THE CONIFEROUS FORESTS OF TAIWAN

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INTRODUCTION

Although much work of botanical survey has been done since the Chinese government again took possession of Taiwan, little is known of the plant ecology of the island. The published work of the botanical survey in the past was concerned primarily with the vascular flora of the island, and the number of published articles, most of which are mainly of a taxonomic nature with incidental ecological observations, is few.

It was ten years ago that the Forest-type Survey of Taiwan was sponsored by the Taiwan Forest Research Institute. Field work was carried out in 1953-54. Being appointed as a member of the five-man field crew, the writer was chiefly responsible for identification of plants, sampling quadrats of lesser vegetation, and observation and description of the physiognomy of the forest to be investigated. This was immediately followed by a joint program of the Chinese-American governments, the Land Use and Forest Resource Survey of Taiwan, in 1954. In connection with this program, the writer was first appointed as one of the field crew members and did the cruising work. Later, he took over the delineation job. Consequently, it was from the aerial photographs that much information concerning vegetation patterns of the island was obtained.

Being employed as a forest researcher at the Taiwan Forest Research Institute, the writer had frequent opportunities to study the plant ecology of the island. The present work is concerned primarily with the general features of the vegetation covering the upper slopes of most high mountains ranging throughout the island, paying particular attention to the composition, the physiognomy, and the detailed structure of the coniferous forest communities occurring in the more elevated regions of the island.

During the past ten years ecological observations were made on forest communities in various localities, including the summits of the highest mountains on the island, and numerical data were obtained. The facts presented here are based mainly upon personal observations from more than four hundred localities representative of the whole area of the island. Information concerning the condition of the existing coniferous vegetation at localities which the writer has not yet visited has been obtained from the aerial photos with which the writer did the delineation work briefly mentioned above.

Judging from the fact that logging operations, mainly clear cutting on a large scale, are steadily reducing the acreage of cedar forest and that of hemlock, it will not be long before the virgin cedar

and hemlock stands in question would have been cleared out. When that time approaches, the island would have to be clothed with second-growth vegetation which may in no way suggest the original forest. It was, therefore, felt that it might be informative to give at the present time a broad and coordinated account of the entire coniferous forest of the island and to give data on composition and aspect of the coniferous forest communities in all parts of the coniferous forest of Taiwan.

ALTITUDINAL DISTRIBUTION OF THE CONIFERS IN TAIWAN

As is known, the vegetation on Taiwan is exceedingly luxuriant and tree growth is definitely a notable feature. In fact, the forest vegetation covers extensive portions of the island ranging from sea level upward to about 3500 meters in elevation, and containing about 1,969,500 hectares (Doverspike et al, 1956), or 55 per cent of the total land area of the entire island. Consequently, forest covers most of the island except the alpine tundra region.

Within the forested area the vegetation is mostly composed of climax forests dominated by evergreen broad-leaved trees at lower elevations, and by coniferous trees on upper slopes, thereby permitting subdivision of the forest region into a hardwood forest zone and a conifer forest zone. The conifer forest zone is much poorer than the hardwood forest zone both in the number of species and of vegetation types; but so far as timber production or forestry economics is concerned, the conifer forest zone is undoubtedly much the more important. Although the conifers cover only one-fourth as much land as the hardwoods, they contain a greater volume of timber, and in terms of economic value they exceed the hardwoods covering the lower mountain slopes.

The coniferous forest on the island occupies a large area approximately 19 per cent of the total area of the forest region (Doverspike et al, 1956). In altitudinal distribution this coniferous forest extends from about 1500 meters upward to the timber line which is reached at about 3500 meters on Yu Shan.

Apparently below the lower limit of the coniferous forest, the slopes are covered with hardwood forests of various types. In these hardwood forests, certain coniferous trees are found. Species of *Podocarpus* occur sparsely all over the ialand at lower elevations. *Keteleeria davidiana* var. *formosana* is scattered in the northern and southern parts of the island at elevations from about 300 to 900 meters. *Calocedrus formosana* grows in the northern and central parts of the island, ranging from 300 to 1900 meters in elevation. *Taiwania cryptomerioides*, *Pseudotsuga wilsoniana* and *Cunninghamia konishii* are of comparatively rarer local occurrence in the central ranges on the island. All of these three native coniferous trees appear to be differentiating species characteristic of the mixed-type of forest made up of hardwood trees as well as conifers at various intermediate altitudes between the hardwood and coniferous forest zones. Because of their scarce occurrence, all of these coniferous species enumerated above are considered economically unimportant, at least at the present time, although their woods are of such excellent quality that their multiplication and extensive planting are justified. Another three conifers are present in different parts of the island. These include one species of the genera *Taxus*, *Amentotaxus*, and *Cephalotaxus*. They, like species of *Podocarpus*, are of limited size and rarer occurrence.

Pinus is represented on the island by four native species. *Pinus massoniana* is the only

coniferous pioneer that is found in the second-growth on the tropical lower slopes, mostly in the northern part and also on the eastern coastal hills. On the whole, this pine is mainly confined to poor sites where the slopes are steep and the ground is rugged, and where there is little vegetative cover other than pine trees. The range of the species may extend upward to 1300 meters in altitudinal distribution on the island. *Pinus morrisonicola* is of wider occurrence, roughly from 300 to 2300 meters, in hardwood forests. In fact, the species is now scarcely found either at lower elevations or mostly present in less accessible places at higher elevations.

The other native pine species, *Pinus taiwanensis* and *P. armandi* var. *masteriana*, occur at higher elevations; the former ranges roughly from 750 to 3000 meters and the latter is known to be of comparatively narrower range in the northern and central parts of the island at high altitudes from 2300 to 3000 meters. Stands of *Pinus taiwanensis* of relatively extensive area are of frequent occurrence near the streamway and tend to be pure at higher elevations, though appearing as scattered individuals in hardwoods at lower altitudes. *Pinus armandi* var. *masteriana* is found scattered usually in the form of small colonies in forests made up chiefly of mixed coniferous species in the subalpine regions.

Within the coniferous forest region, the cedar forests made up chiefly of *Chamaecyparis formosensis* and *Ch. obtusa* var. *formosana*, with a scattering of deciduous broad-leaved trees, commence at about 1500 meters, but in reality the former conifer ranges from 1000 to 2600 meters and the latter from 1200 to 2800 meters in their altitudinal distribution. The range of the hemlock, *Tsuga chinensis* var. *formosana*, is between 1800 and 3200 meters, above which the plant in turn gives place to the fir, *Abies kawakamii*. As to the spruce, *Picea morrisonicola*, it is known to be only of local occurrence. In most cases, it appears as an associate species in the coniferous forest of various types of moderately higher elevations in the coniferous forest region.

The genus *Juniperus* is represented on the island by three forms. Nevertheless, only the alpine juniper, *Juniperus squamata* var. *morrisonicola*, is of common occurrence, forming the scrubby vegetation characteristic of the alpine tundra region. *Juniperus formosana* var. *formosana* is widespread over the mountain slopes ranging from 2300 to 3000 meters in elevation, but *J. formosana* var. *concolor* is localized to the coastal hills of the northeast of the island.

THE CONIFEROUS FOREST AS A WHOLE

The coniferous forest formation on the island occupies an extensive area approximating 19 per cent of the total forested land area or 10 per cent of the total area of the island of Taiwan (Doverspike et al, 1956). Altitudinally the formation extends from about 1500 meters upward to the timber line which is reached at about 3500 meters on Yu Shan (Mt. Morrison).

The coniferous forest formation of Taiwan is a complex vegetational unit most conspicuously characterized by the prevalence of the evergreen but needle-leaved habit of most of the woody constituents. This gives to it a certain uniformity of physiognomy. Hardwood or broad-leaved species, both evergreen and deciduous, occur in the arboreal and shrub layers, particularly in the seral stages and in marginal and transition areas. They are not, however, entirely lacking in any type of climax forest communities wherever they are located in the vast area of the formation.

Since vegetation develops in large measure in response to climate, the great climax unit, the formation, is the long-time expression of climatic control. Throughout the vast area occupied by the formation, the seasonal distribution of rainfall and the length of the growing season are sufficiently alike to favor the dominance of coniferous forest. Upwards, with decreasing precipitation, longer and more frequent drought and poorer soils, the character of the forest changes; it becomes more and more confined to valleys and ravine slopes, with intervening exposed areas occupied by alpine grassland. Also, the shorter growing season and the very low winter temperature extremes eliminate one after another of the tree species. Conversely, downwards, a gradual increase in broad-leaved tree species and a gradual appearance of epiphytes are apparent.

The diversity of topography and greater altitudinal range result not only in local diversity of communities but also in distinct altitudinal zonation of vegetation in this more elevated part of the island. The existence of pure virgin forest stands dominated respectively by various coniferous tree species with distinctive limitation in altitudinal distribution is the most noteworthy feature of the formation under consideration. Topographic features are exceedingly varied. Although only indirectly affecting the nature of the climaxes, topography, especially maturity in the erosion cycle, is important in determining the proportions of the surface occupied by climax and by developmental stages. The principal topographic features of the island are the north-south trending mountain ranges (Figure 1). The heavy rainfall has enabled streams to cut deep canyons into the mountain sides. As a consequence, the mountain ranges are transversely separated by deep, narrow, straight valleys. With high relief and steep slope, the forest-clad mountains are almost impenetrable.

Unity of the Coniferous Forest Formation is emphasized not alone by the evergreen needle-leaved habit, but also by the presence of a number of wide-ranging genera and species, particularly *Chamaecyparis*, *Tsuga*, *Picea*, and *Abies*. None of these genera, except the first, have representatives in other formations. Additional characteristic genera abundantly represented in climax communities over a considerable portion of the coniferous forest include *Pinus*, *Calocedrus*, *Taiwania*, *Pseudotsuga*, *Cunninghamia*, *Taxus*, and *Juniperus*. No coniferous tree species range throughout the coniferous forest except those regularly associated with early seral stages. In fact, pines, particularly *Pinus taiwanensis*, are widespread over much of the area of the Coniferous Forest. By a number of reasons, e.g. the representation of *Chamaecyparis* and *Tsuga* in most parts of the forest, the Coniferous Forest Formation may be more specifically called *Chamaecyparis-Tsuga* Formation.

One of the vegetational features of the formation is that forests comprised of various conifer species together with intervening spaces occupied by herbaceous vegetation of higher elevations give an over-all picture of the formation. The herbaceous vegetation of higher elevations is represented by communities of a grassland type. These herbaceous communities, which are of secondary origin, are found almost completely in possession of extensive areas and are commonly spoken of as alpine grassland.

The forest is a layered community. The canopy, the superior or arboreal layer, is made up of dominant and accessory species. Those trees which are used to designate the climaxes are, of course, dominants of the superior or arboreal layer. In fact, the forest is represented mostly by pure and aged virgin stands, or at least, tending to be pure in composition. The domina nts are

generally characterized by the relatively large development of the trunk as compared with that of the branches. In later life the tree generally loses its lower branches and the branching at the apex becomes less irregular, giving rise to a tree of markedly pyramidal form. The leaves of these coniferous components of the forest are evergreen and vary considerably in appearance. The adult leaves are awl-shaped, linear, and acicular, or assume the form of closely appressed scales.

The subdominant trees and herbaceous vegetation are as much a part of the community as are the larger trees, and in some instances, because of more limitied distribution, even more characteristic of the climaxes of which they are a part. Frequently in disturbed areas, they are better indicators of forest types than are the trees of the secondary forest. In the climax conifer forest communities the sparse undergrowth is generally composed only of few species, in most cases tending to be a single species, namely *Pleioblastus niitakayamensis*. In general, some of the herbaceous perennials or small annuals are sparsely distributed, although some of the species might occasionally appear as closed small patches covering the ground.

As is known, the grass-like alpine bamboo species, *Pleioblastus niitakayamensis*, varies markedly in height, that is to say from half a meter to three meters, in accordance probably with the effect of insolation on air and soil temperatures, and consequently on relative humidity and evaporation and, through them, on the local water situation. It is found, however, that the plant varies relatively little within a given forest region, a fact which is true even within the entire coniferous forest. In fact, the species has its biological optimum in slightly open but evenly stocked forest communities. In contrast, it appears as stunted growth, varying in height, usually more or less than a meter, and forming a type of herbaceous vegetation in possession of formerly forested but then being exposed areas where the removal of tree layer has been brought about as a result of fire disturbance. As a matter of fact, on the outskirts of patches of hemlock or fir forest are usually found broad expanses of this type of herbaceous vegetation dominated by the alpine bamboo species which have been favored by the gradual destruction of the forest trees through the annual fires. The arboreal vegetation may linger on almost unobserved as stunted growth among the grass-like bamboo plants, but it is gradually killed off. As has been seen, this type of herbaceous vegetation is found almost completely in possession of extensive areas, but mainly confined to the dry and sunny south-facing gentle or rolling slopes of high elevations which support chiefly grasses and herbs with some scattered low juniper bushes. So sometimes are the western slopes of mountains, for here the slopes may be noticeably warmer and drier than the eastern ones, owing to the sun's afternoon warmth.

The Coniferous Forest Formation is made up of a number of climax associations differing from one another in floristic composition, in physiognomy, and in genesis or historical origin. While the delimitation of associations may be made on a basis of dominant species, and it is from these that the climax is named, dominants alone may suffice for the recognition of these units. Since the climax association is an abstract concept based upon familiarity with numerous concrete examples, differing in minor details from one another, its delimitation in space is difficult, if not impossible. It is, however, entirely possible to recognize and to map forest regions which are characterized by the prevalence of specific climax types, or by mosaics of types. These regions are natural entities, generally with readily observable natural boundaries based on vegetational features. Boundaries

may in part be determined by the limits of the more or less continuous ranges of characteristic species although there may be relic or advance disjuncts beyond the general range limits. Where bundaries are indistinct, either because of transitions or disturbances caused by various agencies or the lack of sufficient detailed information on vegetation, it is necessary to use more or less arbitrary boundaries, sometimes approximating natural physiographic boundaries.

Forest regions must not be confused with climax associations (cf. Braun, 1950). The determination of extent of any forest region is based upon physiognomy and similarity of composition of forest communities, which in turn result from environmental influences, present and past. Most of the boundaries of the forest regions appear to be determined largely by changing climates and physiography. Although climatic control does not in general determine regional boundaries (Braun, 1964), the influence of climate must not be ignored. In many cases, the boundaries of the forest regions, especially those of regions occupying much of the upper slopes at high elevations, are primarily comparable, if not parallel, to those of the principal climatic types occurring in the Coniferous Forest area. But only to the upper slopes, temperature and length of the growing season are very important. The coniferous forest of Taiwan, which develops in a humid climate, is determined by temperature factors. The subdivision of the formation is in part due to differences in moisture factor.

The present pattern of forest distribution in the more elevated area of the island of Taiwan in terms of forest regions, as shown on the map of forest regions (Figure 2), is somewhat as follows:

1. The *Temperate Humid Forest region,* occuping much of the temperate lower slopes immediately above the Subtropical Forest Formation.

The region is characterised by the development of climax communities in which red cedar (*Chamaecyparis formosensis*) and yellow cedar (*Chamaecyparis obtusa* var. *formosana*) are dominant. It is the stronghold of the humid cedar association, the climax of moderate elevations. The association develops only on moist but well-drained sites. Deeply melanized soil and a duff mull humus layer are the characteristic features. Cool humid climate with moderate high annual precitpiation prevails. This climax reaches its best development in areas where heavy clouds and mists prevail during the most part of the day through most of the year. Although characteristic, the climax is not universally present. Moreover, the region is diversified by inclusions of other climax associations, of which the hardwood-conifer mixed forests are particularly well developed, and by altitudinal variations, because of its generally mountainous character at intermdiate altitudes. Podzols and gray-brown podzolic soils, together with certain melanized types, present a mosaic pattern comparable to that of the vegetation.

2. The *Subalpine Forest region,* occupying a position in rugged area between the lower Temperate Humid Forest and the upper Alpine Forest.

