PART 2

RECOGNIZING FOREST TYPES

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EVERGREEN VS. DECIDUOUS FOREST TYPES
RECOGNIZING EVERGREEN FOREST
RECOGNIZING DECIDUOUS FOREST TYPES
FOREST TYPE AND RESTORATION STRATEGY

Evergreen Forest (EGF)

Above 1,000 m elevation, evergreen forests are rich in biodiversity and protect watersheds. Lack of light limits plant growth beneath the dense canopy.

Magnolias are typical of evergreen forest. The fruit above is Manglietia garrettii.

Understorey shrubs, like Phlogacanthus curviflorus *(below) are shade tolerant, to survive beneath the forest canopy.*

Epiphytes like Aeschynanthus hosseusii *(above) reach the light by growing in the forest canopy.*

Sapria himalayana *(left) needs no light. It extracts nutriment from the roots of lianas (*Tetrastigma *spp).*

Rhododendron vietchianum *(right) is an epiphytic shrub.*

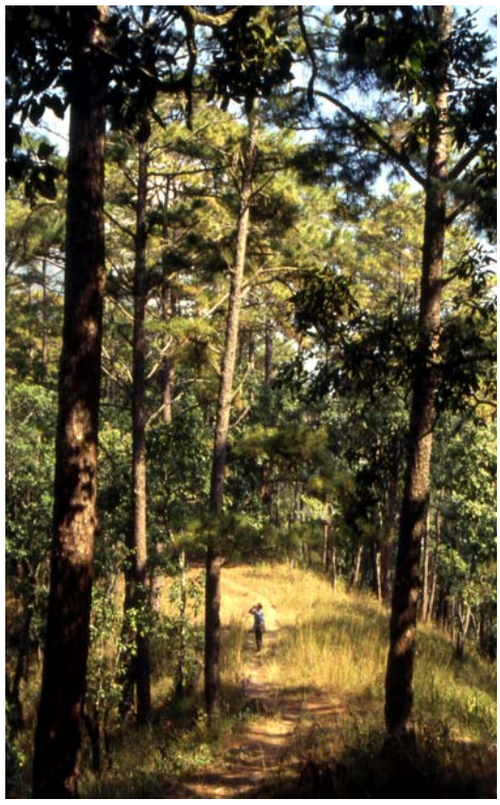
Evergreen Forest with Pine (EG-PINE)

Along fire-prone ridges, above 1,000 m elevation, pines can dominate evergreen forest. Below are a few species, which typically grow with pines.

Hacking kindling wood and resin tapping are destroying Thailand's native pines (above). The trees become weakened and are easily blown over by gales.

Many species of oak or chestnut (Fagaceae) grow alongside pines. Above is Castanopsis argyrophylla.

Impatiens violaeflora *(above) flowers from August to November amongst the ground flora of EG-PINE.*



EG-PINE, Doi Chiang Dhao, 1,200 m elevation.

