Vertical distribution and structure of the tree vegetation in the montane forest of Mt. Pulog, Cordillera mountain range, the highest mountain in Luzon Is., Philippines

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The altitudinal zonation of the montane forest of Mt. Pulog (2924 m altitude), Cordillera mountain range, the highest mountain in Luzon Is., Philippines was described and compared with other mountains in the Philippines and in the tropics. Three vegetation zones were distinguished from ca. 2000 m to 2700 m altitude each indicated by the common dominant species in the site; Zone I (ca. 2000 m to 2400 m altitude), *Pinus* zone composed of a distinct pure *Pinus* forest (ca. 2000 m to 2300 m altitude) and a *Pinus-Deutzia-Schefflera* forest (ca. 2300 m to 2400 m altitude, Zone II (ca. 2400 m to 2600 m altitude), *Lithocarpus-Dacrycarpus-Syzygium-Leptospermum* forest and, Zone III (ca. 2600 m to 2700 m altitude), *Rhododendron-Clethra-Eurya* forest. The floristic character was not similar to the other mountains in southern Luzon and the rest of the Philippines because of the presence of a number of northern types (e.g. *Skiwmia, Pinus, Ilex* and others) on Mt. Pulog. The number of species and species diversity, DBH, and height tended to decrease with increasing altitude. Dominant component species at the upper altitudinal forest zones were found to be the same species forming the understory elements of the lower altitudinal forest zones. The change of the vegetation between each zone was not gradual in contrast with the other tropical mountains. Mt. Pulog appears to be a southern extension of north temperate flora and the northernmost limit of the tropical mossy forest, a unique forest type within the montane zone in the tropics.

**Key words:** altitudinal zones, Cordillera mountain range, floristic character, Mt. Pulog, tropical tree vegetation

INTRODUCTION

Until the present time details on the vertical distribution and structure of the vegetation on Mt. Pulog (2924 m altitude) of the Cordillera mountain range, the highest mountain in Luzon Is., Philippines, has been left unattended. Mt. Pulog has an interesting vegetation formation. Floristically, it is different from the rest of the Philippine mountains by the absence of the dipterocarp flora in its lower slopes (Dickerson 1928). Phytogeographically, Mt. Pulog is the converging point of plant species of Asiatic, Malayan and Australasian origin (Merrill & Merritt 1910). Moreover, the vegetation structure along altitudinal gradients seems to be a unique one in the Philippines. It has a pure pine forest, a mossy forest and a 2000-hectare-grassland summit (Merrill & Merritt 1910). The mossy forest which is a physiognomic variation of the montane forest in the tropics due to physiography (Beard 1955) is very prominent and well-developed in Mt. Pulog.

Some taxonomic literatures already provide data on flora and some particular vegetation zones or species on Mt. Pulog. Merrill and Merritt (1910) wrote about the flora of Mt. Pulog. Jacobs (1972) studied the topography, vegetation and flora of the mountain with particular reference to the grassland summit. Santos (1979) made some observations on a dwarf bamboo, *Yushania niitakayamensis* (Hayata)

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Keng f. on the grassland summit. Buot and Okitsu (1997a) described the woody species composition at various altitude of the mossy forest region. Those taxonomic studies revealed that Mt. Pulog flora has about 528 species of bryophytes, pteridophytes and spermatophytes growing in the various altitudinal zones of the mountain. The flora has been described as unique and essentially Asiatic rather than Malayan.

Three general vegetation types of this mountain had also been already identified by Merrill and Merritt (1910) in the altitudinal range from ca. 1200 m to 2924 m: 1) pine forest, 2) mossy forest and 3) grassland. Recently, Buot and Okitsu (1997b) preliminarily identified three vegetation zones in the mossy forest region of Mt. Pulog. Those vegetational studies, however, reveal still insufficient aspects of the vertical zonation of this mountain.

This paper first aims to clarify the zonation pattern of the vegetation on Mt. Pulog from the pine to the mossy forest (Merrill & Merritt 1910). Then it discusses the floristic character, species diversity, structure of the vegetation and the structure of the altitudinal zonation comparing with other mountains with reference to the phytogeographical characteristics of this mountain.

**STUDY SITE**

Mt. Pulog (16°30'36"N, 120°50'20" E), situated at about 60 km from the coast on the Cordillera mountain range, is the main massif of Mt. Pulog National Park of Benguet, Ifugao and Nueva Vizcaya provinces which includes three main mountains, Mt. Pulog (Fig. 1), Mt. Tabeyo (2819 m altitude) and Mt. Akiki (2318 m altitude). The three mountains are non-volcanic.