This region is characterised by the prevalence of mixed mesophytic climax communities in which dominance is shared by a number of species, particularly hemlock, fir, spruce, yellow cedar, and pines. Its vegetation is a mosaic of unlike climaxes and subclimaxes, and thus may be thought of as an ecotone. Representative examples of the mixed mesophytic association occur frequently in its upper part, and more locally downward. Its most prominent vegetational features are the

preponderance of hemlock trees and the great expanses of subclimax alpine grassland. However, the almost universal dominance of pines in secondary forests and their widespread occurrence throughout the region have obscured some of the regional features, even though the many edaphic and secondary communities take part in the mosaic and further complicate the picture and add to the diversity of the region. Soils found in this region are generally young or imperfectly developed, and shallow, stony, slightly podzolized soils are the most widespread. Small patches of gray-brown podzolic soils may occur on flat mountain tops or gentle slopes.

3. Tne *Alpine Forest region*, the uppermost region of the Coniferous Forest, occupying most of the upper slopes approaching summits or ridges of lofty mountains elevated usually over 3000 meters above the sea level, extending upward to the timber line.

The upper boundary of the region is fringed with scattered juniper bushes or more frequently with a type of shaggy scrub-like communities in which the alpine juniper alone is dominant. The region is characterised by the development of a climax in which fir is the most abundant specise, occurring in all parts of this region. The association, however, in the upper part, tends to be confined to ravine slopes, stretching upwards into the contiguous alpine grassland comprised primarily of the grass-like alpine bamboo species, *Pleioblastus niitakayamensis*. The climax, on the other hand, of the lower part of the region appears to be transitional to the forest immediately below because of the local codominance of spruce or hemlock, or sometimes both. The regional soils are mostly young, shallow, and stony.

Species occur in different combinations in different regions; hence, the ecological significance of a species in one region is often quite different from its significance in another. Also, similar combinations of dominants may be different in their ecological status (Braun, 1964). One example may clarify these points. The hemlock, in the Subalpine Forest region, displays great ecologic amplitude, occurring in mesic slope forests as a dominant, and in many typical mixed mesophytic communities. In the Temperate Humid Forest region, it is normally codominant with yellow cedar, or sometimes together with pines, in the driest ridge-top communities. In the Alpine Forest region, however, it may be codominant with spruce or fir in ravine-slope forests.

The climatic conditions over the area of the Coniferous Forest Formation are exceedingly complicated although over the entire area a prehumid maritime climate is normal and where anything drier is of very rare occurrence. Both altitude and topography play important roles. Generally speaking, localities at different elevations are usually under the influences of various types of climate. Indeed, three types of climate can be distinguished, one in each forest region. As is known, these climatic types may be briefly but precisely symdolized as AB_1'ra', AC_2'ra' and AC_1'ra' (cf. Thornthwaite, 1933; Chen, 1957), which are respectively characteristic of the Temperate Humid Forest region, the Subalpine Forest region, and the Alpine Forest region.

Since floristic composition of plant communities is subject to the slow changes induced by entering migrants capable of taking a place in seral stages or in climax stages, boundaries between the forest regions do not exist. Consequently, boundaries must be chosen arbitrarily at the approximate borders of the temporary dominance of particular climax types in the great area involved. The boundaries of the three forest regions have been determined chiefly by field observations, even though all available information has been used in drawing these boundaries.

THE TEMPERATE HUMID FOREST REGION

No definite limits can be given to this forest region where the topographic features are exceedingly varied. The boundaries of the region are ill-defined, for this is a great tension zone between encroaching more subtropical species and retreating more temperate plants. It is a region of interpenetrating climaxes, but a region distinct in the grouping of its climax dominants. In general, the Temperate Humid Forest region is coextensive with the slopes lying between 1500 and 2500 meters in elevation. Here, the vegetational boundary, like the physiographic boundary, is more or less arbitrary, because of a transition area. As a matter of fact, a broad transition belt intervenes between the Coniferous Forest Formation and the Subtropical Evergreen Forest Formation along the indistinctive lower boundary of the region. The upper boundary is also indefinite and is drawn within the transition to the yellow cedar-hemlock area.

Apparently the area of the Temperate Humid Forest is controlled by the frequent development of prehumid climate of temperate nature. A number of forest communities are rather well illustrated on the slopes of this region. The forest of the lower elevations exhibits many variations related to topography and soil. Quite apart from the luxuriance and variety of the forest communities of moderate elevations, the forest vegetation of the region, particularly that on the higher mountain sides where virgin forest stands of red and yellow cedar trees were beautifully represented, has been so profoundly modified by logging, that for the most part it bears almost no resemblance to the original cover. Although many large trees remain and some parts are essentially virgin, large untouched areas are lacking. Today, one may travel for many miles without seeing red or yellow cedar trees once abundant through much of the area. No vestige of the original forest remains in the most disturbed areas.

The Temperate Humid Forest climax is a community in which the dominant trees of the arboreal layer are *Chamaecyparis formosensis*, *Ch. obtusa* var. *formosana*, *Cyclobalanopsis morii*, *C. longinux*, *Actinodaphne nantoensis*, *Persea acuminatissima*, and *Schima superba* var. *superba*. In the valley of Tachia Chi, *Calocedrus formosana* is also one of the dominants. Additional more or less abundant or local species include *Taiwania cryptomerioides*, *Pseudotsuga wilsoniana*, *Cunninghamia konishii*, *Pinus armandi* var. *masteriana*, *P. morrisonicola*. *P. taiwanensis*, *Tsuga chinensis*, and *Trochodendron aralioides*. Moreover, *Illicium philippinense*, *Lithocarpus amygdalifolius*, *Pasania kawakamii*, *P. ternaticupula*, *Cyclobalanopsis stenophylloides*, *Beilschmiedia erythrophloia*, *Cinnamomum camphora*, *Sassafras randaiense*, *Acer kawakamii* var. *kawakamii*, *A. morrisonense* and *Ternstroemia gymnanthera* may occur in a large proportion of the stands but are never abundant, being components of the understory stratum or the second tree layer. To the species already mentioned, about a dozen others which sometimes appear in climax stands could be added. Not all of these species, however, occur in any one area; some may not be found everywhere that the typical humid cedar climax association occurs. The forest of this region contains by far the largest number of shrubs of any part of the formation, and two or more times as many herbaceous species as any other community in any other region of the conifer forest.

On the whole, the total flora of the forest climax characteristic of the region tends to decrease

with increase of altitude. But whereas this decrease is particularly marked in the case of trees, it is not accompanied by any marked tendency to dominance by single species, because more and more temperate species enter. The typical cedar climax forest community on ravine slopes is an example of terrestrial stratification because there are a number of well-recognized strata above and below the soil surface. In most cases, the forest communities representative of the climax of the region are distinctly four-layered in structure. The interior of this type of forest is unlike that of other forests of the Coniferous Forest Formation. Apart from the luxuriant shrubby undergrowth, small climbers as well as epiphytes are abundant. The epiphytes are usually smaller, almost all herbaceous, and mostly limited to ferns and bryophytes or more lowly cryptogams. Epiphytic mosses tend to be particularly numerous and luxuriant where mists prevail in these forest communities, characteristically blanketing the trunks and also hanging from almost every possible point, so that they create far more of a 'show' than in the three-layered rain forest, and, hence then, the name of 'mossy forest' is frequently applied to such a type of forest community.

Naturally, the aspect of the typical cedar climax forest is one of considerable luxuriance owing to the profusion of shrubs, epiphytes, and climbers as well as of ferns and lower cryptogams. Because of the large number of dominants of the climax, the composition and relative abundance of the dominants vary greatly from place to place. This has resulted in the development of apparently distinct climax communities, all of which are actually a part of one great climax unit.

The Incense Cedar Communities

Ecological studies by Chang (1962) in incense cedar community of moderate elevations furnish data on the composition of this type of conifer forest. The incense cedar community is locally represented on the ravine slopes in the valley of Tachia Chi by pure aged stands. Although only two or three species are common in the canopy, the climax is a floristically rich community. Stratification is apparently one of the integral properties of the climax. The climax, like many found in the Temperate Humid Forest region, is a layered forest community in which four layers can be recognized, although these strata are not separately distinguishable. *Calocedrus formosana* is the predominant species in the canopy or overstory stratum. *Pseudotsuga wilsoniana* is common, and also local codominant, in the canopy. In general, individuals of *Calocedrus formosana* and *Pseudotsuga wilsoniana* are of enormous size, being more or less than 35 meters in height and 130 centimeters in diameter. Some may attain a maximum height of more than 40 meters and a maximum d. b. h. of about 160 centimeters. *Tsuga chinensis* is known to be an occasional tree of the overstory stratum.

Although it is the canopy layer or overstory stratum which primarily characterizes the climax, lower layers also have distinctive features. However, the interdependence of canopy and herbaceous layer is strongly marked. To the few canopy species must be added the lower trees, which seldom or never attain canopy position, as *Engelhardtia roxburghiana, Cyclobalanopsis longinux, C. morii, C. stenophylloides, Castanopsis carlesii* var. *carlesii, C. hystrix, Pasania kawakamii. Actinodaphne nantoensis, Persea acuminatissima,* and *P. thunbergii.* Among the shrubs, *Barthea formosana, Blastus cochinchinensis* and *Ardisia cornudentata* are most generally present and abundant. Other species,

more or less widespread, are *Debregeasia edulis*, *Litsea cubeba*, *Fatsia polycarpa*, *Damnacanthus indicus*, and *Viburnum taiwanianum*. Woody climbers, neither numerous as to species nor abundant as to individuals in the climax, include *Piper futo-kadsura*, *Stauntonia keitaoensis*, *Hedera rhombea* var. *formosana*, *Smilax china* var. *taiheiensis*, and *S. hayatai*.

The emphasis thus far in this specific consideration of the incense cedar community has been upon its woody constituents. The herbaceous vegetation, particularly the pteridophytes, is exceedingly rich and varied. In fact, the herbaceous plants are chiefly those common at lower elevations, that is to say those commonly represented on ravine slopes in the area of the Subtropical Evergreen Forest Formation, as *Pilea brevicornuta* f. *brevicornuta*, *Pellionia scabra*, *Elatostema lineolatum* var. *major*, *Oreocnide pedunculata*, and *Alocasia macrorrhiza*. The many ferns, incluluding *Hicriopteris glauca*, *Plagiogyria formosana* var. *formosana*, *Nephrolepis cordifolia*, *Athyrium maximum*, *Neottopteris antiqua* and *Rumohra amabilis* emphasize the luxuriance of the herbaceous layer.

The Mixed Conifer-Hardwood Forest Communities

In deep ravines, there frequently occur along the creeks or near the stream the *Chamaecyparis-Schima-Cyclobalanopsis* community. In such a conifer-hardwood mixed stand the structure is usually stratified into four layers. The canopy is dominated by *Chamaecyparis formosensis*, *Schima superba* var. *superba*, *and Cyclobalanopsis longinux*. The second tree layer or understory stratum consists largely of *Michelia formosana*, *Persea zuihoensis*, *Prunus phaeosticta*, *Symplocos divaricativena*, and *S. konishii*, with a scattering of youthful individuals of *Chamaecyparis formosensis*. The shrub layer or undergrowth is mainly composed of *Turpinia formosana*, *Barthea formosana*, *Fatsia polycarpa*, *Rhododendron ellipticum*, and seedlings of *Actinodaphne nantoensis* and *Prunus phaeosticta*. The ground flora is characterised by *Pellionia arisanensis* and a variety of ferns, such as *Plagiogyria euphlebia*, *P. stenoptera*, *Pteris quadriaurita* and *Dryopteris melanocarpa*, including *Selaginella delicatula*.

Another type of conifer-hardwood mixed stand that is also of common occurrence on the gentle slopes is the *Chamaecyparis-Cyclobalanopsis* community. The community appears to be a transition, for its distributional range is usually limited below by pure stands of *Cyclobalanopsis morii* and above by pure stands of *Chamaecyparis obtusa* var. *formosana*. The forest tends to be pure in composition so far as the number of species is concerned. In fact, the community is equally composed of *Chamaecyparis obtusa* var. *formosana* and *Cyclobalanopsis morii*. Frequently the coniferous components are taller than the hardwood codominants, although there is no evident difference between the frequencies of these two species codominating the community. Another notable feature is the decline of undergrowth and herbaceous ground cover in number of species.

The Red and Yellow Cedar Communities

On the ravine slopes, in place just above 1000 meters, are encountered the first individuals of the cedar communities, namely *Chamaecyparis formosensis*, and with increase of altitude trees of *Chamaecyparis obtusa* var. *formosana* gradually appear. The red and yellow cedars, *Ch. formosensis*

and *Ch. obtusa* var. *formosana*, are represented sparsely or scattered collectively in very small groups in the hardwood forest which is usually considered as a part of the Subtropical Evergreen Forest Formation, in which few individuals of *Taiwania cryptomerioides* are occasionally found as invaders of the broad-leaved forest. *Taiwania cryptomerioides*, in most cases, is only found as a rare associate, often being accompanied by *Trochodendron aralioides*, in the communities in which *Chamaecyparis formosensis* and *Ch. obtusa* var. *formosana* are dominant or in conifer-hardwood mixed stands on slopes where the soil is deep and fertile and the atmosphere is rather damp.

The cedar forest is frequently composed entirely of *Chamaecyparis formosensis* and *Ch. obtusa* var. *formosana*. These are closely related species which constitute the most important and valuable virgin conifer forests of extensive areas that form the rather broad conspicuous cedar forest belt. Pure stands consisting of each of these two species are commonly found on the lower and upper slopes in the cedar forest belt, and communities comprised mainly of both species are not uncommon. Both of the red and yellow cedar species flourish on the mountainous slopes where the atmosphere is on the whole damp and foggy. The prevalence of either of them depends upon the topographic condition; *Chamaecyparis obtusa* var. *formosana* occurs largely in areas where the slopes are gentle, while *Chamaecyparis formosensis* is distributed mostly in the damp valleys and on ravine slopes along creeks or near streams, the place where the slopes are very steep and the soil as well as the atmosphere are constantly moist or damp.

The *Chamaecyparis formosensis* community and that of *Chamaecyparis obtusa* var. *formosana*, as well as the *Chamaecyparis formosensis-Chamaecyparis obtusa* var. *formosana* forest are commonly represented by well-closed, pure or almost pure virgin stands (Figures 3 & 4). The conspicuous components frequently are much as 30 meters tall, constantly have straight trunks free of side branches, and are of enormous size. Most of the individuals are large trees, some of which attain a maximum height of 50 meters and a maximum d.b.h. of 300 centimeters.

In the cedar communities *Cyclobalanopsis morii*, *C. stenophylloides*, *Trochodendron aralioides*, *Illicium philippinense*, *Sassafras randaiense*, *Acer kawakamii* var. *kawakamii*, *A. morrisonense* and *Ternstroemia gymnanthera* are frequent components of the understory stratum, being found usually in admixture. There may be found several additional coniferous species as associate trees. Each of these conifer associate occurs characteristically either as single trees of considerable size, or else as crowded circumscribed groups of young trees, which undoubtedly owe their juxtaposition to the accidents of seed dispersal. Among these conifers, which may form sub-communities within the cedar forest, are *Pinus armandi* var. *masteriana*, *P. taiwanensis*, *Tsuga chinensis* var. *formosana*, *Cunninghamia konishii*, and *Taiwania cryptomerioides*. Some of these species, particularly the hemlock, may be found as independent pure stands or communities distinctive from the cedar community.

The relatively sparse occurrence of a small number of shrubby species makes the cedar forest clearly distinct from the hardwood forest in physiognomy. Among the widely spaced undergrowth are *Neolitsea acuminatissima*, *Euonymus acutorhombifolia*, *Barthea formosana*, *Blastus cochinchinensis*, *Lyonia ovalifolia* var. *ovalifolia*, *Rhododendron formosanum*, *Rh. morii*, *Vaccinium japonicum* var. *lasiostemon*, *Viburnum foetidum* var. *rectangulatum*, *V. furcatum*, and *V. luzonicum* var. *formosanum*.

The herbaceous layer of such forest communities contains a variety of species including *Rubus*

pectinellus var. *trilobus*, *Crawfurdia lanceolata*, *Ainsliaea morrisonicola*, *Pleioblastus niitakayamensis*, *Miscanthus* spp., *Arisaema arisanensis*, and *A. formosana*. The ferns, such as *Plagiogyria euphlebia*, *P. stenoptera*, *Monachosorum subdigitatum* and *Polystichum aculeatum*, are also noteworthy.

