Dipterocarps

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Introduction

The dipterocarp forests of Southeast Asia constitute a dominant and particularly valuable component of the world's tropical rainforest. As a family of plants, Dipterocarpaceae may perhaps hold the distinction of being the best-known trees in the tropics. Their ecosystems are extremely diverse. They are uneven in their age and multilayered. They grow all the year round under warm temperatures and on sites where there is a large amount of rainfall. However, those growing in the seasonal forest are generally medium sized with the tallest trees being around 20 m with a maximum diameter of about 50 cm. Generally dipterocarps have been observed to occur on soils with very low fertility. Currently the dipterocarps dominate the international tropical timber market, and therefore play an important role in the economy of many Southeast Asian countries. In addition to timber, this family of trees also produces other non-timber products like resins and oleoresins.

Distribution

The present distribution patterns of dipterocarps are thought to reflect routes of colonization and past climatic conditions. They are distributed over the tropical belts of three continents of Asia, Africa, and South America (**Figure 1**). They occupy several phytogeographical zones that mainly conform to climatic and ecological factors. However, in Southeast Asia the Wallace line, which runs east of Philippines and between Borneo and Celebes, is a major phytogeographic boundary for dipterocarps. This phenomenon cannot be explained in terms of climatic differences but requires the intervention of continental drift.

Worldwide there are about 16 genera and about 580 species in the family. Seven main phytogeographical regions are classically recognized within this distribution area

1. Malesia, which constitutes Peninsular Malaysia, Sumatra, Java, lesser Sunda Islands, Borneo, Philippines, Celebes, the Moluccas, New Guinea and the Bismarks. The northern frontier of Peninsular Malaysia delimits this part.
2. Mainland Southeast Asia, which includes Burma, Thailand, Cambodia, Laos, Vietnam, and South China.

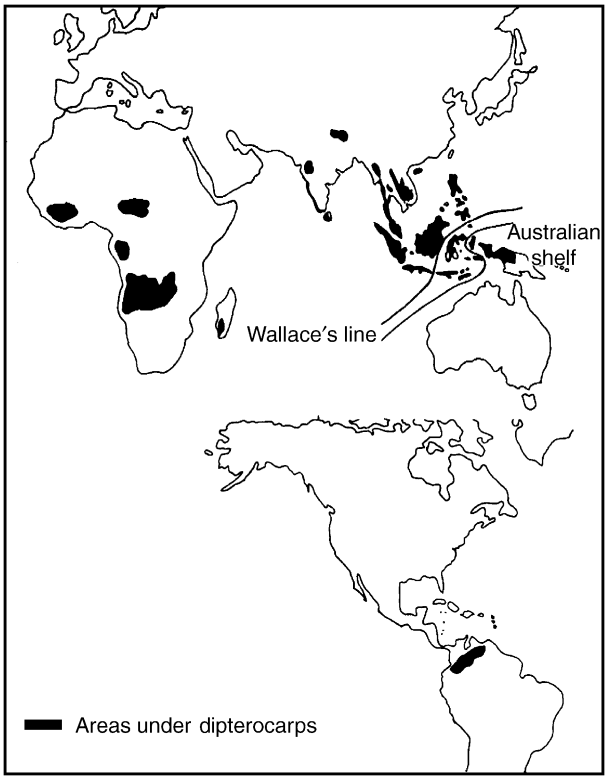

Figure 1 Phytogeographical distribution of the family Dipterocarpaceae worldwide.

3. South Asia, which constitutes India, the Andaman Islands, Bangladesh, and Nepal.
4. Sri Lanka.
5. The Seychelles.
6. Africa, which constitutes Madagascar, a narrow strip from Mali to Sudan in the northern hemisphere, and Congo.
7. South America, which constitutes Araracuara (Colombia), Venezuela, and Guyana.

The South American region corresponds to Guyana, Venezuela and part of the Colombian Amazon, which overlies the Guyana shield. The African region includes a continental area and an insular part in Madagascar. The Asian region corresponds to the Indo-Malesian area, which concentrates a high number of genera and species in the equatorial forest. This area is limited northward by the Himalayan foothills, then approximately by the borders of Assam, Arunachal Pradesh, Burma, Laos, and Vietnam and penetrating into South China including Hainan Island. On the extreme southwest the large belt of Asian dipterocarps reaches the Seychelles and covers India and Sri Lanka. Its eastern border corresponds to New Guinea. The Sundalands delimit the most southern part. No dipterocarp species are found in Australia.