The study site was mainly on the southern and eastern slopes of Mt. Pulog, Benguet province from 2000 m to 2700 m altitude. This site was selected because the tree vegetation types in the altitudinal range was quite intact. Below 2000 m altitude down to the lowest recorded elevation of Mt. Pulog which is 1200 m altitude, there is disturbance from fire and human activities. Commercial pine plantations frequented by fire and agricultural lands are extensive below 2000 m altitude.

The slopes of Mt. Pulog are generally quite steep and the soil is fairly deep apparently formed for the greater part by the rapid decomposition of rock in place except in heavily-eroded steep slopes of the rocky pine forest where soil is very shallow (Merrill & Merritt 1910).

The mean annual precipitation (1974-1994) was 3845 mm in Baguio City, Benguet (ca. 1500 m altitude), south of Mt. Pulog. Annual mean temperature (1974-1994) from the same weather station was 19.4°C. The coldest month, January, had a mean temperature of 12.8°C. Hence at ca. 2000 m altitude, the annual and January mean temperature would be 16°C and 9°C, respectively. At the upper limit of the pine forest, at ca. 2300 m altitude the annual mean would be 14°C and 7°C for the coldest month. The expected temperature reading at ca. 2600 m to 2700 m altitude,
would be 12°C and 5-6°C for the annual mean and the coldest month, respectively.

**METHODS**

Seven sampling sites were identified on the southern and three sites on the eastern slopes of Mt. Pulog from 2000 m to 2700 m altitude to follow the changes in floristic composition, dominance of woody species and forest structure. The point-centered quarter method (Mueller-Dombois & Ellenberg 1974) was used at sites set at elevations 2325, 2400, 2485, 2520, and 2585 m above sea level and a minimum of 20 points composed of 80 quadrats were sampled per sampling site. The distance between points was 15 m to 25 m depending on the steepness of the slope of the sampling site. The sampling points were situated more or less along the contour of the sampling site depending on the topographic conditions. However, at elevations 2615 m and 2700 m, the forest limit, the quadrat technique (Mueller-Dombois & Ellenberg 1974) was used as the vegetation was short and many species tended to be shrubby with many stems. The size of the quadrat was 25 m² each (5x5 m). Likewise, below 2325 m altitude the quadrat technique was also used to determine the vegetation structure of the pure pine forest. The sizes of the quadrats were 720 m² (24 x 30 m) for 2000 m and 2100 m altitude sampling sites and 400 m² (20 x 20 m) for the 2200 m altitude sampling site. Woody species having at least 1.3 m in height were measured from 2000 m altitude to 2585 m altitude. At the forest limit where the vegetation was short, woody species with at least 0.5 m height were included. Identity of the species, the height in m, and the diameter at breast height (DBH) in cm were determined. Sample specimens from each unidentified tree were collected. Likewise, the elevation (m), slope (degree), exposure and the area (m²) were recorded in every sampling site.

Unknown specimens were then identified at the herbarium (CAHP) of the University of the Philippines at Los Baños (UPLB), Laguna, Philippines. Our nomenclature followed mainly that of Merrill (1923a, 1923b, 1925, 1926). Dominance was based on the relative basal area (RBA) derived from DBH values. Absolute basal area values were not used because of the inherent weakness of the point centered quarter method to tend to exaggerate basal area and density values in a given site (Mueller-Dombois & Ellenberg 1974). Besides that, some sampling sites were not also large enough owing to the difficulties encountered in sampling due to unfavorable and dangerous topographic conditions. Hence, relative basal area values were used. All species were then subjected to cluster analysis. First, the dissimilarity matrix of the floristic composition in every sampling site was calculated based on the RBA using the squared Euclidean distance (Tanaka & Tarumi 1995) as follows:

$$d_{ij} = \sum_{k=1}^{m}(x_{ik} - x_{jk})^2$$

where, $d_{ij}$ squared Euclidean distance between plots $i$ and $j$, $m =$ number of species, $x_{ik}$ = relative basal area of the $k$th species in plot $i$, and $x_{jk}$ = relative basal area of the $k$th species in plot $j$. A dendogram was then constructed using the single-linkage clustering or nearest neighbor method (Sneath & Sokal 1973).

Floristic diversity of each sampling site was examined using the Shannon-Wiener's index (Shannon & Weaver 1949) as follows:

$$H' = -\sum_{i=1}^{m} (p_i) \left(\log_{10} p_i\right)$$

where $H'$ = index of diversity, $p_i$ = the proportion of all individuals in the sample which belong to species $i$, and $m =$ number of species.