A very interesting instance of the relationship of epiphytes and associated tree species is the case of *Leucostegia immersa*, a delicate fern species which is only seen on the trees of *Chamaecyparis formosensis*. Other epiphytic ferns that are of common occurrence in the cedar stands are *Cyclophorus adnascens* and species of *Vittaria*. The only woody climber commonly found throughout the cedar forest is *Prinsepia scandens*.

The floor of such a type of forest communities is usually covered with litter or by a clothed carpet of mosses. Occasionally reproduction appears as sparsely scattered seedlings of very small size on the outcrop or on the rotten logs lying on the floor.

The Secondary Hardwood Forest

The occurrence of the pure stand of *Illicium philippinense* on the somewhat flattened top of Tayuan Shan at about 2100 meters is of great interest. This broad-leaved tree species, with aromatic leathery leaves, usually occurs in various types of the coniferous forest of moderate elevations. The small isolated area of the mountain top to which the pure hardwood stand is confined is entirely surrounded by the hemlock slopes, from which the species in question is absent. Therefore the origin of the stand of *Illicium philippinense* is open to question. Consequently, the occurrence of the pure stand of the hardwood species raises questions as to the seed source and the means of migration, i.e. the method by which the seeds that gave rise to the individuals of the forest community under consideration are carried. Here, such questions seem to be worth separate study.

The pure stand of *Illicium philippinense* is indicative of clay soil and considerable moisture. The stand is even-aged and regularly spaced, the individual trees varying from 5 to 12 meters in height and from 5 to 19 centimeters in d.b.h. The stand is very dense; 124 trees were once tallied in an one-twentieth-hectare area. According to the number of annual rings shown by the increment borer the average age was about 80 years at that time. The stand is level-topped, with majority of trees growing very slowly. The undergrowth is dominated by vigorous thickets of *Pleioblastus niitakayamensis*, the exceedingly abundant occurrence of which usually excludes nearly all of the shrubby species and the lesser vegetation or herbaceous plants. The scarcity of herbacouse plants is similar to that which is usually found in the hemlock stands. Another very noteworthy feature of this closed pure stand of *Ilicium philippinense* is the thick mat of mosses completely enwrapping the whole stems of all of the trees forming the stand (Figure 5).

In addition, it is not uncommon that the talus slopes below the cliffs on the south face of mountain sides are covered by youthful forest communities in which *Alnus japonica* alone is dominant. Apparently, such a community is a type of developing secondary growth of early seral stage, which is characteristic of the devastated area caused by severe disturbance, more frequently by dislodgement of rock fragments from cliffs or steep rocky slopes, of the former forest growth mostly representative of the climax of the upper part of the forest region under consideration. The

occurrence of this type of seral forest community on such unusual type of habitat is probably connected with the fact that the dominant species, *Alnus japonica*, perhaps others of the same genus, with high water requirement, is capable of taking advantage of percolation water. Nevertheless, this community may gradually be replaced by a conifer community, more possibly a pine, this in turn by a cedar or hemlock community.

THE SUBALPINE FOREST REGION

The characteristic appearance of this region is brought about by the dominance of the hemlock over much of the area. The region as here defined extends as a broad altitudinal zone from about 2500 to 3000 meters. As a whole, the boundary of the entire forest region is comparable to that of the climatic type prevailing over the area. Its lower boundary is irregular and in places indistinct, and it is more or less arbitrary and lies within a transition zone. Here, the invasion of the temperate species of moderate elevations from the lower slopes has resulted in the mixing of forest types more or less evident along most of the lower boundary of the region which is in contact with the red and yellow cedar forest belt. On the other hand, the extension of the dominant species of the Subalpine Forest into the forest communities of higher elevations, mostly along the ravines, has made evident the transition from the Subalpine Forest. As a consequence, along most of the boundary, both the lower and the upper, the occurrence of forest communities of a mixed-conifer type will in general serve to distinguish the Subalpine Forest region from that below and above.

Vegetationally, in addition to the widespread and abundant hemlock, the region seems to be characterised also by the common occurrence and local prevalence of pines, chiefly *Pinus tiawanensis*, over much of the area, and the dominance of northern conifers in various places, particularly on the steeper slopes with thin stony soils at higher elevations.

The type of prehumid maritime climate characteristic of the region favors the establishment of a coniferous forest, e. g. the hemlock forest occupying a broad band between the other two forest regions of the same great Coniferous Forest Formation. Although not everywhere dominated by the hemlock, the forests of this region have always contained a large proportion of hemlock. True, the hemlock forests occur over a wide range of altitude. The hemlock forests, pure or almost pure hemlock, contain trees of all size classes; there is no indication of successional change. Typical hemlock communities occupy exposed and rocky mountain slopes and rock slides more or less soil covered. Most of these are primary stands; the low-branching, broad-crowned trees of such sites are not desirable to the lumberman. Apart from the widespread dominant species, *Tsuga chinensis* var. *formosana*, various further conifers belonging to several different genera constitute the other main dominants of a type of mixed mesophytic forest communities occupying the steeper rocky slopes.

In spite of the small number of tree species involved, a number of more or less distinct communities of the mixed-conifer type are recognizable. The mixed-conifer type of forest consists primarily of variations in percentage of the conifers, including *Tsuga*, *Picea*, *Abies*, *Pinus*, and *Chamaecyparis*. However, not all of the species occur in any one area. In other words, communities of this type differ from one another in constituent coniferous tree species and in proportional

representation of species, and, in some cases, in the character of the ground layer. As a matter of fact, variations in steepness or exposure and in depth of soil accumulation affect composition.

On the steeper slopes with thin soils at higher elevations, hemlock cannot successfully compete with spruce, but on dry rock exposures, *Pinus taiwanensis* mingles with *Pinus armandi* var *masteriana*. Indeed, the forest of this region also exhibits certain variations in connection principally with topography. The steeper rocky slopes are, in many places, occupied by forest communities in which hemlock, spruce and pine prevail, with locally a scattering of yellow cedar or fir. The pure hemlock forest reaches its best development only in areas where gentle slopes prevail.

In general, the forests of this region lack the luxuriance and variety which are distinctive features of those represented in the Temperate Humid Forest region. This is in part related to less favorable climate, in part to a less varied topography. Climate, soil and forest fire are important factors limiting the extent of the upper part of the Subalpine Forest region.

Quite apart from the so-called alpine grassland, which will be discussed later elsewhere, outstanding in the landscape of this forest region, are the pine communities which in many places extend for miles over gentle slopes formerly occupied by other forest. However, more shade-tolerant species invade the pine communities, in the absence of fire, tending slowly to reestablish the hemlock or other mixed mesophytic forest type appropriate to the habitat.

The Hemlock Communities

The forest which occupies vast areas of the mountain slopes above the cedar forest belt consists of trees of the hemlock, *Tsuga chinensis* var. *formosana* (Figure 6). The hemlock community is distinct in physiognomy because of the linear dark green leaves and the irregular crown of the component species. The hemlock is found in fine development at 2500 meters on gentle north exposures, and reaches its maximum development in stature and size of the trees, which are as large as 50 meters in height and as 200 centimeters in d. b. h., on the ridges or tops of most of the lofty mountains at 2700 to 2900 meters. In approaching both of the lower and upper limit, the hemlock climax forest appears to be confined to ravine slopes, growing on rocky slopes along creek.

The herbaceous and shrub layers of the hemlock forest are usually sparse unless the alpine bamboo species is represented as vigorous undergrowth of thicket form dominating the entire shrub layer. The only shrubby species that are of frequent occurrence in pure hemlock stands are *Berberis kawakamii*, *Sorbus randaiensis*, *Rhododendron morii*, *Viburnum parvifolium*, and *V. taiwanianum*.

The scanty ground cover includes few perennials. Noteworthy among the herbs are species of *Viola*, *Pyrola decorata*, and *P. morrisonensis*. However, the occurrence of hemlock seedlings of a very small size on moss carpet over the angular rock fragments or round outcrops is not infrequent.

The Mixed Mesophytic Communities

The common occurrence of the *Chamaecyparis-Tsuga-Pinus* community in rugged areas or on

steep slopes forms more or less conspicuous transitional zone between the cedar and the hemlock belts. The vegetation characteristic of this transitional belt is the mixed-conifer type of forest in which dominance is shared largely by *Chamaecyparis obtusa* var. *formosana* and *Tsuga chinensis var. formosana*, with a slight admixture of *Chamaecyparis fomosensis*, *Pinus armandi* var. *masteriana*, and *P. taiwanensis*. However, the absence of the pine species in these mixed forest stands of conifers is not infrequent.

The forest varies considerably in age class, owing to landslides, fires, and other disturbances. Some stands are composed of a mixture of both old and young trees. Others contain only trees of the younger age classes. Density varies from almost complete closure to very open mixtures with other plants, principally *Lyonia ovalifolia* var. *ovalifolia*, *Rhododendron morii*, and *Pleioblastus niitakayamensis*. Most of the stands, however, are aged or overmatured; individuals may be 2000 to 3000 years old. The outstanding components of these virgin stands usually range in height from 21 to 31 meters and in diameter from 50 to 110 centimeters. It is usually cosidered that these aged stands represent the maximum possible development of the component species.

Understory vegetation, like that of the hemlock stands, is very sparse. Regarding the undergrowth, notably interesting is the sparse occurrence of *Vaccinium japonicum* var. *lasiostemon* and *Myrsine stolonifera*. The former is a bushy shrub with small leaves and slender branches; the latter is a subshrubby species having slender stoloniferous stems on which alternately arranged lustrous leaves are distantly spaced. *Myrsine stolonifera* occurs only in the well-developed typical mixed mesophytic communities represented by virgin mixed stands of *Chamaecyparis-Tsuga-Pinus*. Here, *Myrsine stolonifera* is always accompanied by *Vaccinium japonicum* var. *lasiostemon*, which, by way of contrast, may also appear in other type of communities in the absence of *Myrsine stolonifera*.

The Spruce Communities

On some sites, the stands of hemlock of the upper slopes of this region grade into pure stands of spruce. This conifer species, *Picea morrisonicola*, is found almost solely in possession of considerable expanses on steeper rocky mountain slopes, where the soil is shallow but the atmosphere is rather damp. Moreover, this coniferous tree species usually constitutes pure stands isolated in small patches surrounded by alpine grassland on the gentle slopes or on the tops of some of the high mountains. As a rule, the spruce forest normally, if not constantly, occupies the upper slopes facing north or northeast, and is usually in connection with grassland on the opposite south or southwest exposures of extensive area. The appearance of individual small groups is not infrequent in some of the devastated areas on the tops of the mountains.

Today, forest communities of the spruce type are represented by pure stands of relatively limited extent. These mostly overmatured but even-aged virgin forest stands are assumed to be the relics of the originally extensive forest of spruce which once covered vast areas of the upper slopes but which have since been disturbed by severe forest fires.

Under forest conditions, the crown of the spruce species is restricted to the upper portion of the tree, and is much broader and shorter than the spirelike top of the fir tree, which almost

exclusively dominates the Alpine Forest region. The boles of the trees are long and cylindrical, and arise from shallow and widespreading root systems. In old-growth stands, trees 40 to 50 meters high, with 90 to 110 centimeters d.b.h., are not uncommon, while individual specimens up to 55 meters high and 150 centimeters in d.b.h. have been reported. In most cases, however, the spruce tree tends to develop dense stands (Figure 7) which, in many places, form the upper edge of the Subalpine Forest. Although the spruce is always tending to constitute pure stands, fir may occasionally become the sole associate in the otherwise pure spruce stands.

The undergrowth in the spruce forest stands is characterized by a scattering of *Osmanthus heterophyllus* var. *bibracteatus* among the trees, but the widespread species, *Osmanthus lanceolatus*, is also found in such a type of forest. Here, like in any other type of coniferous forest within the formation, the luxuriant undergrowth of the alpine bamboo species, *Pleioblastus niitakayamensis*, is not uncommon. Of noteworthy herbs there may be mentioned *Impatiens uniflora*, *Ellisiophyllum pinnatum*, and the more characteristic ferns, e.g. *Dryopteris lepidopoda*. In many places, *Pellionia trilobulata* and *Rubus pectinellus* var. *trilobus* may carpet the ground, both of which are of common occurrence in most of the component communities of the Coniferous Forest Formation.

However, above an elevation of about 3000 meters, most ot the above-mentioned conifers drop out and another type of coniferous climax forest, mainly fir, prevail.

THE ALPINE FOREST REGION

The uppermost forest region of the Coniferous Forest is one in which fir alone is dominant; with it occur hemlock, spruce, and occasionally junipers. The fir occupies some of the higher summits and northerly slopes, extending from about 3000 meters upwards to the timber line. Timber line is reached at about 3500 meters in Yu Shan (Mt. Morrison). This alpine type of forest is not made up of a number of distinct associations, rather a type of forest with only one association which displays a series of faciations of decreasing complexity upwards. The extent of the area of dominance of the fir forest association is controlled chiefly by climatic influences. As a result, the alpine forest region is coextensive with the climatic province of Chen (1957) which is dominated by the type of prehumid climate that may be symbolized as $AC_1'ra'$. However, snow flurries may be expected during the winter time in this region, which lies entirely within the zone of lithosol soil formation. Because of the steepness and poor consolidation of the slopes, together with the severe weathering and denudation by strong wind and violent showers, bare rocks are frequently exposed and the residual soil is very thin.

As has been seen, along most of the lower boundary of the forest region, where the fir forest is in contact with the forest types of subalpine nature, a transition is evident. Here, infiltration from the contiguous areas along the feeding tributaries of many of the major valleys has resulted in a modification of the fir forest as illustrated by the transitional forest communities occurring where fir mingles with either spruce or hemlock or both. On the other hand, the fir forest in turn gradually gives way to the dwarfed and scrubby growth at timber line, with the fir trees scattered and scraggy. Consequently, stunted and twisted trees and patchy scrub of alpine juniper and other associate dwarf shrubs help to emphasize the vegetational boundary of the region. Unlike that of

the other forest regions, the upper boundary of the Alpine Forest region, or that of the great Coniferous Formation, is fairly sharp.

The fir forest is beautifully represented on the higher mountain slopes. The forest vegetation of the region is quite similar throughout its broad expanse. Only in some locations the typical and widespread phases of the fir forest is modified by an admixture of hemlock and sometimes of pine or is supplanted by a mixed-conifer type in which fir, hemlock and spruce predominate as previously mentioned. In general, only one arborescent layer is distinguishable. The interior aspect of the fir forest is entirely different from that of any other community, for the hummocky forest floor is well carpeted with mosses, liverworts, and lichens (*Hylocomium*, *Hypnum*, *Calliergonella*, *Bazzania*, and *Cladonia*). Here, herbs are usually little in evidence. However, the alpine fir forest bears some resemblance to the coniferous forest climax communities characteristic of the other forest regions of the same formation only when the grass-like alpine bamboo, *Pleioblastus niitakayamensis*, forms a type of undegrowth in the form of dense thicket, dominating the shrub layer under the canopy of the fir stands occupying the moister sites. The sparse herbaceous vegetation is made up almost entirely of species ranging throughout the region. Some of these plants are circumboreal in distribution.

The Fir Communities

As has been noted, the vegetation occupying this forest region is characterised by the dominance of the fir species, *Abies kawakamii*, although in many places the alpine grassland is also of common occurrence, occupying extensive areas, but largely characteristic of the south-facing gentle or rolling mountain slopes. The dense pure fir stands are mostly restricted to the upper slopes approaching the summits or ridges of many lofty mountains. In general, the fir forest tends to be even-aged, and is usually well developed at 3200 meters on steep north exposures. On the north and northeast slopes of Yu Shan at about 3500 meters they reach maximum development in stature and size of the trees.

The floor of the dense fir forest is much more heavily and continuously shaded. This is a circumstance which is of great importance in determining the nature of the forest reproduction and also in conditioning the character of the shrubby and herbaceous vegetation. The heavy shade, dense litter, and drier lithosol soil and atmosphere often make the forest floor devoid of any lesser vegetation and undergrowth. Under certain condition, however, the alpine bamboo species appears, and may occasionally cover the ground all over the area occupied by the stand (Figure 8).

In most of the fir stands trees are evenly distributed and equally spaced. The individuals are mostly large trees with straight trunk of enormous size. The spire-like crown with horizontal branches is restricted to the upper portion of the tree. All of the present stands are representative of the old growth of the virgin fir forest. The component trees range in height from 20 to 27 meters and in diameter from 26 to 80 centimeters, while individual specimens with a 100 centimeters d.b.h. have been reported.