In Asia, dipterocarps occupy a large variety of habitats. They are found from the coast to the inland, from riverine to swampy conditions. They occur on dry land on undulating to level terrain, on ridges, on slopes, in valley bottoms, on soils that are deeply weathered and shallow, from well drained to poorly drained conditions, and both on soils rich or poor in nutrients. This to a great extent shows the wide versatility of the species in terms of its ecology. In Peninsular Malaysia the altitudinal zonation of their main habitats types ranges from 0–300 m (known as lowland dipterocarp), 300–750 m (called hill dipterocarp forest), and 750–1200 m (known as upper dipterocarp forests).

The freshwater swamps, especially in drier parts, are rich in the species while in the true peat swamps occurrence is relatively poor. The dipterocarp flora is also poor on limestone and riverine fringes. Asian dipterocarps are limited altitudinally by climatic conditions and the conjunction of altitude and other natural barriers, such as large rivers and watersheds. These have obstructed the distribution of species in Borneo. For example the northwest and northeast of Kalimantan, Sarawak, Brunei, and Sabah are much richer in species than the rest of Kalimantan. The ever-wet areas are also richer in species than the seasonal ones as seen in Sri Lanka by the concentration of species in the southwest quarter, or in the Thai–Malaysian transition belt or from Java to the lesser Sundas.

The genera and species in Asia show much greater diversity compared to Africa and South America. As expected the higher numbers clearly occur in the ever-wet regions. **Table 1** shows the number of genera and species found in the different phytogeographical regions.

Ecological Distribution

For clarity in understanding the ecosystem of dipterocarps, the well-illustrated description from Peninsular Malaysia is referred to in this text. In the other parts of Asia, the ecological conditions are somewhat similar and with very minor variations. The ecosystems in which dipterocarp species are distributed can thus be divided into the following categories based on the altitude and forest type in which they occur.

Table 1 Distribution of genera and species of dipterocarps according to the seven phytogeographical regions

Phytogeographical region	*Number of genera*	*Number of species*
Malesia	14	465
Mainland Southeast Asia	8	79
Sri Lanka	7	45
South Asia	9	58
Seychelles	1	1
Africa and Madagascar	3	49
South America	1	1

The Lowland Dipterocarp Forests

These can also be classified as lowland evergreen rainforest formation. The bulk of the exploitable forests are in this category, which embraces all the well-drained primary forests of the plains, undulating land, and foothills up to about 300 m altitude. In most localities the dipterocarps form a high proportion of the emergent and dominant strata of the forest. Exceptionally, dipterocarps may be almost absent, while occasionally, over small areas, they may be so abundant that large trees of other families are few and scattered. In these lowland dipterocarp forests about 130 species of dipterocarps, representing all the main groups, occur. In any one forest reserve there may, exceptionally, be as many as 40 species, but between 10 and 30 is a more usual number. In most lowland reserves *Shorea* is represented by two or three species, and is the most conspicuous woody component of the forest. Usually one or two species of *Dipterocarpus* are also present.

The Hill Dipterocarp Forests

These too can also be classified as a lowland evergreen rainforest formation. They are the climax vegetation of the altitudinal zone immediately above the lowland dipterocarp forests. On inland ranges the altitudinal limits are approximately 300–750 m, but on isolated mountains, or on coastal ranges, this zone may be depressed to much lower altitudes. The lines delimiting the hill dipterocarp forests cannot be drawn strictly along the topographical contours; they descend the ridge and ascend the valleys, and the lower limit may range between 150 and 450 m on the same hill system.

The main difference between the hill dipterocarp forests and the lowland dipterocarp forests is in specific composition of the dominants of the upper strata of the vegetation. There is usually a slight diminution in size of the larger trees accompanied by a slight increase in number per unit area on ridge tops and towards the upper limits of the hill dipterocarp forests. Many of the lowland dipterocarps are represented in the hill forests, although they become scarce towards the upper limits of these forests, but many species appear in the hill forests that never, or only very exceptionally, occur in the lowland forests. Predominant among these is *Shorea curtisii*, one of the *Shorea* group that tends to be

gregarious on ridges; it is readily distinguished in the forest, and is a useful indicator of hill dipterocarp forest. Where this species is abundant the light-colored crowns of the *S. curtisii* trees mark the hill dipterocarp forest zone as a blue–gray band along the mountainsides.

In these forests all the main dipterocarp groups, except perhaps *Dryobalanops* and *Pentacme*, are represented. At the lower levels of the zone, where many of the lowland dipterocarps still persist, the forests are the richest both in species and volume of dipterocarps. Beyond the limits of the lowland species the number of dipterocarp species represented is usually less per unit area than in the lowland forests, although *Vatica* is usually better represented. This reduction in species, however, is often more than offset by the greater number of individuals, thus fully maintaining the predominance of the dipterocarps in these forests.