**RESULTS**

**Species composition**

There were a total of 36 woody species belonging to 21 families determined on the southern and partly on the eastern slopes of Mt. Pulog (Table 1). Twenty-two species belong to the plant families mainly in the temperate regions such as Pinaceae, Ericaceae, Fagaceae, Podocarpaceae, Lauraceae, Saxifragaceae, Rutaceae, Caprifoliaceae, Compositae, Theaceae and Aquifoliaceae. Pinaceae had one species; *Pinus kesiya* Royle ex Gordon. Ericaceae had five species; *Rhododendron subsecisse* Rendle, *Vaccinium indutum* Vid., *Vaccinium sp.*, *Gaultheria cunningiana* Vid. and, *Di-
phycosia sp. FAGACEAE was represented only by two species; Lithocarpus woodii and Lithocarpus sp. Podocarpaceae had only one species; Dacrycarpus stenophylla de Laub. Lauraceae had three members; Neolitsea microphylla Merr., N. megacarpa Merr. and Persea philippinensis Elm. Saxifragaceae was represented by Deutzia pulchra Viv., Polyosma philippinensis Merr. and an unknown Saxifragaceae species. Rutaceae had two species; Skimmia japonica Thunb. and Euodia reticulata Merr. Caprifoliaceae was represented by Viburnum odoratissimum Ker. while Compositae had Vernonia benguetensis Elm. Theaceae was represented by two species; Eurya nitida (Korth.) Dyer and E. coriacea Merr. and Aquifoliaceae was represented by only one species, Ilex crenata Thunb. forma luzonica (Rolfe) Loes.

Conversely, fourteen species, being smaller in number than the temperate families, belong to the tropical taxa such as Euphorbiaceae, Clethraceae, Myrsinaceae, Cyatheaceae, Myrtaceae, Rubiaceae, Araliaceae, Winteraceae, Proteaceae and Sabiaceae. Euphorbiaceae was represented by Macaranga dipertocarpifolia Merr. and Daphniphyllum glaucescens Bl. Clethraceae had Clethra luzonica Merr. Myrsinaceae had Kapanea philippinensis (A. DC.) Mez. and Maesa denticulata Mez. Cyatheaceae was represented by Cyathea fuliginosa (Christ.) Copel. Myrtaceae had three species; Decaspermum paniculatum (Lindl.) Kurz., Syzygium besukiense (Miq.) Masamune and the Australian Leptospermum flavescens Sm. The species of Rubiaceae was Psychotria crispiplila Merr. Araliaceae had Schefflera oblongifolia Merr. Winteraceae was represented by the Australian Drimys piperita Hook. f. Proteaceae had Helicia robusta Wall while Sabiaceae was represented by Meliosma multiflora Merr.

Altitudinal zones

Table 1 and the dendrogram (Fig. 2) reveal three altitudinal zones of forest tree species on the montane zone of Mt. Pulog from 2000m altitude to 2700m altitude. The cluster at a dissimilarity level of about 2.5 shows three vegetation zones. The three forest zones are: Zone I) Pinus forest, Zone II) Lithocarpus-Dacrycarpus-Syzygium-Leptospermum forest and, Zone III) Rhododendron-Clethra-Eurya forest.

Zone I. Pinus forest zone, 2000m to 2400m altitude (sampling sites 1, 2, 3, 4)

The Pinus zone on Mt. Pulog has two distinct group as shown in the cluster at a dissimilarity level of about 1.5 (Fig. 2). These two groups are, the pure Pinus forest from 2000m to 2300m altitude (sampling sites 1, 2, 3) and the mixed pine-broadleaved forest designated as Pinus-Deutzia-Schefflera forest at 2300m to 2400m altitude (sampling site 4).

The pure Pinus forest. On Mt. Pulog, pure Pinus forest reaches up to 2300m altitude. Pinus kesiyia is the only canopy tree to be found in the site. It forms an open park-like forest often associated with some species as Eupatorium adenophorum (Compositae), Coriaria intermedia (Coriariaceae) and Imperata cylindrica (Gramineaceae).

The maximum DBH value was 57cm found in sampling site 1. The maximum height was 30m found in sampling site 1. The pine was the only tree species in the sampling site, hence the RBA recorded for the three sampling sites was 100% each.

The pure pine forest on Mt. Pulog occurs only on very steep and frequently eroded slopes with poor, rocky and shallow soil having low water holding capacity. This makes the site always dry favoring establishment of pines.

Pinus kesiyia forest on Mt. Pulog is one of the few Pinus kesiyia forests in the tropical Asia. Others are found in northern Thailand (Walker & Pendleton 1957, Whitmore 1984, Santisuk 1988), Burma (Stamp 1925, Walker & Pendleton 1957), Vietnam (Walker & Pendleton 1957), Chittagong (Bangladesh) (Merrill & Merritt 1910) and in Assam (India) (Merrill & Merritt 1910, Bor 1938).