The heaviest fir stands are very poor in both shrubs and herbaceous plants. The shrubby

species are usually sparingly distributed in the forest. Among them may be mentioned *Rubus calycinoides* var. *calycinoides*, *Sorbus randaiensis*, *Rhododendron rubropilosum*, *Vaccinium merrillianum*, and *Damnacanthus angustifolius*. The Formosan juniper, *Juniperus formosana* var. *formosana*, frequenently occurs as the only common undergrowth in the open fir stands of the upper slopes. The poverty of herbaceous species on the fir foest floor is contrasted with the large number of species found in the cedar forest. Conspicuous are *Oxalis griffithii* var. *taimonii*, *Pyrola morrisonensis*, and *Shortia transalpina*. The only fern species occasionally found is *Dryopteris morrisonensis*. Where the soil or atmosphere is moist or damp, the local occurrence of mosses and *Selaginella labordi* on the forest floor is not infrequent.

The Fir-Hemlock Communities

Altitudinally, the fir species may expand its range down into the hemlock belt, while the hemlock often extends upward beyond the upper limit of its normal distribution range and thus may appear in the fir association. As a consequence, another type of mixed conifer forest consisting of the fir and the hemlock is commonly found on the ravine slopes between 2800 and 3100 meters (Figure 9). This type of mixed conifer forest communities tend to be many-aged and open. Fir is usually the most abundant canopy tree, while hemlock dominates in the understory.

The absence of shrubs and herbaceous plants in this type of mixed coniferous forest is the most noticeable feature. The forest floor is chiefly covered with a mat of mosses on which grow *Shortia exappendiculata* and *Mecodium polyanthos*. The abundant occurrence of mosses enwrapping the boles of most of the trees indicates the moist nature of this type of forest.

The Alpine Juniper Forest

In connection with his work on the bryogeography of Formosa, the writer made a collecting trip to Hsueh Shan (Mt. Sylvia) in 1961. Here, a type of alpine juniper forest was found. This is rather an unusual type of forest which had been unknown to the island foresters and botanists until it was reported by Liu (1961) who visited the area at the same time. This type of virgin forest is represented by pure stand of the alpine juniper species, *Juniperus squamata* var. *morrisonicola*, which is entirely confined to a specialized kind of habitat, the protected flattish and rolling slopes in and around a depression of considerable extent. The depression is the place where the Green Tarn is almost centrally located at an elevation of about 3400 meters in the vicinity, but below, of the coupled peaks of Hsueh Shan. Here, the topography is almost entirely depositional. The soils formed and accumulated in this spot are deeply melanized, deeper, richer, and much moister.

The aspect of this type of virgin forest is unlike that of other forests in the alpine forest region. The appearance of the forested slopes and the interior flats is almost park-like. Occurring in a pure stand, the trees may be rather widely placed or clustered in dense groups. There is no brushy layer; instead, there is a carpet of moisture-loving mosses, grasses, sedges, and other herbaceous plants.

The alpine juniper forest is overmatured. The individuals are mostly large trees with straight but conspicuously tapering trunks of considerable size, some of which attain a maximum height of 18 meters and a maximum d.b.h. of 180 centimeters. The aged tree bears certain resemblance to the spruce tree in over-all appearance.

A careful examination of the annual rings of larger branches reveals the exceedingly slow growth of the alpine juniper species, for the annual rings are not visible to a naked eye, but more or less easily discernible when examined with a hand lens. Here, although the individuals grow on the best sites in the sheltered spot, the tree exhibits but exceedingly slow growth. Evidently, the slow growth that characterizes the species must not be influenced by environmental conditions but genetically controlled.

In reference to the relatively huge diameter of most of the individual trees of the forest and their indistinctive annual rings brought about by the exceedingly slow growth, the alpine juniper forest is estimated to be about 4000 to 6000 years in age. Thus, this unusual type of forest is supposed to be the most aged of all the forests of various types occurring on the island.

However, the alpine juniper forest appears to be a physiographic climax. The possibility of the representation of this particular climax type elsewhere on other highest mountains ranging on the island (cf. Liu, 1961) remains doubtful. Although very limited in extent, the forest of this type is so unusual in composition and so striking in appearance as to warrant separate mention.

Moreover, the occurrence of the unusual type of forest at timber line raises questions as to causal factors. Of course, only further careful investigations can show how this may come about, but it seems safe to assume that humidity and the protected depositional topography have a good deal to do with it.

THE PINE FOREST AS PART OF THE CONIFEROUS FOREST

Noteworthy in the landscape of the area of the great Coniferous Forest Formation are the pine communities which, in many places, extend for miles over the mountain slopes formerly occupied by other forest types. Almost in any part of the area, pine forests or the intermediate types of communities in which pines are dominant appear to be secondary. Any remnant of the original pine forest is unknown.

As has been known, *Pinus armandi* var. *masteriana*, *P. morrisonicola* and *P. taiwanensis*, singly or incombination, compose the pine forests of the area of the Coniferous Forest. On the island of Taiwan, each of these pine species reaches the Temperate Humid Forest region; *Pinus morrisonicola* does not enter the other regions of the formation. *Pinus taiwanensis* is found farther upwards than the other two species. Original pine forest stands are but all gone. Fires have been particularly severe in areas dominantly pine. Even the humus may be completely destroyed, leaving either the mineral soil or the rocky exposure.

Not much about the pine forest ecology has been investigated. According to the best knowledge of the writer, *Pinus taiwanensis* forms open or closed communities, sometimes miles in extent, on ravine slopes near the streamway, occurring in particular abundance in the valley of Tachia Chi, at about 2000 to 3000 meters. In fact, pure stands of *Pinus taiwanensis* are frequent, being usually

limited to the ridge-top areas of the mountains ranging over the central parts of the island. The pine forest which contains *Pinus armandi* var. *masteriana* as dominant is always a part of the Coniferous Forest Formation. Younger second-growth stands of uniform-size trees of *Pinus armandi* var. *masteriana*, sometimes with a scattering of *Pinus taiwanensis*, prevail over much of the areas of the Coniferous Forest, excluding the Alpine Forest region. In many places, *Pinus armandi* var. *masteriana* mingles with *Pinus taiwanensis*. Forest communities in which *Pinus morrisonicola* alone is dominant are of rare occurrence, being probably confined to the inaccessible areas of moderate elevations. Nevertheless, *Pinus taiwanensis* and *P. morrisonicola* usually appear as scattered individuals among woods at lower elevations beyond the limit of the Coniferous Forest Formation.

As an example, the pine forest commonly shows up as dense pure stands of old-growth on drier slopes. The dense stock in the pine forest is composed largely of trees having tall, straight, and clear cylindrical boles ranging from 25 to 32 meters in height and from 32 to 77 centimeters in diameter. On the tops of mountains where slopes are gentle the forests are found as isolated small groups in the alpine grassland. These small groups are composed of overmatured individuals of enormous size; therefore they are conspicuously the relics of the pine forest formerly occupied the area and composed of *Pinus taiwanensis* or *P. armandi* var. *masteriana*, or of a combination of both pine species, which have since disappeared due to forest fires.

It is noteworthy that the pine areas have the poorest ground layer. The forest floor is commonly covered with a thick mat of litter of needles from the pine trees which excludes nearly all of the lower plants, including shrubs, herbs, and ferns. Consequently, the pure stands of *Pinus taiwanensis* are two-storied community in which the canopy is dominated by the conspicuous pine components and the understory by *Rhododendron morii*.

Although the forest of *Pinus taiwanensis* always tends to be pure, admixtures of hemlock, spruce, yellow cedar, other than *Pinus armandi* var. *masteriana*, are not uncommon. The understory consisting solely of *Rhododendron morii*, as is just mentioned, is of usual occurrence under the canopy of the pine forest.

It is interesting to note that, in many places, there may occur a transition seral stage between the alpine grassland and the pine forest in succession. Here, it has to be taken into consideration. As has been noted, in the area of the Coniferous Forest, particularly at the higher elevations where stands are exposed to the constant drying influence of wind and sun, fire may be so common as to become a major factor controlling the vegetation of this part of the island. As a result, grassland of extensive area, frequently with relics of aged single individuals, or of trees in small groups, of pine species, is characteristic instead of the potentially possible conifer forests. Also, many instances have been observed of rapid invasion of grassland by arboreal species, particularly *Pinus armandi* var. *masteriana* and *P. taiwanensis*, in the absence of fire. Nevertheless, the type of alpine grassland maintains itself as a result of recurrent disturbance. Evidently, here, fire is responsible for such a disturbance, preventing the successful establishment of a climatic climax forest community. Apparently, the alpine grassland in this area is representative of a subclimax stage in succession.

The transition seral stage between the alpine grassland and the pine forest is indeed ecologically

significant and is much more important in connection with the conversion of the grassland to the pine forest. Although the grassland may fill up steadily with pine trees if protected from fire, most of the invading trees, especially the youthful individuals, may be killed as the periodic or frequent fires sweep over the grassland interspersed with pine invaders. However, the transition or the reversible succession between the alpine grassland and the pine forest is invariably influenced or controlled by fire. Furthermore, the degree of transition may vary from one extreme to the other, depending chiefly on the intensity and frequence of fire disturbance, in addition to the abundance of seed parents of pine species and the actual proximity of these seed trees to the grassland. Nevertheless, the successional transition under discussion is worth further investigation or separate study. But in reality logging and forest fire have tended to increase the extent of pine forest at the expense of hemlock and red and yellow cedars, all commercially valuable species.

Mixed *Pinus armandi* var. *masteriana-Pinus taiwanensis* stands appear to be developmentally more advanced. Only when the humus becomes well incorporated does vegetational development go beyond a pine stage. When that seral is reached, the conversion to other type of coniferous forest would have taken place finally as a result of the inability of the pines to reproduce successfully in the more advanced developmental stages and of the gradual dying of old pines. Successional development in the several pine communities will lead, ultimately, to the establishment of the regional climax forest of hemlock and red and yellow cedars, or of the mixed mesophytic type appropriate to the habitat. This development is exceedingly slow, taking centuries for its completion and is possible only in the absence of fire.

THE ALPINE GRASSLAND AS A WHOLE

As has been seen, the vegetation of the Coniferous Forest Formation consists of forests of various coniferous species with intervening spaces occupied by herbaceous vegetation. The herbaceous vegetation is found almost completely in possession of extensive areas over a wide range of altitude, usually above 2000 meters, and is commonly referred to as alpine grassland.

These stretches of grassland are usually communities dominated by grasses of medium height. Many different species are found, but they are predominantly perennials. All of them, however, are light-demanding species and have certain features in common. Some are creeping forms, rooting at the nodes, others are deep-rooted and very xerophytic tufted forms. Some of them grow in excess of two meters in height, but sod-forming species are also dominants. Among the dominants the most noteworthy is perhaps the alpine bamboo species, *Pleioblastus niitakayamensis*, which is more or less abundant, ranging all over the area of the Coniferous Forest Formation. *Miscanthus transmorrisonensis*, too, is plentiful and frequent over much of the grassy slopes, but perhaps not commonly present in woods. As a matter of fact, both species are predominant. Upwards, however, *Miscanthus transmorrisonensis* exhibits dominance with diminishing frequence but *Pleioblastus niitakayamensis* shows notably increasing prevalence of occurrence. Also included are various species distinctly less abundant but nevertheless thus completely distributed. Among these are *Agropyron ciliare*, *Agrostis canina* var. *formosana*, *A. flaccida* var. *morrisonensis*, *A. morrisonensis*, *Andropogon shimadae*, *Anthoxanthum formosanum*, *Aulacolepis agrostoides* var. *formosana*,

A. treutleri, *Brachypodium kawakamii*, *Bromus formosanus*, *B. morrisonensis*, *Calamagrostis matsudana*, *C. morrisonensis*, *C. niitakayamensis*, *C. sublanceolata*. *Deschampsia caespitosa* var. *festucaefolia*, *Festuca japonica*, *F. ovina* var. *vulgaris*, *F. ovina* var. *purpurascens*, *Miscanthus kanehirai*, *Phleum alpinum*, *Poa nankoensis*, *P. takasagomontana*, *P. tenuicula*, *Trisetum spicatum* var. *formosanum*, *Bulbostylis densa*, *Carex* spp., *Luzula effusa*, *Scirpus morrisonensis*, and *Juncus modicus*.

Herbs which are characteristic of this type of alpine grassland include a number of species. Some are geophytes while others are more or less xerophilous. The distribution of these plants varies a good deal. Among the grasses they illustrate almost every kind of distribution over the extensive grassland area. Some are by no means evenly distributed over the grassy slopes while others are more local or uncommon. Still others occur in only some of the apparently favorable places. Evidently, in the distribution of these species over the grassland area, there is predominantly correlation with edaphic conditions of one sort or another. The question of shade and mutual protection is also of great importance. Among these species are *Cerastium takasagomontana*, *Viola stenocentra*, *V. tozanensis*, *Hypericum nagasawai*, *Polygala japonica*, *Hydrocotyle nepalensis*, *Mazus japonicus*, *Gentiana arisanensis*, *G. formosana*, *G. scabrida*, *Swertia randaiensis*, *Anaphalis horaimontana*, *Cirsium kawakamii*, *Senecio morrisonensis*, *Solidago decurrens*, *Sonchus arvensis*, *Lilium formosanum*, *Veratrum formosanum* form. *albiflora*, *Aletris formosana*, and *Platanthera brevicalcarata*. Among the pteridophytes *Lycopodium complanatum*, *L. obscurum* and *Pteridium aquilinum* occur over a wide area and are often enough to be seen, but their occurrences are generally well spaced and they rarely grow in great quantity. The last-mentioned species, however, may be locally codominant with *Miscanthus transmorrisonensis*.

Plants of a shrubby nature are often associated in this type of alpine grassland but do not reach a greater height than the herbaceous cover. Prominent among these are *Juniperus formosana* var. *formosana* and *J. squamata* var. *morrisonicola*; the former is found over a wide range of altitude but the latter is usually confined to high mountain tops, where the sloping is gentle, at timber line. Both species, however, frequently appear as low bushes scattered over much of the area of the grassland communities of higher elevations. Among others may be mentioned *Salix fulvopubescens*, *Berberis kawakamii*, *Ribes formosana*, *Elaeagnus morrisonensis*, *Gaultheria cumingiana*, *G. itoana*, *Rhododendron noriakianum*, *Rh. pseudochrysanthemum*, *Rh. rubropilosum*, and *Vaccinium merrillianum*. Again, except *Photinia lasiopetala*, which may appear as a small tree or shrub of local occurrence among the grasses, various further shrubby species belonging to several different genera of rose family are also widely represented in the communities of this type, such as *Cotoneaster morrisonensis*, *Rosa morrisonensis*, *R. transmorrisonensis*, *Rubus calycinoides* var. *calycinoides*, *R. elegans*, *Spiraea formosana*, *S. morrisonicola*, and *Stranvaesia niitakayamensis*.

The arboreal vegetation may linger on as stunted growth among the grasses, but it is gradually killed off. The old growth of hemlock consists of a small number of trees and is frequently found along the waterway or streams running through the grassland. Sometimes the same is true of red and yellow cedars and fir. Old trees of spruce and pines (*P. armandi* var. *masteriana* and *P. taiwanensis*) are of occasional occurrence, either singly or in very small groups scattered over vast stretches of grassland. Both pines are found to be the common invader of this type of grassland

communities.

On the whole, the general unity of this type of alpine grassland is evidenced by the commonest and most widespread predominants, *Pleioblastus niitakayamensis* and *Miscanthus transmorrisonensis*, occurring in nearly all of the component communities. Since there is altitudinal difference in frequence of distribution of these two predominant species, within the grassland local segregation and variations in relative abundance of the predominants result in the development of somewhat distinct communities which may be termed *Miscanthus*, *Miscanthus-Pleioblastus* and *Pleioblastus*, or, more generally speaking, alpine grass, grass-bamboo, and alpine bamboo. The alpine *Pleioblastus* community is most widespread, occurring chiefly on high mountain slopes and tops, which appears magnificent in its extent and identity. Commonly, on gentle slopes of moderate elevations, *Miscanthus transmorrisonensis* becomes abundant, resulting in the *Miscanthus* type. The *Miscanthus-Pleioblastus* community is very local, sometimes forming a strip between the other two types of alpine grassland under consideration.