In the hill dipterocarp forest zone on coastal hills, or on hills that the geologically recent recession of the sea has rendered inland, several dipterocarps are represented, which are absent or rare on ranges remote from the sea, for example, *Shorea glauca*, *S. lumutensis*, *S. gratissima*, *Dipterocarpus rotundifolius*, *D. penangianus*, and *Cotylelobium malayanum*. These hill forests too represent a great potential wealth.

The Upper Dipterocarp Forests

These are also classified as tropical lower-montane evergreen rainforest subformation, which is a transition zone between the tropical lowland evergreen rain forest and the tropical upper montane rainforest of the higher mountains. This is the zone into which the hill dipterocarp forests blend. It is represented only on the higher mountains, the altitudinal limits being approximately from 750 to 1250 m altitude on inland ranges, but on isolated mountains or coastal ranges, where the vegetation zones tend to be depressed and telescoped, it may be represented by a narrow belt lying between 600 and 900 m altitude.

There is a marked difference in floristic composition of the vegetation as one passes from the hill dipterocarp forests into the upper dipterocarp forests. Almost all the lowland forms are absent and the montane forms, which predominate in the next highest zone, become more and more in evidence. The dipterocarps are represented by only a few species, but these are so characteristic, and sometimes so abundant in these forests, that it is desirable to recognize a separate forest zone of which they are the chief indicator species. The predominant, typical species is *Shorea platyclados*. However, *S. ovata*, *S. ciliata*, *S. submontana*, *Hopea montana*, *Dipterocarpus retusus*, *D. costatus*, and *Vatica heteroptera* are also characteristic. These forests are mainly of value for soil protection, but limited areas rendered accessible by the roads to hill stations may produce commercial timber.

The Montane Oak Forests

These forests can also be classified as tropical lower-montane evergreen rainforest subformation. The upper dipterocarp forests form the lower levels of this subformation, and the montane oak forests the upper. The altitudinal range of the montane oak forests is usually between 1050 and 1500 m. These altitudes are above the normal range of dipterocarps.

Peat Swamp Forests

These are classified as tropical woodland formations but they are most closely allied to the tropical freshwater swamp forest. They belong to a vegetative formation that occupies vast alluvial flats along the northwest and southwest coasts of Borneo, around the coasts of the Rio and Lingga archipelagos, on the east coast of Sumatra, and on the west, and to some extent the east coast of Peninsular Malaysia. All the chief timber-producing families of the lowland dipterocarp forests are represented in the peat swamp forests, but the number of species of each is comparatively small. These species are, with very few exceptions, entirely different from any found on dry land, but most of them are widely distributed throughout the peat swamps. Dipterocarps are important components of the peat swamp forests. The number of species is small, but they show a marked gregarious tendency and frequently form a high proportion of dominant and emergent trees of the forest. Species like *Shorea albida*, *S. rugosa*, *S. teysmanniana*, *Anisoptera marginata*, *S. platycarpa*, *S. dealbata*, *Dipterocarpus coraceus*, *D. chartaceus*, *Hopea resinosa*, *H. mengarawan*, and *Vatica wallichii* are commonly found in this habitat.

Riparian Fringes

The narrow strips of vegetation found along, and characteristic of, river courses are regarded here as riparian fringes. These have also been classified as tropical riparian woodland formation, but it is perhaps more appropriate to regard them as a series of edaphic formations zoned from river mouth to source. A constant supply of telluric (rising from the soil) moisture is the predominant edaphic factor, while the zones are determined mainly by the incidence of tidal influence, width of stream, rate of flow, and altitude. At the mouth of a stream, the first zone, which is under saline influence, is inhabited

mainly by mangrove swamp species. Further upstream a transition zone occurs, which is still under tidal influence but in which the water is mainly fresh. This riparian zone is not normally inhabited by dipterocarps, but *Vatica wallickii* has been reported to occur towards its upper limits. Beyond tidal influence there is a pronounced change in specific composition of the riverbank flora. Many of the species are particularly adapted to this riparian habitat. Some have narrow leaves to reduce resistance to flood water, the so-called stenophyllous plants, while some have fruits specially adapted for dissemination by water or capable of germinating and establishing themselves under water. Several dipterocarps are characteristic of these communities. The best known and most abundant is *Dipterocarpus oblongifolius*, but in the same category *Shorea sumatrana*, *S. palembanica*, and *Hopea odorata* could also be placed. The gnarled trunks of these trees overhang the streams, forming what have been called gallery forests. The following species also frequently occur in this zone of riparian vegetation, but they are less characteristic of the differentiated riparian fringe than of any damp soil in the vicinity of streams or of land subject to periodic inundation. These would include *Shorea assamica*, *S. macrantha*, *S. hemsleyana*, *Hopea kelantanensis*, *H. mengarawan*, *H. sangal*, *Dryobalanops oblongifolia*, *Vatica bancana*, *V. lobata*, and *V. wallichii*. The upper reaches of the larger rivers are in the montane forest zone and no dipterocarps are represented in the riparian fringes.