The Pinus-Deutzia-Schefflera forest. The mixed pine-broadleaved forest at 2300m to 2400m altitude (sampling site 4) is the lower limit of the mossy forest. Mosses, liverworts and lichens cover abundantly the ground, and the trunks and crowns of trees. This forest is the transition between the pure Pinus forest below 2300m altitude and the typical mossy forest.
Table 1. Tree species composition in the various sampling areas. RBA-relative basal area in % derived from DBH values. Dominant and codominant species are indicated by asterisks (*) and are bordered by a line.

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<td>N101W</td>
<td>N58E</td>
<td>N22E</td>
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<td>Neolitorea magaazara Merr. (Lauraceae)</td>
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<td>Castelhera camtiana Vld. (Ericaceae)</td>
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<td>Maza denticulata Mez. (Myrsinaceae)</td>
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<td>Dipeonia sp. (Ericaceae)</td>
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<td>Ilex crenata Thunb. f. Luxonia (Rolfe) Loes. (Aquifoliaceae)</td>
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<td>Vaccinium sp. (Ericaceae)</td>
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The maximum DBH was 177cm while the maximum height was 25m (Table 1).

The three top dominants of this forest are P. kesiya Royle ex Gordon, Deutzia pulchra Vid. and Schefflera oblongifolia Merr. (Table 1) with RBA values of 67%, 9.1% and 6.3%, respectively.

These three dominating species occupied the canopy layer. The dominant pine trees in this forest, however, differ from those found in the pure pine forest by being richly laden with bryophytes and lichens on their trunks and crowns. Shrubby and herbaceous vegetation were crowding the understory of this vegetation zone. Few stands of Rhododendron subsessile Rendle and Clethra luzonica Merr. which usually dominate in higher altitudes were observed in this forest.

**Zone II.** Lithocarpus-Dacrycarpus-Syzygium-Leptospermum forest zone, 2400m to 2600m altitude (sampling sites 5, 6, 7, 8)

This zone is a well-developed mossy forest characterized by having large and tall trees covered with lichens and bryophytes on their trunks and branches. The maximum DBH was 95cm while the maximum height was 35m (Table 1).

There were seven tree species dominating this forest zone. The most common were Lithocarpus woodii (Hance) A. Camus, Dacrycarpus steudii de Laub., Syzygium besukiense (Miq.) Masamune and Leptospermum flavescens Sm. Lithocarpus woodii was dominant in the four sampling sites in this zone and was the top dominant in sampling sites 5 and 6 with RBA values of 52% and 19.6%, respectively. Dacrycarpus steudii was dominant in sampling sites 6, 7 and 8. It had the highest RBA in sampling site 7 (37%), being the top dominant. Syzygium besukiense was top dominant in sampling site 8 with RBA of 35%. Leptospermum flavescens with RBA of 20.3% was the second domi-
nent species in sampling site 8.

The other dominants were the lauraceous *Neolitsea microphylla* Merr. in sampling site 5, with RBA of 7.8%, the fagaceous *Lithocarpus* sp. in sampling sites 6 and 7 with RBA of 11.4% and 19%, respectively, and the theaceous species, *Eurya nitida* (Korth.) Dyer in sampling site 5 with RBA of 14.5%.

This lauro-fagaceous, podocarpaceous, theaceous and myrtaceous mossy forest zone is unique in being composed of tall and large trees with prominent crowns.

Zone III, *Rhododendron-Clethra-Eurya* forest zone, 2600m to 2700m altitude, (sampling sites 9, 10)

This is the upper limit of the mossy forest region being the forest limit on Mt. Pulog. Above this zone is the grassland summit with scattered *Rhododendron sub sessile* and *Vaccinium* sp. in steep slopes.

Vegetation was composed of few species (8 species each for sampling site 9 and 10) with small individuals having a maximum DBH of 21 cm (sampling site 9) and 11 cm (sampling site 10). The forest height tended to be very low with a maximum height of 8 m (Table 1).

There were four dominant species, *Rhododendron sub sessile*, *Clethra luzonica*, *E. nitida*, and *S. besukien se*. *Clethra luzonica* was top dominant in sampling site 9 (RBA of 48%) while *R. sub sessile* was the top dominant in sampling site 10 (RBA of 41.6%).

It is noteworthy that the dominants of this zone (*C. luzonica* and *R. sub sessile* particularly) are components of the lower zones (zone I and zone II) as understory elements especially in sampling site 4.

**Altitudinal changes in forest structure**

Changes in forest structural features along the different altitudinal zones of Mt. Pulog are illustrated in Fig. 3. The number of species per sampling site decreased with increasing altitude (17 species in sampling site 4 and 8 species in sampling site 10) excluding the pure pine in zone I (Fig. 3A). Species diversity, $H'$ showed considerably higher values at the lower (1.12 dit for sampling site 4) than at the higher altitudes (0.8 dit for sampling site 10) with the excep-

![Fig. 3](image-url)
shrubby.