Most of the grass communities in this area of the Coniferous Forest Formation are undoubtedly natural but no small part represents areas that have been cleared, then cultivated, and finally abandoned. Some of these communities, however, are slowly reverting to woodland.

THE ALPINE TUNDRA REGION

The alpine tundra lies above timber line in high mountains. It occurs on Hsiukuluan Shan, Nanhuta Shan, and Kuan Shan, besides the two well known highest mountains, Yu Shan (Mt. Morrison) and Hsueh Shan (Mt. Sylvia), which are about 120 kilometers apart. Yu Shan is located in the south-central part while Hsueh Shan is situated in the north-central part of the island. The summit of Yu Shan is 3997 meters above sea level while Hsueh Shan is about 3884 meters. The alpine tundra is bounded on the lower margin by fir forest which has already been mentioned. The timber line on Yu Shan occurs at about 3500 meters while on Hsueh Shan it is reached at about 3400 meters.

The climate is much more severe than in the forested areas which are roughly peripheral, but below, to this region. The growing season is short and its temperatures are relatively low. Here, the winters are very cold, and the whole area is usually covered with snow during the period from December to April. Precipitation is less than that of the fir slopes lying immediately below the tundra. The constant high winds, however, prevailing throughout the year, undoubtedly cause high rates of evaporation and transpiration. As a result, both temperatures and water often become limiting factors.

In this region the ground is covered largely with typical coarse, angular soil particles and very little organic material. The soil particles tend to increase in size along with the increase of elevation. Consequently, the tops of most of the high mountains mentioned above are merely accumulations of rock fragments of huge dimensions.

The alpine tundra is conspicuously characterized by vegetation that is low, dwarfed, deformed, and frequently matlike, and includes a high proportion of grasses and sedges. The herbs are mostly perennials of a rosette type. Mosses and lichens may grow everywhere and form a thick carpet with

the low herbs. The number of species is small compared with floras of temperate climates. Most of the genera, however, are found throughout the Northern Hemisphere wherever tundra occurs.

Because of the pronounced difference between the vegetation covering the lower portion of the Alpine Tundra region and that which is found on the upper slopes in proximity to the summit of Yu Shan, the region may be divided into two parts, namely the Juniper Scrub area and the Bare Rocky Summit area.

The Juniper Scrub Area

This is the relatively small area, estimated to be about 1500 hectares, above the altitudinal limit of tree growth. In fact, the area lies below the bare rocky summits and ridges of the high mountains, a constant exposed area whose lower margin is at about 3700 meters. The surface materials that mantle the ground of this area consist largely of typical coarse, angular rock fragment with little organic matter. Big rock fragments, however, are also frequently found.

The transition from the fir slopes to the treeless area is usually gradual, with a thinning out of fir trees, which here are commonly dwarfed and distorted. Characteristic of timber line are several scattered fir trees that cannot survive in the treeless area, although they are the conspicuous components of the fir forest covering the forest region immediately below it.

The vegetation of this area is characterised by the presence of dense thickets made up largely of the alpine juniper species, *Juniperus squamata* var. *morrisonicola* (Figure 10). This juniper rarely reaches two meters in height, although it appears in place of Hsueh Shan in the form of tree-growth, and is usually many-stemmed or branchy and procumbent in appearance, ordinarily forming pure stands in the form of impenetrable thickets that are conspicuously characterised by the uniform tips of numerous crowded branches. As has been known, the alpine juniper stands almost constantly dominate the mountain tops or slopes approaching the bare rocky summits and ridges of some of the high mountains. *Rhododendron pseudochrysanthemum* and *Berberis morrisonensis* are the frequent associates found in the more or less extensive tracts of the alpine juniper scrub.

As has been noted, the scrub area is almost entirely covered by the low, dwarfed and densely matted alpine juniper stands. Besides, the occurrence of a number of species of grasses and sedges is also a noteworthy feature. Among the grasses may be mentioned *Anthoxanthum formosanum, Calamagrostis morrisonensis, Deschampsia caespitosa* var. *festucaefolia, D. flexuosa, Bromus morrisonensis*, and *Brachypodium kawakamii*. Conspicuous sedges are *Carex alliiformis, C. apodostachya, C. oxyandra, C. pseudo-arenicola*, and *C. transalpina*.

The Bare Rocky Summit Area

This is the particularly striking area above the upper limit of the scrubby vegetation area, which is reached at about 3700 meters on the tops of some of the high mountains. It occupies the highest parts, but the least area, of the Central Range, including only the summit ridges and peaks of Yu Shan, Hsueh Shan, and Hsiukuluan Shan. The ridges have been formed where stronger

rocks have resisted erosion. These often extend unbroken for miles, with slopes but slightly indented by streams; in places they are cut by gaps. They may decline in elevation toward their ends, or may bifurcate, or be joined by other ridges. The sandstones which form their crests are often steeply inclined or almost vertical. The slopes in many places are vast rock slides, tumbled masses of sandstone blocks, or steep barrenshale slopes.

The areographic extent of this limited area is estimated to be about 400 hectares, which is really too small to be noticeable by the layman; even the foresters or botanists scarcely pay attention to it. Therefore the whole alpine tundra region, inclusive of both areas here delimited, has often been considered a part of the Alpine Forest region. However, the separation of the alpine tundra from the forest region is more logical in many respects.

Edaphically, this area is an accumulation of big angular rock fragments, some of huge dimensions, broken loose from their native strata. So far as the landscape is concerned, the area is vividly characterized by the absence of any vegetation cover. Consequently, this peculiar bare rocky area deserves to be referred to as a desolate cold desert constantly exposed to the influences of low temperatures and high winds.

Although this area seems to be entirely devoid of vegetation, sparse perennials may get a foothold in the seams or fissures of the rock fragments, and frequently a close examination will reveal minute crusts of lichens attached to the rock as if a part of it.

A very small number of species of grasses and herbs are infrequently found to be singly and entirely confined to the fissures of some of the rock fragments. All of the small perennials that are found to be of occasional occurrence in this area are mostly xerophytes of a rosette type. Some of them are succulents, while others have massive fibrous root systems; a few species are perennial woolly herbs. These herbaceous plants include *Cerastium trigynum* var. *morrisonense*, *Cardamine arisanensis*, *Arabis alpina*, *A. morrisonensis*, *Hypericum randaiense*, *Sedum alfredi*, *Parnassia palustris*, *Potentilla morrisonicola*, *P. tugitakensis*, *Geranium uniflorum*, *Oreomyrrhis involucrata* var. *involucrata*, *Ellisiophyllum pinnatum*, *Hemiphragma heterophylla*, *Gentiana arisanensis*, *Galium morii*, *Scabiosa lacerifolia* f. *leucantha*, *Adenophora morrisonensis*, *Leontopodium microphyllum*, *Anaphalis horaimontana*, *A. nagasawai* *Artemisia niitakayamensis*, *Ponerorchis kiraishiensis*, and *Pleione formosana*. Among the noteworthy annual grasses here may be mentioned *Trisetum subspicatum* and *Brachypodium kawakamii*.

An interesting case of altitudinal distribution of the species found in this unusual bare area is that the species occurring at the highest stations are not herbaceous plants but rather the woody species, *Berberis morrisonensis*. A single specimen of the plant, *Berberis morrisonensis*, about 50 centimeters high was once found growing alone at 3995 meters on the east exposure of the summit of Yu Shan.

DISCUSSION

A forest community exists in a physical environment composed of the atmosphere surrouning the aerial portions and the soil containing the subterranean portions. This environment is not static but rather is changing constantly due to the rotation of the earth, the fluctuations in solar radiation,

the changing atmosphere, the weathering of the soil, and indeed the effects of the forest community itself upon both the local climate and the locall soil. The forest community and its habitat together comprise an ecological system, or *ecosystem*, in which the constituent organisms and their environments interact in a vast and complex energy cycle.

The forest community is produced by the interactions between forest trees and other forest organisms on one hand with the forest environment on the other, over a period of time. Consequently, the forest should be considered as a complex ecosystem arising out of the interactions of the forest trees and their environment, so many factors are involved over so long a period of time that it is wise to conclude with a consideration of forests as they actually are and not necessarily as they should appear to be in accordance with our philosophy.

A forest community is affected most strongly by the conditions that existed at the time the present individuals became established on that site, but it is also affected by all that has happened since that time. In the forest, the history of logging, land clearing, fires, windstorms, insect and disease epidemics, and other happenings that affect the life and growth of the trees all will influence the present forest stand. Climatic fluctuations and the development of the soil profile also cannot be ignored. The more we can learn of the history of the land and of the plants and animals that occupy it, the better we can understand the present communities. As Braun (1964) sums the matter up:

> The pattern of forest distribution, the configuration of forest regions, is a result of environmental influences of the present and of the past. The development of the land surface has been slow, and it has been shown that many of its features are reminiscent of the past. The development of soil is in part dependent upon topography and climate, in part on the reactions of occupying vegetation, which in turn is influenced by topography and climate. Changes in climate, in topography, or in soil bring about changes in vegetation. These, however, do not always keep pace with the environmental change. Vegetation is not everywhere in complete equilibrium with its present environment. This is attested by its lack of uniformity even within single forest region.

On the island of Taiwan, forests are widespread on land surface in humid climates below the alpine tundra. Each forest community follows a definite life-cycle in which it becomes established, develops, reaches maturity, and in turn gives way to another community either similar or different in composition. The structure and composition of the forest community change from time to time and from place to place. The spatial variation within a forest may include abrupt changes from one type of forest to another and also gradual changes in which the character of the forest changes with changing dominance or abundance of the component species, the appearance of new species, and the dropping out of others. Forest associations or types, therefore, may change in composition either drastically or gradually over space.

Wherever one type of forest association abuts on another distinctly different type of forest association, it will be found this abrupt change is related to an abrupt change in site conditions or to a completely different vegetational history of the two associations. The existence of discrete associations, therefore, is evidence of the existence of discrete differences in growing conditions, either now or in the past. The boundary between two associations is usually a belt rather than a sharp line. It is a belt or zone, though, which may vary widely in width. It usually embodies some

of the ecological features of the two associations, but has a characteristic ecological structure of its own.

The interrelationship between condensed moisture and trees has been the subject of much speculation. Fog and dew may well be quite important in determining the growth and distribution of forests, but the extent and mechanism of the effect has proved difficult to demonstrate in precise experimentation (Spurr, 1964). There seems to be an obvious correlation in many parts of the earth between the distribution of certain trees and the presence of fog belt. In Taiwan, the most spectacular example occurs on mountain slopes of moderate elevations where red and yellow cedars characterize the typical temperate humid forest.

The general tendency towords cooler and damper conditions as we ascend mountains usually leads to marked attendant changes in the vegetation. A good example of the usual forested sequence in mountainous districts is well seen in Taiwan. Here, the vegetational zonation of mountains appears to be fairly familiar to most island foresters and botanists. True, the altitudinal zonation of vegetation on the island is conspicuously recognized by the distinctive zonal distribution of the hardwood forest and the coniferous forest on the forest slopes. On the high mountains, e.g. Yu Shan and Hsueh Shan, there is usually interposed between the bare rocky summit area and the high forest a shrub formation forming a girdle commonly known as the zone of juniper scrub. Finally, above the alpine shrubs a zone of alpine herbs is more or less distinguishable. Above this there is no appreciable vegetation. The major and most obvious segregation of the coniferous forest of Taiwan is into three altitudinal zones or, as already described, forest regions. However, this zonation is hardly detailed enough and it is usually to incorporate a fourth zone and to speak of temperate, subalpine, alpine forest, and alpine tundra.

The major associations of the Coniferous Forest Formation of Taiwan are recognized as cedar, hemlock and fir. Each of these major associations is, in some part of the coniferous forest, a regional climax, there occupying a variety of sites within the limits of altitudinal zones, and thus generally emphasizing climatic control, rather than topographic or edaphic control. Yet each of these associations occurs in favorable situations outside of the area of its dominance, outside of the region it characterizes. Communities representative of different associations, and even of different formations, may occur side by side. This is particularly true of the lower part of the temperate humid forest region.

The climax is not static althoug its period of endurance may be thousands or hundreds of thousands of years. Slow changes, which may be due in part to gradual evolution of species and changing magnitude of adaptability, in part to changing climate resulting in change in range of species, in part to continuing migration of species, modify each climax. Although each has its unifying characters, no climax is the same throughout its area. Spatial variations emphasize the variable responses of the climax or illustrate the long-time development which is possible. The recognition of three major associations in the Coniferous Forest Formation is an illustration of man's attempt to classify forest vegetation. Each is a more or less artificial unit. All of these associations are variable, and intermediate or transitional types of climaxes may occur.

Here, the extent of the area of dominance of any forest association is equal to that of the corresponding forest region previously delimited and is controlled chiefly by climatic influence.

Extremes in annual variations in temperature or precipitation, while they may adversely affect the vegetative vigor or the seed production of individuals of particular species, will not affect the climax as a whole. Even if continued for a number of years, they can have little effect except by causing slight oscillations of margins through their limiting effects on species distribution. However, long-protracted trends or climatic shifts, such as have taken place in the past, have had profound effects upon the extent and distribution of climax associations and are in part responsible for differences in composition in different geographic areas. Such climatic shifts have brought about mass migrations, or expansions or contractions of vegetation types. We may be justified in assuming that the climatic requirements of a given association have remained reasonably constant through the ages, that protracted dry periods must have resulted in contraction of mesic associations and corresponding expansion of xeric associations. At the same time, we must certainly admit the possibility of slow progressive changes in requirements or rather adjustments of vegetation. Migration and evolution, not alone of species but of physiologic adjustments of species and hence of vegetation, must have been determinative, the attempt to reconstruct the past must be based chiefly upon the paleobotanic record, the disjunct distribution of communities and species, and physiographic history.

The Future of the Cedar Forest

In the forest as a whole, the most valuable conifers are two cedar species. *Chamaecyparis formosensis* and *Ch. obtusa* var. *formosana*. Both have been a major forest resource for decades, and it will continue to be so by reason of the superior qualities of the wood in resistance to decay and in adaptability to many uses. Unfortunately, in reality these valuable species are now in danger to become extinct (Lee, 1962).

Both species are represented in virgin stands of matured to overmatured trees ranging in age from 200 to 2000 years. In these virgin stands the individuals of both species have been found to be very unevenly spaced, ranging from four or five to about a hundred or more per hectare, averaging about 40 trees. Irrespective of the density of the forest stand, in many places, usually not a single seedling of natural reproduction can be found under the canopy of the forest. Only in places seedlings or small youthful trees are found scattered here and there along roads in the cutover areas. This is undoubtedly indicative of the fact that both species appear to be light-demanding plants, although the red and yellow cedars have reached their best development only on ravine slopes where mists prevail most of the time in the forest. However, in areas where the cedar forests prevail, it seems too cloudy or too foggy for seed to germinate and for seedlings to develop successfully under the forest canopy. Consequently the lack of seedlings or natural reproduction in the cedar forest is to be expected.

As a matter of fact, logging, basically clear cutting, on a large scale, has taken place in the cedar forest since the beginning of this century. The commercially important cedar forest resource is almost entirely exhausted, and only overmatured virgin stands of both cedar species are found in but few inaccessible mountain areas. The components of the tree layer of these virgin cedar forest stands are mostly overmatured or diseased, and have lost their ability to produce seed. Logging operations are steadily reducing the acreage of cedar forest. Furthermore, within recent

years logging in hemlock forest, which is mainly confined to the higher altitudes, has been practiced. The excellent timber stands of cedar have supplied a continuous stream of timber for the past sixty years, but the natural vegetation, the valuable virgin coniferous forests, has been eliminated from vast areas. In general, the sudden and complete exposure of the soil following clear cutting cannot be other than less favorable to the new stand and on steep slopes may lead to an actual loss of top soil by erosion.

Conditions in natural stands point strongly to the fact that there is no factor more important in relation to disease than tree vigor. Stands on good sites are generally not damaged significantly by native diseases, but those on poor sites often suffer severely. Where forest conditions have been largely destroyed over extensive areas by unregulated cutting, the new stand, particularly in its juvenile stages, is likely to suffer more severely from disease than would normally be the case. The destruction of normal forest conditions can lead to such profound changes in site that on the less favorable locations it may be impossible to establish again a satisfactory stand of the climax species for decades, even by planting. It is evident that in cutting timber the selection method or one of its modifications should be practiced, where possible, instead of clear-cutting, unless clear-cutting has been nature's method. In Taiwan, as a rule, clear-cutting with natural regeneration is to be preferred to clear-cutting with artificial reproduction.

