical wet rainforest are characterized by species with very few individuals (Whitten *et al*., 1996). In a study conducted on Mount Gede Pangrango, only 1 tree species (1.4%) was represented by more than 30 individuals ha^{-1}, whereas 53 species (72.6%) had 1–10 individuals and 19 species (26.0%) had 11–30 individuals (Meijer, 1959, in Whitthen *et al*., 1996). Those species in alliances 1 and 2 that are distributed at very low density (≤ 1 individual ha^{-1}) and species with higher density but a very restricted distribution need special attention in conservation plans because such species are threatened with extirpation from the submontane zone of Mount Salak. Species with few individuals have difficulty reproducing successfully, and those with limited distributions are susceptible to environmental fluctuations due to both natural and anthropogenic disturbance. According to Cody (1986), such fluctuations can negatively affect resource availability (i.e., both nutrients and living space) for these rare species, which may threaten the existence of rare tree species in the submontane zone.

There were only a few dominant species in each alliance, representing less than 10% of the total number of species in each alliance. One factor that may have caused the high IVI value, which indicated the dominance of these species, was that they were represented by more individuals than the other species. Because species diversity is composed of species evenness and richness (Barnes *et al*., 1998), the relatively high H' of alliance 1 compared to the other alliances arose because the e and R values of alliance 1 were higher. Another factor that supported the high H' value in alliance 1 was that this alliance had many soil macronutrients that were at higher levels than found in the other alliances. On average, four of the six macronutrients examined by Wiharto (2009) at the study site were higher in alliance 1 than in the other alliances (total N, K, Ca, and Mg). The soil total N of alliance 1 was always significantly greater than that of the other alliances. In addition, the soil Al content of alliance 1 was lowest among the alliances, meaning the risk of Al poisoning was lowest in alliance 1. Together, these factors likely allow the ecosystem of alliance 1 to support more individual trees and tree species.

The existence of many more rare species in alliance 1 (Table 1) appears to reflect the other factors that support higher species diversity in alliance 1. According to Whitten *et al*., (1988), an ecosystem with an abundance of rare species would have more space available for many species, which would in turn increase species diversity.

The lower value of species diversity at alliance 2 appears to be caused by strong competitive pressure from bamboo species, with the result that other species have difficulty growing. As noted by Heyne (1987), bamboo has a very high growth capacity and produces groves. Generally, in an area where bamboo is the dominant plant, few other species are able to grow.

Conclusions

There were 72 tree species found in alliance 1, and *Schima wallichii* was the species with the largest number of individuals. Three species were each represented by only 1 individual. We identified 71 tree species in alliance 2, and *Pinus merkusii* was the species with the largest number of individuals. Seven species had only 1 individual. Alliance 3 had 56 tree species, and *P. merkusii* had the largest number of individuals. Five species were represented by 1 individual. The natural mixed forest of alliance 1 had the highest value of H' (range: 2.666–3.391) and the bamboo forest of alliance 2 had the lowest (range: 1.163–3.233). Alliance 1 had the highest species evenness (e range: 1.136–1.403) and alliance 2 had the lowest (0.551–1.331). Alliance 1 had the highest species richness (R

Table 6. Shannon-Wiener diversity index (*H'*), evenness index (*e*), and richness index (*R*) of each alliance

Alliance 1				Alliance 2				Alliance 3			
1*	2*	3*	4*	1*	2*	3*	4*	1*	2*	3*	4*
3	2.78	1.179	1.85	2	2.769	1.31	2.613	1	2.233	0.949	1.333
4	2.666	1.136	1.81	6	1.711	0.766	0.841	9	2.838	1.227	1.881
5	2.84	1.905	2.05	7	2.448	1.169	1.976	11	1.683	0.77	1.051
8	2.983	1.376	2.31	16	1.16	0.551	0.621	12	3.015	1.328	2.053
10	2.91	1.295	2.48	17	2.07	0.972	1.635	41	2.93	1.244	1.925
13	2.697	1.222	1.82	18	2.4	1.044	1.914	47	3.5	1.434	2.588
14	2.9	1.381	2.49	19	2.75	1.186	2.149	48	3.25	1.351	2.259
15	3.06	1.355	2.57	21	1.81	0.86	1.51				
20	3.06	1.306	2.23	22	2.5	1.081	2.165				
24	3.391	1.403	2.66	23	2.85	1.269	2.653				
25	3.27	1.36	2.32	26	2.26	1.066	2.002				
30	3.281	1.365	2.58	27	2.53	1.133	2.912				
31	3.21	1.534	2.35	28	2.548	1.087	1.951				
33	3.166	1.312	2.36	29	3.033	1.881	2.829				
35	3.2	1.321	2.09	32	2.865	1.233	2.685				
37	2.94	1.23	1.91	34	3.233	1.275	2.155				
38	3.009	1.27	1.96	36	2.823	1.176	2.079				
39	3.072	1.279	2.08								
40	3.294	1.364	2.48								
42	3.193	1.305	1.97								
43	3.08	1.236	2.05								
44	3.27	1.349	2.33								
45	3.229	1.359	2.59								
46	3.13	1.335	2.22								
49	3.263	1.305	2.31								
50	3.2	1.305	2.14								
51	3.24	1.321	2.2								
52	3.35	1.362	2.3								
53	3.231	1.292	2.13								
54	3.142	1.27	1.97								
55	2.96	1.205	1.69								
56	3.26	1.336	2.29								
57	3.34	1.38	2.47								
58	3.12	1.276	2.04								
59	3.16	1.311	2								
60	3.93	1.215	2.05								

Note: 1=Stand; 2=*H'*; 3=*e*; and 4=*R*.

Table 7. Comparison of the mean H', e, and R values between alliances

Alliance comparison for H'			
Statistical test	1 vs. 2	1 vs. 3	2 vs. 3
Mann-Whitney U	52**	85	37
Alliance comparison for e			
Statistical test	1 vs. 2	1 vs. 3	2 vs. 3
Mann-Whitney U	51**	97	36.5
Alliance comparison for R			
Statistical test	1 vs. 2	1 vs. 3	2 vs. 3
Mann-Whitney U	200.5*	74.5	55.5

Note : ** $P<0.01$.; * $P<0.05$

Table 9. The number of stands in various H' classes

Alliance	H' value		
	<2	2–3	>3
1	0	10	26
2	3	12	2
3	1	3	3

Table 8. Statistical descriptions of the H', e, R value of each alliance

Statistical descriptions of the H' value of each alliance							
Alliance	Mean	Min	Max	Range	Std. Error	CV* (%)	N*
1	3.105	2.67	3.39	0.73	0.031	5.986	36
2	2.457	1.163	3.233	2.07	0.128	21.405	17
3	2.778	1.683	3.498	1.815	0.235	22.379	7
Statistical descriptions of the e value of each alliance							
Alliance	Mean	Min	Max	Range	Std. Error	CV* (%)	N*
1	1.302	1.136	1.403	0.267	0.011	4.998	36
2	1.068	0.551	1.331	0.78	0.049	18.821	17
3	1.186	0.77	1.434	0.664	0.09	20.162	7
Statistical descriptions of the R value of each alliance							
Alliance	Mean	Min	Max	Range	Std. Error	CV* (%)	N*
1	2.197	1.691	2.662	0.971	0.041	11.260	36
2	1.901	0.621	2.829	2.208	0.142	30.756	17
3	1.870	1.051	2.588	1.537	0.198	28.150	7

Note: CV=coefficient of variation; N=number of stands sampled

range: 1.691−2.662), followed by alliance 2 (0.621−2.829) and alliance 3 (1.051−2.588).

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