**DISCUSSION**

**Floristic character and species diversity**

The tree flora of Mt. Pulog is in striking contrast to that of the other parts of the Philippines (Dickerson 1928, Merrill 1926). It presents a number of temperate types that do not occur elsewhere in the archipelago, suggesting their derivation from the north. Typical tropical families such as Arecaceae, Pandanaceae and Dipterocarpaceae are not represented in Mt. Pulog (Dickerson 1928). Contrarily, the flora in southern Luzon and the rest of the Philippines in general is Malayan in nature (Dickerson 1928, Merrill 1926, 1946, Ashton 1993, Buot et al. 1997). This is evidenced by the well-developed dipterocarp forest formation lacking in the Cordillera mountain range (Whiteford 1911a, 1911b, Brown & Matthews 1914, Dickerson 1928, Schoenig et al. 1975, Seidenschwarz 1988).

Merrill and Merritt (1910) reported that in the lower altitudes of the *Pinus* forest (ca. 1500m altitude) some tropical evergreen broadleaves such as *Pittosporum pentandrum* Merr., *Ficus hauili* Blanco, *F. nota* Merr., *Premna odorata* Blanco and others, were noticed at deep ravines and stream depressions. These species are widely distributed at low altitudes in the Philippines. In the Benuet region, however, they occur only in gullies and stream depressions. Some Australasian elements represented by *Leptospermum* (Myrtaceae), *Dacrycarpus* (Podocarpaceae) and *Drimys* (Winteraceae) among others are also present in Mt. Pulog. These species however are also well-developed in the northern hemisphere and must have reached Australia through Malaya (Merrill and Merritt 1910). Its occurrence on Mt. Pulog, however, had not yet been explained and needs to be studied to better understand this peculiar distribution pattern.

Thus, the floristic character of Mt. Pulog is quite unique in the Philippines and phytogeographically, the mountain is the floristic converging point of plant species of Asiatic, Malayan and Australasian origins.

The number of species and species diversity (Fig. 3A, 3B) were higher in the lower slopes of the mossy forest region of Mt. Pulog (*Pinus-Deutzia-Schefflera* forest of zone I and II) in contrast to that of the upper zone (zone III). Sampling site 5 (zone II) has also lower number of species and species diversity and could be attributed to the smaller site sampled due to unfavorable topographic conditions (deep and sharp gullies). There were 17 species in sampling site 4 and there were only 8 species in sampling site 10 (Fig. 3A, Table 1). This decreasing trend of the number of species and species diversity towards higher altitudes had also been observed by Brown (1919), Schoenig et al. (1975), Whitmore (1984) and Ohsawa et al. (1985). Furthermore, on Mt. Pulog, and in the tropics, the species in the higher altitudes were also smaller in size and shorter in stature (Fig. 3C, 3D) compared with the forests in the lower altitudes. DBH values of the pure pine forests in sampling sites 1–3, however, were not as high as expected of lower altitude forests, the highest recorded DBH being 57cm only (Table 1, Fig. 3C). This could be due to the extremely stressful conditions in the pure pine zone compared with the mixed pine and the lauro-fagaceous forests.

The reason for the variation in forest structure along the altitudinal gradients is that, in tropical mountains, there is insufficient heat in such high altitudes (ca. 2600m altitude in the case of Mt. Pulog) to support enough organic production and to form a tall forest. The year-round decrease in temperature in higher altitudes cuts down available energy (for photosynthesis) needed to form a high forest (Ohsawa 1995). In temperate mountains with their seasonal climate, the amount of available energy during summer is often large enough to sustain maximum forest dimensions (Ohsawa et al. 1985).

**Structure of the altitudinal zonation on Mt. Pulog**

The first striking observation is the apparent similarity of the dominants of the higher altitudinal zones to that of the understory elements of the lower altitudinal zones. This is evident in the case of *Clethra* and *Rhododendron* which were the dominant component species in the upper forest zones of Mt. Pulog (zone III) and which happened to be the constituents of the lower forest zones (sampling site 4 of zone I)
as understory elements (Table 1). This had also been observed in Mt. Makiling (Brown 1919, Trelease & McLean 1919), in Mt. Apo (Schoenig et al. 1975), in Mt. Kerinci (Ohsawa et al. 1985), and in tropical mountains in general (Whitmore 1984, Ohsawa 1991). Hence the upper forest zones seem to be equivalent in floristic composition to the understory of the lower forest zones. This differs from that of the temperate mountains as in Japan, where the higher altitudinal vegetation zones (e.g. conifer zone) are composed of different species from the lower zones (e.g. evergreen broadleaves).