Reforestation on the cutover areas previously occupied by the cedar stands is urgently needed, but the difficulties relating both to the natural regeneration and artificial planting of cedar trees must be overcome. In fact, extensive areas that have been logged are growing only weeds and shrubs that make reforestation more difficult each year. Natural regeneration in most areas is unsatisfactory either because it is too slow and too sparse, or because only inferior tree species become established. As a consequence, natural regeneration of the cedar forest, under the present forest conditions, appears to be hopeless.

After the removal of the canopy trees in the cedar forest, the individuals of the understory, almost exclusively broad-leaved tree species, now fully occupy the space, converting the forest into a hardwood stand. This conversion to hardwood forest would have taken place finally as a result of the inability of the cedar seeds to germinate and of the seedlings, if any, to develop or compete successfully with the hardwood species. As has been noted, the grass-like alpine bamboo species, *Pleioblastus niitakayamensis*, which is known to be an aggressive pest to the coniferous forest of Taiwan, has the ability to invade the forest stand promptly when natural openings are made in the forest as a result of severe disturbance. When the invasion of the stand by the bamboo is once carried out, the stand is usually kept closed by the thick mat of densely widespread rhizomes of this pest as long as it exists in the stand, and all of the shrubs and herbaceous plants that were formerly of common occurrence in the stand are excluded, let alone the seedlings of both cedar species. In addition, a kind of tall grasses, species of *Miscanthus*, in other cases, frequently takes over the cutover areas immediately after the removal of the tree layer, and stands equaling the original forests will probably never again occupy most logged areas. This serious disturbance of natural vegetation has resulted in the devastation of the primeval forests and the deterioration of the forest soils, which once supported desirable climax forest communities. Evidently, the cutting of the cedar forest has far exceeded reforestation and if this is to continue, the island will lose one of

its greatest natural resources.

The most valuable commercial forest of cedar on the island has long been attacked by heart-rotting fungi. Because diseases in general work slowly and insidiously, control is likely to be neglected until too late to prevent loss. Although there is no available information on the actual loss resulting from diseases in the cedar forest of Taiwan, that the wood-destroying fungi have reduced the stand of saw timber by tremendous quantity is apparent. The loss from diseases is mainly composed of heart rot.

Stereum sulcatum Burt. is found invariably associated with *Chamaecyparis formosensis,* in which it causes white pocket rot. The advanced stage appears as few to many elongated, somewhat spindle-shaped, more or less pointed pockets or cavities parallel to the grain and separated by apparently sound wood. In the pockets the wood is reduced to a white soft fibrous mass of cellulose. In some cases the pockets may be empty.

Hymenochaete sp. is restricted to *Chamaecyparis obtusa* var. *formosana.* The Heart rot of this species is just as common and widespread as the white pocket rot of *Chamaecyparis formosensis.* In cross section the rot is usually circular in area, commonly destroying all the heartwood and leaving only a shell of sapwood; the decay does not encroach on the living sapwood.

The roles that these fungi play in the cedar forest in terms of succession, and the final result of their serious attack to the cedar forest in the future, is unknown at the present time. It is that the fall of the attacked trees brought about by wind during the visit of typhoons usually results in openings in the stand. As soon as the openings are made in the canopy of the forest, the alpine bamboo, *Pleioblastus niitakayamensis,* frequently invades the stand. As a result, the invasion by this pest usually makes the natural reproduction impossible and crowds out the seedlings already present. In the cedar forest, however, seedlings only occur on the outcrops and on the rotten trunks lying on the forest floor; thus the fall of attacked trees may furnish suitable seed beds for the natural regeneration of the attacked tree species.

It is interesting, even fortunate, to note that only aged trees are susceptible or affected by these fungous diseases, while the immature trees are mostly immune. The association of *Chamaecyparis formosensis* with *Stereum sulcatum* versus the connection of *Chamaecyparis obtusa* var. *formosana* with *Hymenochaete* sp. is a very interesting case in the infection of these fungous species to the susceptibility of these allied cedar species. The two cedar species are phylogenetically and morphologically closely related; but each of them is only susceptible to one of these two fungus species, and neither of them is found affecting both cedar species.

The cedar trees have been subjected to serious attack by these fungus species, or at least to attack which would cripple them sufficiently to prevent their successful competition with other immune or less susceptible individuals; therefore, these pests, and the means of combating them, should have been intensively studied. Unfortunately, in reality the effects of these parasitic fungi on the particular cedar communities have been but very little studied by the island pathologists. There is, however, need of critical study of the relation of the fungus species to their habitat and on the means of fighting against the pests, difficult as the problem may be.

In brief, heart rot is of importance in connection with the loss from disease, and it is particularly true of the diseases occurring in forests for wood production. Although it is difficult to evaluate

exactly the damage caused by the diseases, trunk and butt rots predispose to windbreak and wind throw, especially in areas like Taiwan, where typhoons usually visit frequently during the period of time from May to October, and such trees are dangerous in the immediate vicinity of roads, trails, and camps.

Since diseased trees are undesirable to the lumberman, logging has been practiced so far in the way that trees in good conditions are cut, while those overmatured and diseased individuals are left over in the forest. Apparently, the aged or overmatured trees are no longer reproductive, for they may have already lost their ability to bear seeds. The diseased trees may be genetically susceptible or less resistant to the fungous diseases. However, this has been the way of logging practiced on the island. Trees of inferior qualities are usually left standing and scattered over the logged area in the forest as if they were mother trees, and in reality they do function as seed trees in the natural regeneration of the forest. Of course, these trees which are left over, on account of their poor qualities, are indeed undesirable as regards health and vigor. Consequently the health of the forests is steadily declining, and the damage by pathogenic fungi is constantly increasing. However, this type of modification of selection method, by means of which the best trees are taken out, leaving only the aged and diseased individuals scattered in the logged area to perform the function of normal seed trees, will deplete the strength of the forest. This means that, wherever natural regeneration is possible, the way of logging, which has been practiced so far on the island, is even worse than clear-cutting with artificial reproduction.

It is unlikely that decay of the heartwood only will have any effect on the quality of seed, although this demands investigation to determine whether undesirable hereditary characters may be associated with liability to decay. It is well known that races of trees within a species and individuals within a race vary in their susceptibility to both nonfectious and fungous diseases. In selecting seed trees, however, those individuals which appear to be less vigorous or actually show disease should be avoided. Furthermore, diseased trees should be removed during the intermediate and final cuttings because each one, unless it is soon to die, continues to occupy growing space that could be better utilized by a thrifty tree and also increases the likelihood of the spread of infectious diseases to other trees in the stand. In general, repeated intermediate cuttings should consistently improve the seed quality of a stand. Natural regeneration, however, if possible, under the present forest conditions, will be slower as to the lack of suitable healthy and vigorous seed trees.

From the above-mentioned facts, it appears to be predictable that both of the red and yellow cedars will be of but little importance in the coniferous forest on the island in the near future. Also, the future of the cedar forest may be foreseen, which at least seems to be unpromising, if not entirely hopeless. Nevertheless, it should be born in mind that the cedar forest has been one of the greatest natural resources of Taiwan, and it has supplied a continuous stream of timber for the past sixty years. Therefore, every effort should be made to protect the most valuable endemic conifers, i.e. *Chamaecyparis formosensis* and *Ch. obtusa* var. *formosana*, from becoming extinct.

In addition, except on an experimental basis, there is little need for introducing exotics into this country, which has a great variety of conifers as well as hardwoods admirably adapted to the various forest regions.

The Future of the Alpine Grassland

As has been stated, in the area of the Coniferous Forest Formation many tracts which were once covered with coniferous forest are covered largely with grasses of medium height, through which fires of great intensity rage frequently during the drier seasons. When fires have once been started, they may carry on over enormous tracts of country, and may, or may not, occur over the same area each year. The effect, however, is the same, although the origin of the vast majority of the fires is unknown.

As the fires sweep over the forested areas, most of the trees are killed, the forest canopy is thus opened, the litter is burned off and the soil is exposed to the drying influences of sun and wind. The humus in the soil disappears, and without litter or trees to furnish litter no more humus is formed: A soil lacking humus and bare of litter is subject to erosion. This process carries away the most fertile portion of the soil. In extreme cases the entire surface layer of soil may be eroded, leaving exposed the subsoil or even the underlying rock. Thus the forest vegetation is impoverished, and more often stretches of vegetation of natural grassland have entirely replaced the burned forest as a result of fire. The grassland, like bamboo grove, is usually regarded as subclimax vegetation which is the result of fire disturbance.

It is believed that these grasslands when protected from fire, fill up steadily but slowly with tree-growth, which, as a rule, advances from edges towards the center of the grasslands. The invasion of grasslands by trees may be very slowly as illustrated by the infiltration of fir trees from the forest into the contiguous alpine grassland dominated by the alpine bamboo species on high mountain slopes, or it may be very rapid in areas where there is no frost and rainfall is heavy, together with abundant seed trees of pine species in proximity to the grassland. Many instances, in fact, have been observed of rapid invasion of grassland by arboreal species, particularly *Pinus armandi* var. *masteriana* and *P. taiwanensis*, following the introduction of fire-protection. True, northerly slopes and moist sites afford some advantage to reforestation by the above-mentioned conifers.

The tendency of grasslands, if protected from fire, to be invaded by forest, raises the question as to the extent to which the former are a natural formation in the high mountais in Taiwan. Evidence points to the fact that at all events Taiwan is primarily a forest country, and that most of the extensive grasslands have been brought into existence and maintained as such by the agency of periodic fires. In the absence of fire, this type of grassland communities tends to be replaced by tree-growth. Consequently, the alpine grasslands of the mountains ranging on the island of Taiwan, like the alpine meadows existing in other parts of the world, e.g. those of the western American mountains, are certainly good examples of fire-cauesd grassland that have persisted for hundreds of years under climates suitable for tree-growth. Field observations, however, emphasize that the possible shifting of the grassland type of vegetation to forest communities, or vice versa, as postulated by Liu (1963), is beyond doubt. In the present century, grasslands within forested regions are being invaded by forest throughout the world, partly because of the improvement in modern fire-suppression techniques and, in some cases, partly because of a change in climate (Spurr, 1964).

In Taiwan, however, natural grasslands are to be found particularly on the cliffs and river-beds which have partly or wholly dried up, but these are probably not permanent but rather seral stages, and may be expected in time to become clothed with tree-growth. On the tops of high mountains, where tree-growth is absent owing to exposure, perhaps, and coldness, grasslands of an apparently permanent character are to be found; here, as a rule, the grasses are short and wiry, and their occupation is also limited in area.

The Future of the Work

The present work which deals with the Coniferous Forest of Taiwan is indeed embryonic. Although it presents much of the writer's knowledge resulting largely from field observations and investigations made by him through many years, there is still much work to be done. From the survey of vegetation, particularly of the climax communities, of the three forest regions already presented, it is possible to determine only certain distributional facts which are significant in the study of forest distribution and its controlling factors. But the underlying causes of these distributional facts have been left untouched.

The problems of forest distribution involve a broad survey of the nature and extent of development, and of the distributional characteristics of the major forest climaxes, together with a search for evidence of past distribution and past influences. Their consideration should lead to an orderly, if not complete, story of forest distribution and relationships.

As a matter of fact, the lack of fossil records that may afford information as to the vegetational history during the past ages has prevented the writer to elucidate the fascinating natural history of the Coniferous Forest Formation of the island. Since the topography of the land surface, its altitude, the nature of the substratum, and the development of soils are intimately related to, in fact partly determine the nature of, occupying vegetation, a knowledge of the history of development of the land surface is requisits for an understanding of its vegetation cover. Unfortunately, facts which may be used in the construction of the physiographic history of the island are also meager. As a consequence, under the present conditions, it is almost impossible to bring to this work a depth and a breadth that could have been achieved otherwise.

It is believed, however, that a dynamic approach to the vegetation of this great area as a whole, an approach such as is frequently used in developmental studies in limited areas, will enable us to relate and to differentiate the three generally recognized forest regions of the area, to understand the pattern of interpenetrating climaxes.

Finally, it is hoped that the publication of the present work may be able to prepare the way for those island foresters or botanists who may be ambitious as to a prefect elucidation of the Coniferous Forest of Taiwan.

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臺灣針葉樹森林

王 忠 魁

筆者前曾服務於臺灣省林業試驗所有年。其間經常入山，對於多種植物社會從事野外觀察與實地調查工作，並曾先後兩次參與臺灣森林資源調查工作。結果竟使筆者對於本島針葉樹林得窺全貌，並進而知其分佈概況及其社會組成分子與其內部結構情形。茲僅就筆者所知有關本島各種針葉樹森林社會的種種實況，將本島整個針葉樹森林社會群系區別爲三個森林社會群落，即紅檜扁柏群落，鐵杉群落與冷杉群落。各個群落的分佈地區乃相當於筆者對此整個針葉樹林帶所劃定的林區，依次爲溫帶潤濕林區，亞高山林區及高山林區。此等林區實又相當於本島種種氣候區域。足證植物的分佈端視氣候如何而定。

當今臺灣最寶貴的紅檜扁柏原始林木，行將砍伐殆盡。不久整個繁茂壯麗的針葉樹森林或將面目全非。因此本篇關乎臺灣針葉樹森林的初步粗淺報告，或能有助於關心本島森林的學者與同好瞭解此一針葉樹森林的現狀及其將來的厄運。至其過去的發展歷史，因缺乏有關的植物化石資料，殊難推斷。復以筆者所知有限，更未敢妄論之。惟當今國家大力提倡科學之際，筆者不揣冒昧，倉促成文，公諸同好，非同等閒，實望能收拋磚引玉之效，並期各方多多教正。

CONIFEROUS FORESTS OF TAIWAN

Chung K'uei Wang

Because of the great range of altitude in the area of the great coniferous forest formation of Taiwan, where the forests are interrupted here and there by expanses of alpine grassland, distinct altitudinal sequences occur. A number of peaks rise above timber line.

Within the coniferous forest formation, the forest of lower elevations exhibits many variations related to topography and soil. Mixed hardwood-conifer forest occupies usually the lower slopes, generally below 1500 meters. Pure cedar forest occupies most of the slopes ranging from about 1500 to 2500 meters. But this cedar forest is all being gone. A forest of hemlock thrives on slopes from about 2500 to 3000 meters. Higher, fir becomes more abundant, and hemlock finally drops out. Lastly, the fir forest in turn gradually gives way to the dwarfed and scrubby growth at timber line.

The major aisociations of the coniferous forest formation are recognized as *cedar*, *hemlock*, and *fir*. Each of these is a regional climax. Accordingly, the segregation of the area of the great coniferous forest of Taiwan is into three forest regions, i.e. the *temperate humid*, *subalpine*, and *alpine forest* region.

The alpine tundra occurs above the timber line on some of the highest mountains. Timber line is reached at about 3500 meters on Yu Shan. A number of arctic-alpine species are found on the summits of the highest mountains.