Heath Forests

In Borneo there are large areas of lowland primary forest to which the provisional name 'heath forest' has been applied. These forests are an edaphic climax type, developed on pale, light-textured, acid sandy soils that seem to resemble a European podsol. *Shorea glauca* occurs gregariously in this forest type. The only dipterocarps in addition to *S. glauca* found in this zone are *Hopea semicuneata* and *Vatica odorata*.

Limestone Rocks

The limestone rocks, which are such a striking feature of the Asian landscape, bear a very different vegetation from that of the surrounding forest. This vegetation contains a calciphilous, or chalk-loving, element, as well as a cremnophilous, or cliff-dwelling element. The small trees and shrubs that dominate this vegetation can mainly be classed in the latter category. It has been stated that dipterocarps shun chalk, and it is true that they are absent from most of the limestone hills. This is probably because xerophyllous, adaptable dipterocarps have lacked access to them. On the limestone hills of Langkawi, Perlis, and the north of Kedah in Peninsular Malaysia, several dipterocarps, that have adapted and that withstand seasonal desiccation in territories to the north, have established themselves. These are *Hopea ferrea*, *Pentacame siamensis*, *Shorea talura*, and *Vatica cinerea*. All these species are also the inhabitants of the semi-evergreen or moist deciduous forests of Burma and Thailand. All these species occur also on soils other than limestone, but *H. ferrea* seems to show a distinct preference for limestone, or perhaps it would be more correct to say that it is unable to maintain itself in competition with other species except on limestone.

BRIS Formations

This is the name adopted to describe a type of vegetation that is occasionally found on the coasts of Borneo, Sumatra, the Malay Peninsula, and the intervening islands. BRIS is the abbreviation for Beach Ridges Interspersed with Swales. These BRIS formations are stretches of white sand, deposited by a combination of river and tidal action. They are most common immediately behind the beaches, but the older formations may occur inland as islands among more recent and dissimilar alluvial deposits. The vegetation of these areas is typically sparse grassland, interspersed with shrubs, among which *Rhodomyrtus tomentosa* is usually conspicuous, and solitary or grouped, small, frequently gnarled, dwarfed trees. Two species of dipterocarps have been reported to grow in such sandy formation. These include *Shorea talura* and *Cotylelobium* sp.

The Family of Dipterocarps

The family of dipterocarps contains 16 genera and 580 species. The genera have further sections and subsections. Details up to the section level are given in **Table 2**, which shows that there is a largely discrete distribution of this family in the neotropics, Africa, and Asia.

Non-Timber Products

Production of oleoresins is characteristic of most members of the family. The volatile portion consists mainly of sesquiterpenes that are used for caulking and varnish. Also, the fruits of many *Shorea* and sometimes *Dryobalanops* are boiled as vegetables. The fruits of *Shorea* section *Pachycarpae* and some others are rich in fat. The seeds contain up to 70% fat, which is similar to cocoa butter but has a higher melting point and is favored for manufacturing

Table 2 Genera and sections of the family Dipterocarpaceae

Genus	*Section*
Hopea	*Hopea*
	Dryobalanoides
Neobalanocarpus	—
Shorea	*Shorea*
	Richetioides
	Anthoshorea
	Mutica
	Ovalis
	Neohopea
	Rubella
	Brachypterae
	Pachycarpae
	Doona
	Pentacame
Parashorea	
Dryobalanops	
Dipterocarpus	
Anisoptera	*Anisoptera*
	Glabrae
Upuna	
Cotylelobium	
Vatica	*Sunaptea*
	Vatica
Stemonoporus	
Vateria	
Vateriopsis	
Monotes	
Marquesia	
Pakaraimaea	

chocolates and cosmetics. Camphor is another product from dipterocarps especially from *Dryobalanops*, which is used as incense (*see* **Non-wood Products**: Resins, Latex and Palm Oil).