Several explanations such as mineral shortage, frequent fog/cloud incidence (Grubb 1977), temperature effects (Ohsawa 1991, 1993) and UV-B radiation (Flenley 1992) had been given for this replacement phenomenon along altitudinal gradients on tropical mountains.

The second important observation on the vegetation zonation on Mt. Pulog is the quite distinct boundary between each vegetation zone along the altitudinal gradient (Table 1 and Fig. 2). Other mountains in the Philippines such as Mt. Makiling (Brown 1919, Trelease & McLean 1919) and Mt. Apo (Schoenig et al. 1975) have a gradual shift of vegetation change along altitudinal zones; the change of the vegetation is unnoticeable. On Mt. Pulog, the *Pinus* forest (zone I) is sharply differentiated from the succeeding *Lithocarpus-Dacrycarpus-Syzygium-Leptospermum* forest (zone II) in terms of floristic composition and general physiognomy (Table 1, Fig. 2). The latter is composed largely of tall lauro-fagaceous, podocarpaceous, theaceous and myrtaceous species which in turn are in sharp contrast to the low-statured, one-storied *Rhododendron-Clethra-Eurya* forest in zone III (Fig. 2).

The entire altitudinal range of the montane forest of Mt. Pulog could be classified into two distinct general vegetation zones (Fig. 4) based on structure and physiognomy (Table 1, Fig. 2). The two distinct vegetation zones are the lower montane vegetation zone and the upper montane vegetation zone following Grubb (1974), Whitmore (1984), Grubb and Stevens (1985), Ohsawa (1991, 1993) and Richards (1996).

The boundary line between the lower and upper montane vegetation zones on Mt. Pulog is set at ca. 2600m altitude. The huge and tall trees which are components of the lower montane zone reached their upper limit at 2600m altitude on Mt. Pulog. These tall and large trees on Mt. Pulog included *Pinus, Lithocarpus, Dacrycarpus, Syzygium, Leptospermum* and others (zone I, II). Above this zone, the small trees (*Rhododendron, Clethra, Vaccinium* among others) lesser than 10m in height started to proliferate signifying the shift to the upper montane vegetation zone (zone III). The main distinguishing characteristic between the lower montane and the upper montane zones is the physiognomy particularly the vegetation height. Lower montane zone is composed of tall and huge trees (15m to 33m high) while the upper montane zone is composed mainly of short and small trees and shrubs (1.5m to 18 m high) (Grubb 1974, Whitmore 1984, Grubb & Stevens 1985, Richards 1996). In addition, Ohsawa (1991, 1993) also emphasized the floristic and leaf morphological difference between the lower montane and the upper montane zones in the tropics. The lower montane vegetation zone is largely composed of notophyllous/mesophyllous trees belonging to families, Lauraceae, Fagaceae, Theaceae and Myrtaceae while the upper montane vegetation zone is composed of microphyllous small trees and ericaceous shrubs.

The lower montane vegetation zone on Mt. Pulog could be further subdivided into an extensive *Pinus* forest (zone I) from 2000m to 2400m altitude (probably could be extended below 2000m altitude down to the lowest recorded elevation of Mt. Pulog at 1200m altitude), and a *Lithocarpus-Dacrycarpus-Syzygium-Leptospermum* forest (zone II) from 2400m to 2600m altitude (Fig. 2, 4).

**Comparison of Mt. Pulog with other mountains**

The natural pure *Pinus kesiya* forest (zone I) in the dry steep slopes of the lower montane vegetation zone of Mt. Pulog (Fig. 4) has no equivalent in the tropical mountains such as Mt. Makiling, Mt. Apo, Mt. Kerinci, Mt. Kinabalu or Mt. Wilhelm. However *Pinus kesiya* had been observed in the tropical lower
montane pine-oak and pine-deciduous dipterocarp forests in northern Thailand at ca. 700m to 1800m altitude (Walker & Pendleton 1957, Santisuk 1988), in the oak forest of Burma at ca 1000m altitude (Stamp 1925, Walker & Pendleton 1957), in the forest at sea level in Vietnam (Walker & Pendleton 1957), in the forests of Chittagong district (Bangladesh) (Merrill & Merritt 1910) and Khali hills, in Assam (India) at ca. 1500m to 2200m altitude, the type locality of the species from which the species epithet of Pinus kesiya was derived (Merrill & Merritt 1910, Bor 1938).