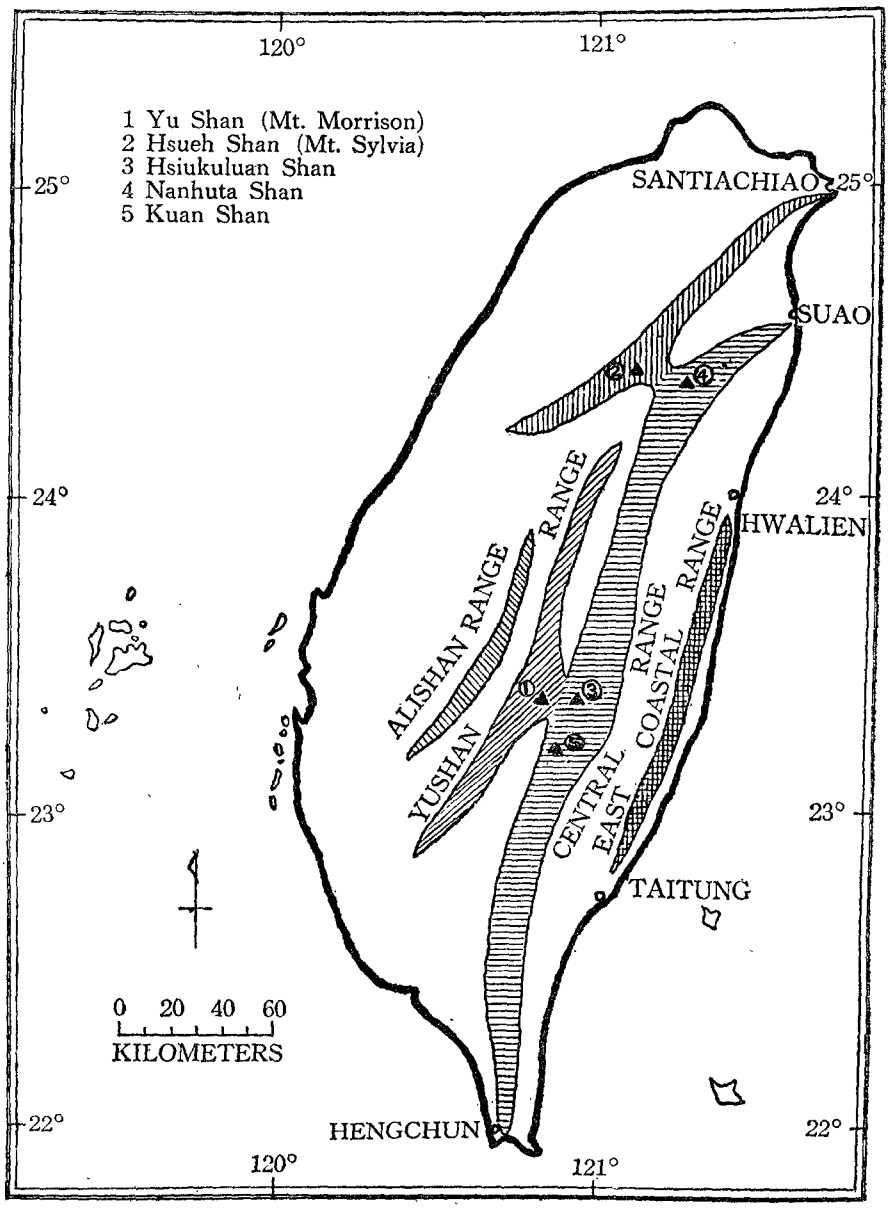

Figure 1. Outline map of mountain ranges on Taiwan

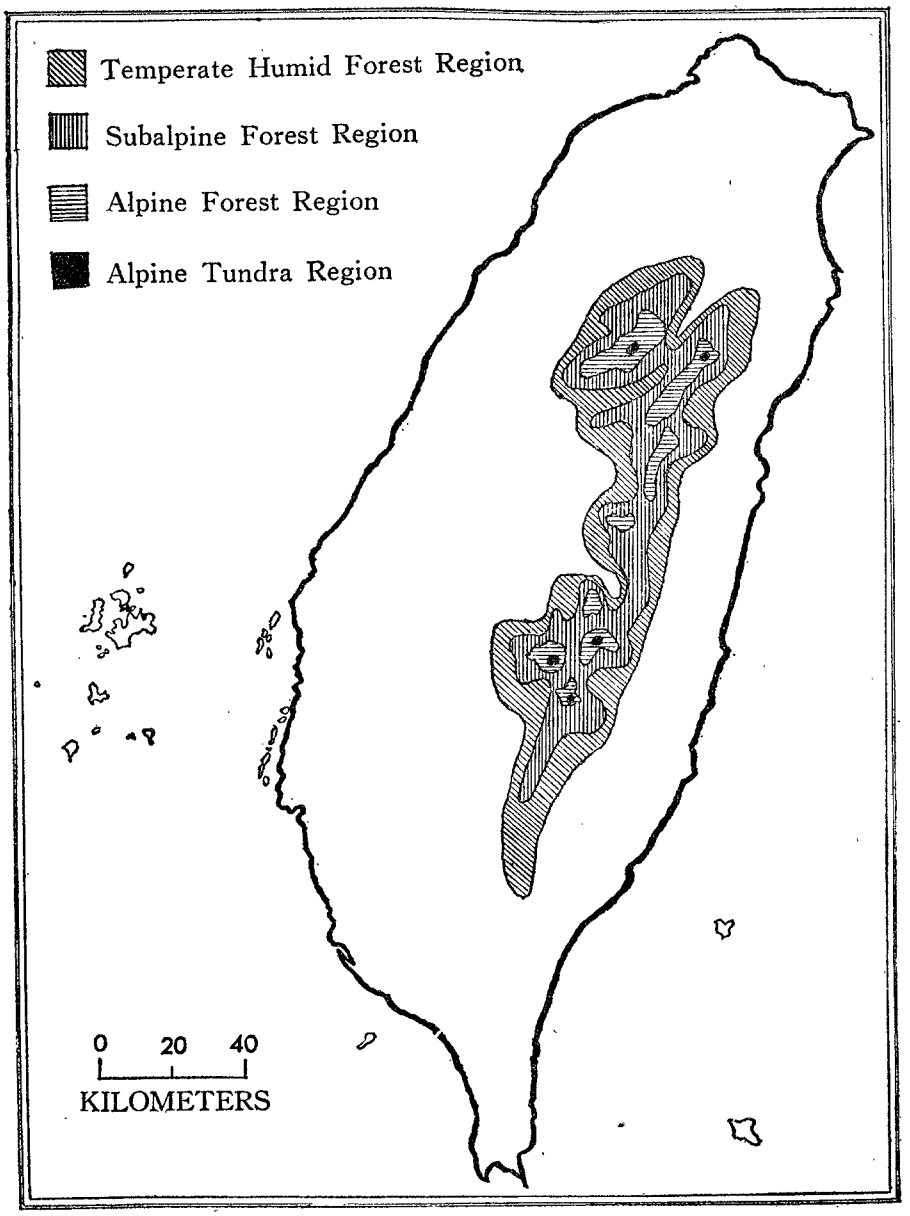

Figure 2. Coniferous forest regions of Taiwan

Fig. 3. Pure young stand of second growth of *Chamaecyparis formosensis* occurring on the temperte slope at about 2300 meters. Note the fair density of the stand and the better distribution of the components.

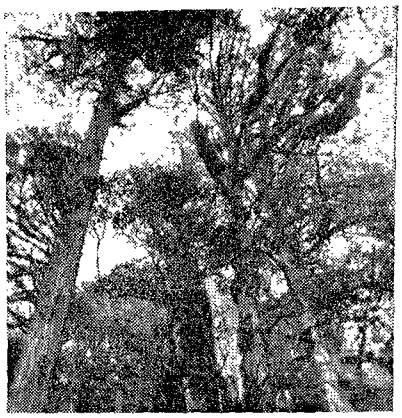

Fig. 4. Virgin pure stand of *Chamaecyparis obtusa* var. *formosana* occurring on the steep temperate slope at about 1900 meters. Note the fairly straight bole of the huge tree standing on the left in the foreground.

Fig. 5. Pure stand of *Illicium philippinense* isolated on the top of the mountain at about 2000 meters. Note the unusual density of the stand, the poor development of the trees, and the thick mat of mosses wrapping the stem of the trees. The dense undergrowth showing up in the foreground is *Pleioblastus niitakayamensis.*

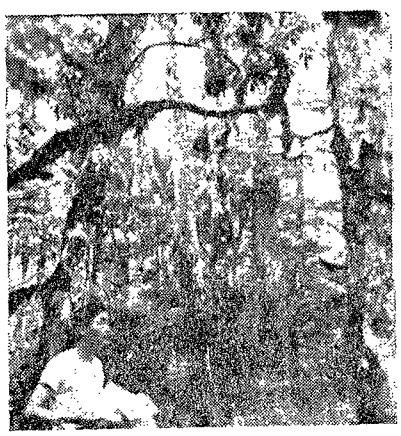

Fig. 6. Pure stand of *Tsuga chinensis* var. *formosana* on the gentle temperate slope at about 2000 meters. The broad-leaved tree showing up on the top in the foreground is *Illicium Philippinense.* The grass-like undergrowth on the right in the foreground is *Pleioblastus niitakayamensis.*

Fig. 7. Pure stand of *Picea morrisonicola* occurring on the mountain slope at abont 3000 meters near Yu Shan.

Fig.8. Pure stand of *Abies kawakamii* occurring on the ridge of the mountain at about 3100 meters. Note the fair density of the stand and the egual spaced distribution and the straight clear stems of the trees. The grass-like undergrowth on the right in theforeground is *Pleioblastus niitakayamensis.*

Fig. 9. Mixed stand of *Abies kawakamii-Tsuga chinensis* var. *formosana* on the steep slope at about 3050 meters in Pahsien Shan, Taichung.

Fig. 10. Dwarf scrub of *Juniperus squamata* var. *morrisonicola* densely mated on the west facing slope above timber line near the summit of Yu Shan.

INDEX OF PLANT NAMES

The following is an alphabetical list of scientific names of plants mentioned in the text. English and Chinese names of most of these plants are also included.

Abies Miller; Fir; 冷杉
4, 13.
Abies kawakamii (Hayata) Ito; Taiwan fir; 臺灣冷杉
3, 17, 38.
Acer kawakamii Koidzumi var. *kawakmii*; *Alpine maple;* 臺灣高山槭
8, 11.
Acer morrisonense Hayata; Taiwan red maple; 紅柄槭
8.
Actinodaphne nantoensis (Hayata) Hayata; Nantou actinodaphne; 南投黃肉楠
8, 9, 10.
Adenophora morrisonensis Hayata; Alpine lady-bell; 玉山沙參
25.
Agropyron ciliare (Trinius) Francht; Ciliary wheatgrass; 緣毛鵝冠草
21.
Agrostis canina Linnaeus var. *formosana* Hackel; Taiwan velvet bentgrass; 臺灣糠穗草
21.
Agrostis flaccida Hackel var. *morrisonensis* Honda; Alpine soft bentgrass; 姣玉糠穗草
21.
Agrostis morrisonensis Hayata; Alpine bentgrass; 玉山糠穗草
21.
Ainsliaea morrisonicola Hayata; Alpine ainsliaea; 玉山鬼督郵
12.
Aletris formosana Hayata; Taiwan colicroot; 臺灣粉條兒菜
22.
Alnus japonica (Thunberg) Steudel; East Asia alder; 東亞赤楊
12, 13,
Alocasia macrorrhiza (Linnaeus) Schott; Indomalaysian alocasia; 姑婆芋
10.
Amentotaxus Pilger: Amentotaxus; 穗花杉
2.
Anaphalis horaimontana Masamune; Alpine pearly everlasting; 高山珠光菊
22, 25.
Anaphalis nagasawai Hayata; Stony pearly everlasting; 中澤氏珠光菊
25.

Andropogon shimadae Ohwi; Shimada beardgrass; 島田氏白草
21.
Anthoxanthum formosanum Honda; Taiwan vernalgrass; 臺灣春茅
21,24.
Arabis alpina Linnaeus; Alpine rock-cress; 筷子芥草
25.
Arabis morrisonensis Hayata; Taiwan rock:cress; 玉山芹葉菜
25.
Ardisia cornudentata Mez; Common spearflower; 角刺平地木
9.
Arisaema arisanensis Hayata; Alishan dragonroot; 阿里山虎掌
12.
Arisaema formosana Hayata; Taiwan dragonroot; 臺灣虎掌
12.
Artemisia niitakayamensis Hayata; Alpine wormwood; 玉山黃花蒿
25.
Athyrium maximum (Don) Milde; Big lady fern; 大蹄盖蕨
10.
Aulacolepis agrostoides Ohwi var. *formosana* Ohwi; Taiwan eastern grass; 臺灣東方草
21.
Aulacolepis treutleri Hackel; Alpine eastern grass; 高山東方草
22.
Barthea formosana Hayata; Taiwan barthea; 臺灣芭茜
9, 10, 11.
Bazzania Gray; 鞭蘚
17.
Beilschmiedia erythrophloia Hayata; Red bark slugwood; 瓊楠
8.
Berberis kawakamii Hayata; Kawakami barberry; 川上氏小蘗
14, 22.
Beroeris morrisonensis Hayata; Alpine barberry; 玉山小蘗
24, 25.
Blastus cochinchinensis Loureiro; Cochinchina blastus; 柏拉木
9, 11.
Brachypodium kawakamii Hayata; Alpine short-stalked grass; 高山鵝觀草
22, 24, 25.
Bromus formosana Honda; Taiwan bromegrass; 臺灣雀麥
22.
Bromus morrisonensis Honda; Alpine bromegrass; 玉山雀麥
22, 24.
Bulbostylis densa Handel-Mazzetti; 密葉球柱草

22.

Calamagrostis matsudana Honda; Matsuda reedgrass; 松田氏野青茅

22.

Calamagrostis morrisonensis Hayata; Yushan reedgrass; 玉山野青茅

22, 24.

Calamagrostis niitakayamensis Honda; Alpine reedgrass; 高山野青茅

22.

Calamagrostis sublanceolata Honda; Robust reedgrass; 短葉野青茅

22.

Calliergonella Loeske; Red-stemmed moss; 赤莖苔

17.

Calocedrus Kurz; Incense cedar; 肖楠

4.

Calocedrus formosana (Florin) Florin; Taiwan incense cedar; 臺灣肖楠

2, 8, 9.

Cardamine arisanensis Hayata; Alpine bitter-cress; 阿里山碎米薺

25.

Carex Linnaeus; Sedge; 薹

22.

Carex alliiformis Clarke; 蒜葉薹

24.

Carex apodostachya Ohwi; 斷根薹

24.

Carex oxyandra Kudo; 針葉薹

24.

Carex pseudo-arenicola Hayata; 高山沙薹

24.

Carex transalpina Hayata; Alpine sedge; 過山薹

24.

Castanopsis carlesii (Hemsley) Hayata var. *carlesii*; Carles chinquapin; 長尾尖錐栗

9.

Castanopsis hystrix A. de Candolle ex Seemann; Red chinquapin; 鉤栗

9.

Cephalotaxus Siebold & Zuccarini; Plum-yew; 頭形杉

2.

Cerastium takasagomontana Masamune; Mountain mouse-ear chickweed; 高山卷耳

22.

Cerastium trigynum Villars var. *morrisonense* Hayata; Alpine mouse-ear chickweed; 玉山婆婆指甲菜

25.

Chamaecyparis Spach; Cedar; 扁柏

4, 10, 13, 14, 15.

Chamaecyparis formosensis Matsumura; Red cedar; 紅檜

3, 6, 8, 10, 11, 12, 15, **28**, 30, 31, **37**.

Chamaecyparis obtusa Siebold & Zuccarini var. *formosana* (Hayata) Rehder; Yellow cedar; 臺灣扁柏

3, 6, 8, 10, 11, 15, **28**, 30, 31, **37**.

Cinnamomum camphora (Linnaeus) Siebold; Camphor tree; 樟

8.

Cirsium kawakamii Hayata; Alpine thistle; 高山薊

22.

Cladonia; Reindeer moss; 石蕊

17.

Cotoneaster morrisonensis Hayata; Taiwan cotoneaster; 玉山舖地蜈蚣

22.

Crawfurdia lanceolata Hayata; Alpine trailing gentian; 狹葉蔓龍膽

12.

Cunninghamia R. Brown; China fir; 杉木

4.

Cuninghamia konishii Hayata; Taiwan China fir; 香杉

2, 8, 11.

Cyclobalanopsis Oerstedt; Eastern oak; 青岡櫟

10.

Cyclobalanopsis longinux (Hayata) Schottky; Long-glans oak; 錐果櫟

8, 9, 10.

Cyclobalanopsis morii (Hayata) Schottky; Taiwan red oak; 高山櫟

8, 9, 10, 11.

Cyclobalanopsis stenophylloides (Hayata) Kuto & Masamune; Alishan oak; 狹葉櫟

8, 9, 11,

Crclophorus adnascens Desvaux; Trailing fern; 樹龍

12.

Damnacanthus angustifolius Hayata; Narrow-leaved damnacanthus; 細葉虎刺

18.

Damnacanthus indicus Gaertner; Indian damnacanthus; 臺灣虎刺

10.

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10.

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22, 24.