Diversity and Conservation in Dipterocarps

Chromosome number is one of the genetic mechanisms responsible for diversification at intraspecific and specific levels. It has been found that dipterocarp species and genera are remarkably uniform with respect to chromosome number. Polyploid species are known only in two genera, namely *Hopea* and *Shorea*, while aneuploidy has been observed only in the genera *Anisoptera* and *Dipterocarpus*. These two ploidy levels assist in diversification at the species level. Breeding systems is another primary determinant of the pattern of genetic diversity in natural populations of dipterocarps. Studies indicate that in this family self-incompatibility exists in a large number of the species and hence most of these species are outcrossers. This mechanism provides the populations to have a high level of genetic diversity (*see* **Genetics and Genetic Resources**: Genetic Systems of Forest Trees).

Concerning conservation, as exploitation of these species for timber has been going on at a rapid phase in the Asia-Pacific regions, national governments have come to the realization that conservation of samples of relatively intact forest is necessary for balanced land use. National parks and other forms of protected area are some of the most universally adopted mechanisms for conservation of the species in this family (*see* **Ecology**: Biological Impacts of Deforestation and Fragmentation).

Conclusion

As can be seen the dipterocarps form an intricate part of the natural forest system in the tropics. The family exhibits a wide variation of characteristics in its growth and occurrence over a range of habitats.

As a forest ecosystem, the dipterocarp forests are a habitat for hundreds of thousands of animal and plant species that form an intrinsic network of interactions. The question being asked all over the world is whether such a complex ecosystem can tolerate anthropogenic disturbances such as timber extraction. However, to date there is still no clear answer to the long-term effects of logging of such forest on species diversity and continued sustenance of such an ecosystem. There is an urgent need to quickly bridge these gaps in knowledge to ensure that this natural treasure so vital to the well being of our planet is conserved and sustainably used to ensure perpetuity of these valuable resources.

See also: **Ecology**: Biological Impacts of Deforestation and Fragmentation. **Genetics and Genetic Resources**: Genetic Systems of Forest Trees. **Non-wood Products**: Resins, Latex and Palm Oil. **Tropical Forests**: Monsoon Forests (Southern and Southeast Asia); Tropical Dry Forests; Tropical Montane Forests.

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Eucalypts

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Eucalypts and the Australian Vegetation

Eucalypts are remarkably prevalent in the woody vegetation of Australia, dominating an estimated 127 million ha of forest, comprising nearly all vegetation types in Australia (302 communities) and occurring as codominants in a further 30 communities, with the exceptions of rainforest, the vegetation of the central arid zone, and higher montane regions. This natural distribution includes a wide variety of habitats from sea level to the alpine treeline, from the tropics to below 43° S latitude. Although this natural distribution is almost exclusively confined to Australia (except for a handful of tropical species to the north), eucalypts have been introduced to more than 90 countries where they have a multitude of uses, including industrial plantations conservatively estimated at 9.5 million ha in area (*see* **Tree Breeding, Practices:** Genetic Improvement of Eucalypts).

The genus *Eucalyptus* (family Myrtaceae) was named in 1788 by Charles-Louis L'Heritier de Brutelle, from a specimen of *E. obliqua* collected in 1777. Since then over 700 species have been recognized, derived from 13 main evolutionary lineages. The current taxonomic status of the eucalypts is still debated, especially the inclusion of the bloodwoods (*Corymbia* and *Angophora*) within *Eucalyptus*, or as separate genera (*see* **Tree Breeding, Practices:** Genetic Improvement of Eucalypts).

Eucalypts are highly variable in form, ranging in habit from forest trees, generally of between 30 and 50 m in height, but in some species more than 70 m (*E. deglupta*, *E. diversicolor*, and *E. grandis*, with the tallest flowering plant in the world *E. regnans* approaching 100 m in height), to woodland trees 10–25 m high, largely single-stemmed but spreading, to mallees that are multistemmed from the ground level, usually less than 10 m in height, and to some eucalypts that grow as shrubs less than 1 m in height, such as the subalpine yellow gum *E. vernicosa*.

Classifications of Eucalypt Forests in Australia

Most classifications of Australian vegetation are derived from Specht's structural classification, based on the life form and height of each stratum and the foliage cover of the tallest stratum. Eucalypts are not a major component of the closed forests (tropical and temperate rainforests) that comprise 3% of the Australian forest, but do dominate an estimated 78% of the forested area in Australia (from the most recent estimates of the National Forest Inventory or NFI). The NFI classification includes four broad classes of eucalypt forest: tall, medium, and low eucalypt forest, and mallee (**Figure 1**).

Tall Eucalypt Forests (Tall Open Forests)

Tall eucalypt forests (tall open forests or wet sclerophyll forests in previous classification schemes) are those that exceed 30 m in height with a projected foliage cover of 30–70%. These forests occupy