Coniferous forests in northern Thailand may be considered as a severe destruction stage of the lower montane oak forest or dipterocarp forest caused by biotic (burning, cutting, grazing) or edaphic (soil erosion) factors (Santisuk 1988). On Mt. Pulog, traces of fire occurrences and other human activities (agriculture) were observed in the pure pine forests below 2000m altitude. However, in the sampling sites above 2000m altitude which are protected sites, traces of fire occurrences were not observed. In these localities, the pine stands were confined in very steep, highly-eroded rocky slopes apparently having a very low water holding capacity. Thus, even with the high annual average precipitation record in Benguet (3845 mm from 1974-1994), the steep pine forest is left dry. The P. kesiya forest above 2000m altitude on Mt. Pulog may represent a topo-edaphic climax on precipices or shallow, stony soils that are simply too dry and infertile for other trees to grow. The pure stands of P. taiwanensis in Taiwan lower montane forest at ca. 500 m to 2500m altitude had been interpreted also as a topo-edaphic climax though it is considered as a seral stage in many habitat types maintained by fire (Hsieh et al. 1994).

Some few shrubs, herbs and grasses such as Coriaria intermedia, Vaccinium myrtoides, and others were observed sparsely scattered in the open sites within the pure pine forest (sampling sites 1, 2, 3 of zone I) of Mt. Pulog. Neither pine seedlings nor seedlings of other trees found in the Pinus-Deutzia-Schefflera forest (sampling site 4 of zone 1) were observed under the canopy of the pure pine stands. Pine seedlings were reported to only develop on well-lighted sites with podzolic, well-drained mineral soil (Whitmore 1984). In the narrow valleys in the pure pine forest, small

![Fig. 4. A comparison of the altitudinal vegetation zones of Mt. Pulog with other Philippine mountains. Alt is altitude.](image-url)
trees and ericaceous shrubs (*Rhododendron*, etc.) were observed. In the lower elevations (ca. 1500m altitude), the pine occurs exceptionally with some evergreen broadleaves and grasses in the gullies and stream depressions. This could be explained by the relatively drier condition on the slopes and ridges compared with those in the gullies and stream depressions (Merrill & Merritt 1910). In addition, clouds which are frequent on Mt. Pulog upper montane forest region (at 2600m to 2700m altitude) as in other tropical mountains (van Steenis 1972, Leigh 1975, Sugden 1982, Whitmore 1984, Kitayama 1991, Ohsawa 1993) promoting moist and mossy condition, go down to the lower limit of the mossy forest only (ca. 2300m altitude) except in severe stormy seasons. Hence the pine forest (below 2300m altitude) is left relatively cloud-free and consequently, relatively drier enhancing the optimum growth and development of the pure pine stand.

The lower montane mixed pine forest, i.e., the *Pinus-Deutzia-Schefflera* forest of Mt. Pulog at 2300m to 2400m altitude (zone 1) resembles the lower montane pine-oak forest in northern Thailand in being a mixed coniferous and evergreen broadleaved forest. The difference however is on the associated species. In northern Thailand, *P. kesiya* is associated mainly with Fagaceae (700m to 1800m altitude) and to a lesser degree with Dipterocarpaceae (800 m to 1200m altitude) (Santisuk 1988). On Mt. Pulog, *P. kesiya* is associated mainly with Saxifragaceae, Araliaceae and Lauraceae (Table 1) though in higher elevations (ca 2485m altitude) at sampling site 6 (Table 1) *P. kesiya* was associated with Fagaceae.

The lower montane *Lithocarpus-Dacrycarpus-Syzzygium-Leptospermum* forest (zone II) of Mt. Pulog (Fig.4) has floristic equivalents on Mt. Wilhelm (Wade & McVean 1969, Johns 1982) and Mt. Kinabalu (Kitayama, 1987, 1991, 1992). The Australasian species, *Dacrycarpus* and *Leptospermum* are also dominant elements in the montane zone of these mountains. *Dacrycarpus*, which was observed to occur in the lower montane forest at 2400m to 2600m altitude on Mt. Pulog had been reported to occur on Mt. Kinabalu, Borneo in the lower montane forest at ca. 1200m to 2100m altitude and in the subalpine forest at 2900m to 3600m altitude (Kitayama 1987, 1991, 1992). On Mt. Wilhelm in New Guinea, *Dacrycarpus* occurred in the midmontane, upper montane and subalpine forests at ca. 2000m to 3800m altitude (Wade & McVean 1969, Johns 1982). On the other hand, *Leptospermum* which dominated at 2400m to 2600m altitude on Mt. Pulog, was reported to dominate in the lower subalpine forest of Mt. Kinabalu at ca. 2900m to 3400m altitude (Kitayama 1987, 1991, 1992).