Deschampsia flexuosa Trinius; Crinkled hairgrass; 卷葉芒

24.

Dryopteris lepidopoda Hayata; Taiwan evergreen wood fern; 長春蕨

16.

Dryopteris melanocarpa Hayata; Black-dotted shield fern; 黑孢鱗毛蕨

10.

Dryopteris morrisonensis Hayata; Alpine shield fern; 玉山鱗毛蕨

18.

Elaeagnus morrisonensis Hayata; Alpine oleaster; 玉山胡頹子

22.

Elatostema lineolatum Forster var. *major* Thwaites; Big-leaved elatostema; 大葉冷清草

10.

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Engelhardtia roxburghiana Wallich; Common engelhardtia; 黃杞

9.

Euonymus acutorhombifolia Hayata; Rhomboid-leaved evonymus; 銳菱葉衛矛

11.

Fatsia polycarpa Hayata; Taiwan fatsia; 常花八角金盤

10.

Festuca japonica Makino; Japanese fescue; 東洋銀針草

22.

Festuca ovina Linnaeus var. *purpurascens* Honda; Purple sheep fescue; 紫穗銀針草

22.

Festuca ovina Linnaeus var. *vulgaris* Koch; Common sheep fescue; 高山銀針草

22.

Galium morii Hayata; Alpine bedstraw; 高山豬殃殃

25.

Gaultheria cuuiugiana Vidal; Taiwan winter green; 秋林丹

22.

Gaultheria itoana Hayata; Alpine winter green; 白珠樹

22.

Gentiana arianensis Hayata; Alishan gentian; 阿里山龍膽

22, 25.

Gentiana formosana Hayata; Taiwan gentian; 臺灣龍膽

22.

Gentiana scabrida Hayata; Rough gentian; 糙葉龍膽

22.

Geranium uniflorum Hayata; Alpine cranesbill; 單花香葉草

25.

Hedera rhombea Bean var. *formosana* (Nakai) Li; Taiwan ivy; 臺灣常春藤

10.

Hemiphragma heterophylla Wallich; Himalayan snapdragon; 喜馬拉雅玄參草

25.

Hicriopteris glauca (Thunberg) Ching; Common weedy fern; 裏白
10.
Hydrocotyle nepalensis Hooker; Himalayan pennywort; 喜馬拉雅天胡荽
22.
Hylocomium B.S.G.; 塔苔
17.
Hymenochaete Leveille; Heartwood-rot fungus; 臺灣扁柏心腐菌
30.
Hypericum nagasawai Hayata; Nagasawa tutsan; 中澤氏小連翹
22.
Hypericum randaiense Hayata; Alpine tutsan; 臺灣金絲桃
25.
Hypnum Dillenius; 灰苔
17.
Illicium philippinense Merrill; Alpine anise; 高山八角
8, 11, 12, **37.**
Impatiens uniflora Hayata; Alpine snapweed; 高山鈎船花
16.
Juncus modicus Braun; Alpine wire-grass; 玉山龍鬚草
22.
Juniperus Linnaeus; Juniper; 檜
3, 4.
Juniperus formosana Hayata var. *concolor* Hayata; Coast juniper; 綠背刺柏
3.
Juniperus formosana Hayata var. *formosana*; Formosan juniper; 臺檜
3, 18, 22.
Juniperus squamata Lambert var. *morrisonicola* (Hayata) Li & Keng; Alpine juniper; 玉山香柏
3, 18, 22, **24**, **38.**
Keteleeria davidiana (Franchet) Beissner var. *formosana* Hayata; Taiwan Keteleeria; 臺灣油杉
2.
Leontopodium microphyllum Hayata; Taiwan edelweiss; 細葉薄雪草
25.
Leucostegia immersa Presl; Red-cedar fern; 翠雲蕨
12.
Lilium formosanum Wallich; Taiwan lily; 臺灣百合花
22.
Lithocarpus amygdalifolius (Skan) Hayata; Almond-leaved tanoak; 苦扁桃葉石櫟
8.
Litsea cubeba (Loureiro) Persoon; Mountain spicy tree; 山胡椒
10.
Luzula effusa Buchanan; Alpine wood rush; 玉山糠星草

22.

Lycopodium complanatum Linnaeus; Ground pine; 地刷子

22.

Lycopodium obscurum Linnaeus; Japan stone crop; 玉柏

22.

Lyonia ovalifolia (Wallich) Drude var. *ovalifolia*; Tibet lyonia; 南燭

11, 15.

Mazus japonicus (Thunberg) O. Kuntze; Japanese teat flower; 通泉草

22.

Mecodium polyanthos (Swartz) Copeland; Wood filmy fern; 菱葉蕗蕨

18.

Michelia formosana (Kanehira) Masamune; Taiwan michelia; 烏心石

10.

Miscanthus Andersson; Eulalia; 荻

12, 23, 29.

Miscanthus kanehirai Honda; Kanehira eulalia; 臺灣萱草

22.

Miscanthus transmorrisonensis Hayata; Alpine eulalia; 過山芒

21, 22, 23.

Monachosorum subdigitatum (Blume) Kuhn; Budding fern; 南洋稀子蕨

12.

Myrsine stolonifera (Koidzumi) Walker; Stolon-bearing myrsine; 蔓竹杞

15.

Neolitsea acuminatissima (Hayata) Kanehira & Sasaki; Alpine neolitsea; 尖葉新木薑子

11.

Neottopteris antiqua Masamune; 山蘇花

10.

Nephrolepis cordifolia (Linnaeus) Presl; Common sword fern; 腎蕨

10.

Oreocnide pedunculata (Shirai) Masamune; 有梗紫苧蕁

10.

Oreomyrrhis involucrata Hayata var. *involucrata*; Mountain myrrh; 山香菜

25.

Osmanthus heterophyllus (Don) Green var. *bibracteatus* (Hayata) Green; Polymorphic tea olive; 異葉枸骨

16.

Osmanthus lanceolatus Hayata; Narrow-leaved sweet olive; 狹葉山桂花

16.

Oxalis griffithii Edgeworth & Hooker f. var. *taimonii* (Yamamoto) Masamune; Alpine wood-sorrel; 高山酢醬草

18.

Parnassia palustris Linnaeus; Alpine grass-of-parnassus; 梅花草
25.
Pasania kawakamii (Hayata) Schottky; Kawakami tanoak; 大葉校栗
8, 9.
Pasania ternaticupula (Hayata) Schottky; Three-cup tanoak; 三斗石櫟
8.
Pellionia arisanensis Hayata; Common mountain pellionia; 阿里山冷水花
10.
Pellionia scabra Bentham; Trailing pellionia 蔓赤草
10.
Pellionia trilobulata Hayata; Alpine pellionia; 冷水花
16.
Persea acuminatissima (Hayata) Kostermans; Acuminate machilus; 尖葉楠木
8, 9.
Persea thunbergii (Siebold & Zuccarini) Kostermans; Common machilus; 猪脚楠
9.
Persea zuihoensis (Hayata) Li; Incense machilus; 香楠
10.
Phleum alpinum Linnaeus; Alpine timothy; 高山鼠尾草
22.
Picea A. Dietrich; Spruce; 雲杉
4, 13.
Picea morrisonicola Hayata; Taiwan spruce; 臺灣雲杉
3, 15, *38*.
Pilea brevicornuta Hayata form. *brevicornuta*; Common artillery-plant; 阿里山冷清草
10.
Pinus Linnaeus; Pine; 松
2, 4, 13, 14, 15.
Pinus armandi Franchet var. *masteriana* Hayata; Taiwan Armand pine; 臺灣華山松
3, 8, 11, 14, 15, **19**, **20**, **21**, 22, 32
Pinus massoniana Lambert; Chinese red pine; 馬尾松
2.
Pinus morrisonicola Hayata; Taiwan white pine; 臺灣五葉松
3, 8, 19, 20.
Pinus taiwanensis Hayata; Taiwan red pine; 臺灣二葉松
3, 8, 11, 14, 15, **19**, **20**, **21**, 22, 32.
Piper futo-kadsura Siebold & Zuccarini; Pepper; 風藤
10.
Plagiogyria euphlebia Mettenius; Wart-foot fern; 華中瘤足蕨
10, 12.
Plagiogyria formosana Nakai var. *formosana*; Taiwan wart-foot fern; 臺灣瘤足蕨

10.

Plagiogyria stenoptera Diels; Wood wart-foot fern; 耳形瘤足蕨

10, 12.

Platanthera brevicalcarata Hayata; 粉蝶蘭

22.

Pleioblastus Nakai; Alpine bamboo; 玉山矢竹

23.

Pleioblastus niitakayamensis (Hayata) Ohki; Alpine bamboo; 玉山矢竹

5, 12, 15, 16, 17, **21**, 23, 29, 30, **37**, **38**.

Pleione formosana Hayata; Alpine orchid; 臺灣一葉蘭

25.

Poa nankoensis Ohwi; Mountain bluegrass; 南港莓繫

22.

Poa takasagomontana Ohwi; Alpine bluegrass; 高山莓繫

22.

Poa tenuicula Ohwi; Slender bluegrass; 山禾

22.

Podocarpus L'Herit; Podocarp; 羅漢松

2.

Polygala japonica Houttuyu; Alpine milkwort; 瓜子金

22.

Polystichum aculeatum Schott; Hairy Hardy fern; 毛蕨

12.

Poneorchis kiraishiensis Ohwi; Taiwan golden orchid; 臺灣金蘭

25.

Potentilla morrisonicola Masamune; Alpine cinquefoil; 玉山金梅

25.

Potentilla tugitakensis Masamune; Silver cinquefoil; 高山萎陵菜

25.

Prinsepia scandens Hayata; Taiwan prinsepia; 假皂莢

12.

Prunus phaeosticta (Hance) Maximowicz; Dark-spotted cherry; 墨點櫻桃

10.

Pseudotsuga Carriere; Douglas-fir; 帝杉

4.

Pseudotsuga wilsoniana Hayata; Taiwan Douglas-fir; 臺灣帝杉

2, 8, 9.

Pteridium aquilinum (Linnaeus) Kuhn; Bracken fern; 蕨

22.

Pteris quadriaurita Retzius; 粗蕨草

10.

Pyrola decorata Andrews; Elegant shinleaf; 常春鹿蹄草
14.
Pyrola morrisonensis Hayata; Alpine wintergreen; 玉山鹿蹄草
14, 18.
Rhododendron ellipticum Maximowicz; Common rhododendron; 光柄杜鵑
10.
Rhododendron formosana Hemsley; Taiwan rhododendron; 臺灣杜鵑
11.
Rhododendron morii Hayata; Giant rhododendron; 翠雲杜鵑
11, 14, 15, 20.
Rhododendron noriakianum Suzuki; Mountain rhododendron; 丹紅杜鵑
22.
Rhododendron pseudochrysanthemum Hayata; Alpine rhododendron; 玉山杜鵑
22, **24.**
Rhododendron rubropilosum Hayata; Red-hairy rhododendron; 紅毛杜鵑
18, 22.
Ribes formosana Hayata; Taiwan gooseberry; 臺灣茶藨子
22.
Rosa morrisonensis Hayata; Alpine rose; 玉山薔薇
22.
Rosa transmorrisonensis Hayata; Glandular rose; 過山薔薇
22.
Rubus Linnaeus; Raspberry; 懸鈎子
11.
Rubus calycinoides Hayata ex Koidzumi var. *calycinoides*; Yushan dewberry; 玉山懸鈎子
18, 22.
Rubus elegans Hayata; Alpine raspberry; 高山懸鈎子
22.
Rubus pectinellus Maximowicz var. *trilobus* Koidzumi; Alpine dewberry; 刺蓼寒莓
12, 16.
Rumohra amabilis Ching; Graceful shield fern; 美葉鳳尾蕨
10.
Salix fulvopubescens Hayata; Alpine willow; 山柳
22.
Sassafras randaiense (Hayata) Rehder; Taiwan sassafras; 臺灣檫樹
8, 11.
Scabiosa lacerifolia Hayata form. *leucantha* Masamune; Taiwan morning-bride; 艷陽花
25.
Schima Reinwardt ex Blume; Choisy good timber; 荷樹
10.
Schima superba Gardner & Champion var. *superba*; Chinese guger-tree; 荷樹

8, 10.

Scirpus morrisonensis Hayata; Alpine bulrush; 針蘭

22.

Sedum alfredi Hance; Alpine stonecrop; 高山佛甲草

25.

Selaginella delicatula Alston; Tender spike-moss; 翠雲草

10.

Selaginella labordi Hieronymus; Alpine spike-moss; 玉山卷柏

18.

Senecio morrisonensis Hayata; Alpine groundsel; 玉山黃菀

22.

Shortia exappendiculata Hayata; Taiwan bells; 臺灣裂緣花

18.

Shortia transalpina Hayata; Alpine bells; 過山裂緣花

18.

Smilax china Linnaeus var. *taiheiensis* (Hayata) Koyama; Mountain catbrier; 圓葉菝葜

10.

Smilax hayatae Koyama; Hayata catbrier; 早田氏菝葜

10.

Solidago decurrens Loureiro; Taiwan goldenrod; 獨枝黃花

22.

Sonchus arvensis Linnaeus; Common sow-thistle; 苣賣菜

22.

Sorbus randaiense (Hayata) Koidzumi; Taiwan mountain ash; 臺灣花楸

14, 18.

Spiraea formosana Hayata; Taiwan spirea; 臺灣繡線菊

22.

Spiraea morrisonicola Hayata; Alpine spirea; 玉山繡線菊

22.

Stauntonia keitaoensis Hyaata; Nantou stauntonia; 溪頭野木瓜

10.

Stereum sulcatum Burt; Heartwood-rot fungus; 紅檜蓮根心腐菌

30.

Stranvaesia niitakyamensis (Hayata) Hayata; Taiwn stranvaesia; 臺灣假沙梨

22.

Swertia randaiensis Hayata; Taiwan columbo; 臺灣獐牙菜

22.

Symplocos divaricativena Hayata; Alpine symplocos; 展枝山礬

10.

Symplocos konishii Hayata; Mountain symplocos; 小西氏山礬

10.

Taiwania Hayata; Taiwania; 臺灣杉
4.
Taiwania cryptomerioides Hayata; Taiwania; 臺灣杉
2, 8, 11.
Taxus Linnaeus; Yew; 紫杉
2, 4.
Ternstroemia gymnanthera (Wight & Arnold) Sprague; Japanese ternstroemia; 厚皮香
8, 11.
Trisetum spicatum Richter var. *formosanum* Ohwi; Taiwan spike trisetum; 臺灣三芒草
22.
Trisetum subspicatum Beauvois; Alpine trisetum; 高山三芒草
25.
Trochodendron aralioides Siebold & Zuccarini; Bird-lime tree; 昆欄樹
8, 11.
Tsuga Carriere; Hemlock; 鐵杉
4, 13, 14, 15,
Tsuga chinensis (Franchet) Pritzel ex Diels var. *formosana* (Hayata) Li & Keng; Taiwan hemlock; 臺灣鐵杉
3, 8, 9, 11, 13, 14, 15, *37*, *38*.
Turpinia formosana Nakai; Taiwan turpinia; 臺灣山香圓
10.
Vaccinium japonicum Miquel var. *lasiostemon* Hayata; Scarlet blueberry; 扁枝越橘
11, 15.
Vaccinium merrillianum Hayata; Alpine blueberry; 高山越橘
18, 22.
Veratrum formosanum Loeske form. *albiflora* Masamune; Taiwan false-hellebore; 臺灣藜蘆
22.
Viburnum foetidum Wallich var. *rectangulatum* (Graebner) Rehder; Mountain viburnum; 高山莢蒾
11.
Viburnum furcatum Blume & Maximowicz; Round-leaved viburnum; 圓葉莢蒾
11.
Viburnum luzonicum Rolfe var. *formosanum* (Hance) Rehder; Common viburnum; 紅子仔
11.
Viburnum parvifolium Hayata; Small-leaved viburnum; 小葉莢蒾
14.
Viburnum taiwanianum Hayata; Taiwan viburnum; 臺灣莢蒾
10, 14.
Viola Linnaeus; Violet; 堇菜
14.
Viola stenocentra Hayata; Mountain violet; 臺灣如意草
22.

Viola tozanensis Hayata; Wood violet; 高山如意草
22.
Vittaria Smith; 書帶蕨
12.