The upper montane vegetation zone of Mt. Pulog (zone III) at 2600 m to 2700 m altitude (Fig. 4) appears to be floristically related to the summit mossy forest (ca. 900 m to 1114 m altitude) of Mt. Makiling (Fig. 1 and Fig. 4) and that of the warm temperate zone of Mt. Kerinci, above 2400m altitude (Ohsawa et al. 1985). In addition, it is more or less floristically related to the upper mossy forest region (ca. 2400m to 2500m altitude) of Mt. Apo (Fig. 4), southern Philippines (Fig. 1). On Mt. Makiling a dormant volcano, constriction of vegetation zones discussed by Numata (1971) referring to a kind of miniature of vegetation zones on low mountains is observed. Thus *Clethra* and *Vaccinium* are found at elevations 900m to 1114m (Fig. 4). In the very narrow but typical mossy forest zone of Mt. Makiling (Brown, 1919, Trelease & McLean 1919) while on Mt. Apo, another dormant mountain volcano, *Rhododendron-Vaccinium* communities descend at 2400m to 2500m altitude (Fig. 4) due to the effects of sulfuric emissions near the summit crater (Schoenig, et al. 1975, Numata 1971).

It is evident in the aforementioned discussion and in Fig. 4 that the altitudinal zonal limits between the lower and upper montane vegetation zones vary with different mountains. This had also been the observations of Grubb (1974), Whitmore (1984), Grubb and Stevens (1985) and Richards (1996). On Mt. Pulog, the boundary line is at ca. 2600m altitude. On Mt. Makiling, it is at ca. 900m altitude while on Mt. Apo it is at ca. 2400m altitude (Fig. 4). On Mt. Kinabalu the boundary between the lower and upper montane is at ca. 2100 m altitude (Kitayama 1987) while on Mt. Wilhelm it is at 3000m altitude (Grubb 1974). In
Malayan mountains, the boundary line is at ca. 1500 m altitude (Whitmore 1984). On Mt. Kerinci (Sumatra), the boundary line is at 2370m altitude whereas on Mt. Pangrango (Java), the boundary line is at 2300m altitude (Ohsawa 1991). These variations chiefly depend on the Massenerhebung or mass elevation effects (Grubb 1974, Richards 1996). Hence in larger and higher mountains the boundary line is on higher altitudes compared with smaller mountains.

CONCLUSION

The peculiarity of Mt. Pulog lies on the occurrence of a number of northern types *Pinus, Skimmia, Ilex* and others) in the altitudinal forest vegetation zones of the montane forest which cannot be observed in other Philippine mountains. The *Pinus keiske* forest at 2000 m to 2400m altitude in the lower montane zone of Mt. Pulog (zone I) is floristically similar to the pine forests in northern Thailand, Burma, Vietnam, Chittagong (Bangladesh) and in Assam (India). The extensive lower montane mossy forest at 2300m to 2600m altitude (zone II) is well-developed and is composed of tall and large trees floristically related to Borneo and Australia while the mossy forest in the upper montane (zone III) is composed of small trees and shrubs floristically related to the summit mossy forest of Mt. Makiling, the upper mossy forest of Mt. Apo and the warm temperate zone of Mt. Kerinci. From the standpoint of phytogeography, Mt. Pulog and its vicinities in the Cordillera mountain range appear to be a southern extension of some north temperate flora and serve as the converging zone of Asiatic (*Pinus, Skimmia, Ilex* and others), Malayan (*Sycygium, Macaranga, Cytisaea* and others) and Australasian (*Dacrycarpus, Leptospermum* and *Drimys*) floristic elements. Moreover, Mt. Pulog and its vicinities in the Cordillera mountain range is the northern-most limit of the tropical mossy forest region, a unique forest type in tropical mountains.

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Distribution and succession of West Himalayan forest types in the eastern part of the Nepal Himalaya. Mountain Res. Dev., 6: 143-157.


摘要
フィリピン・ルソン島のブログ山において植生垂直分布を記述した。植物地理学的特性をふまえて、それらが他の熱帯山地のものと比較しブログ山での特徴を検討した。以下の三つの植生帯が認められた。1. Pinus 林 (2000-2400 m, 2300-2400 m は Pinus 純林, 2400-2600 m は Pinus-Deutzia-Schefflera 林), 2. Lithocarpus-Dacrycarpus-Syzygium-Leptospermum 林 (2400-2600 m), 3. Rhododendron-Clethra-Eurya 林 (2600-2700 m)。ブログ山では、北方の温帯要素（Skimmia, Pinus, Ilex など）が多く出現するため、ブログ山の特徴は、ルソン島南部や他のフィリピンの山地とは異なっていた。標高が増加するにつれて、種数、多様性、胸高直径、樹高などは減少する傾向にあった。垂直上部の植生帯における林冠優占種の多くは垂直下部の植生帯における林床構成要素であった。各種植生帯の境界ははっきりしており、他の熱帯山地のようにやや次第に変わるものではなかった。ブログ山は、北方の温帯フロラの南限であり、また熱帯山地林において独自の森林型を呈する熱帯雲霧林の北限にあたる。