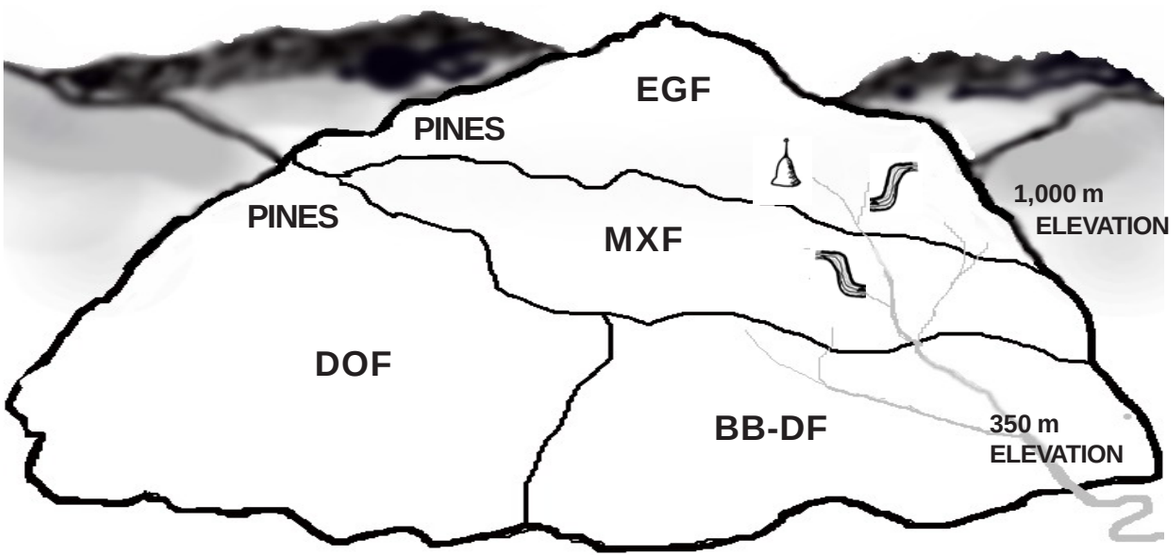
RECOGNIZING FOREST TYPES

When India gradually began to collide with the rest of Asia around 50 million years ago, the event not only threw up the mighty Himalayan Mountains, but also a tail of lesser mountains swirling away to the east and south. This geological incident provided northern Thailand with its main topographical features: broad valleys, separated by steep mountain ridges orientated very approximately north to south, with elevations ranging from 300 m in valley bottoms to 2,565 m at the summit of Thailand's highest mountain, Doi Inthanon. Such varied topography created a wide range of different physical conditions. As a result, the northern region supports a greater variety of forest types, in close proximity to each another, than any other part of the country. This diversity of forest types provides a wide range of wildlife habitats. Consequently, the region supports remarkably high biodiversity. The northern mountains are home to at least 150 mammal species and 383 bird species. Chiang Mai University's Herbarium holds records for >3,500 vascular plant species from the north, of which >1,120 are trees. Although adjacent forest types may have many species in common, each also has unique characteristics, which must be taken into consideration when planning forest restoration.

Why is it important to recognize forest types?

Forest restoration directs and accelerates natural forest succession in order to recreate original forest ecosystems as closely as possible. The original forest type, therefore, defines the goal of the activity. Consequently, identification of the original forest type is critical when planning forest restoration projects. It determines which tree species must be grown in nurseries and which trees are planted on each particular site to be restored. So, wherever biodiversity conservation is a major management priority, the composition of original forest provides a bench mark, against which progress and the ultimate success of forest restoration are measured.

Diagramatic representation of the distribution of main forest types on a typical mountain in northern Thailand. EGF = Evergreen Forest; MXF = Mixed Evergreen-Deciduous Forest; BB-DF = Bamboo-Deciduous Forest (former Teak Forest); DOF = Deciduous Dipterocarp-Oak Forest (after Maxwell and Elliott (2001)).



Section 1 – Evergreen vs. Deciduous Forest Types

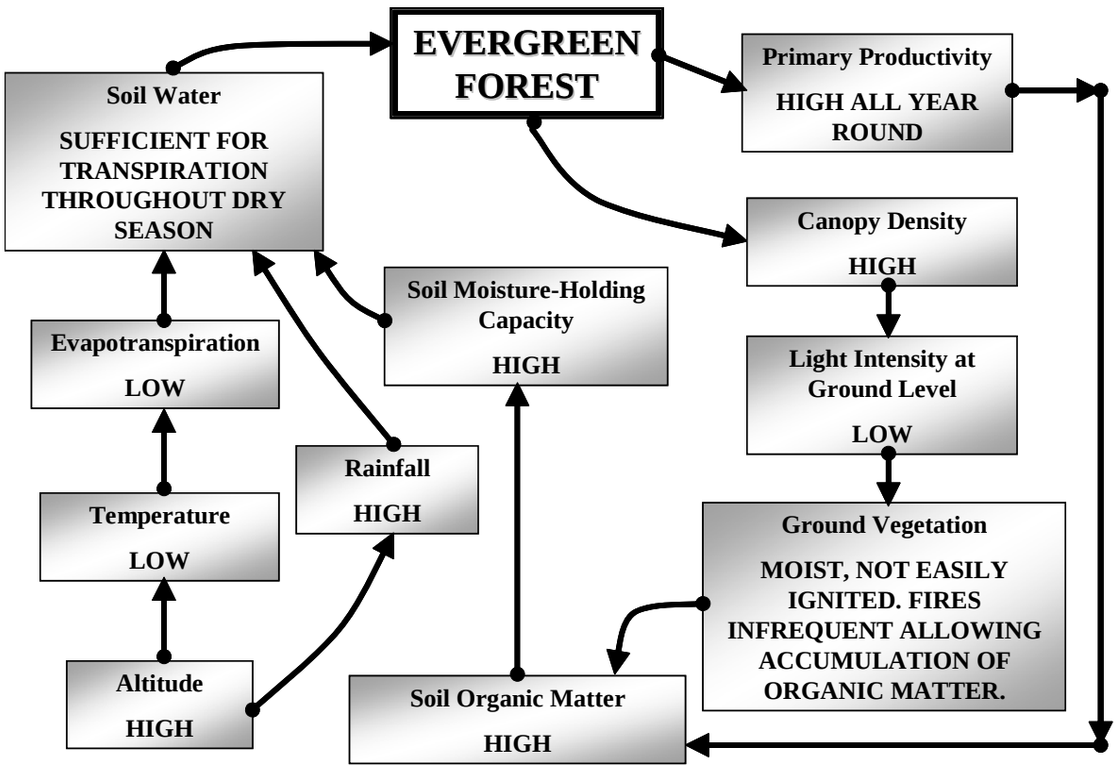
The forests of northern Thailand can be broadly divided into evergreen and deciduous types, with evergreen forests growing above (very) roughly 1,000 m elevation and deciduous forests growing lower down. Soil moisture is the over-riding factor that determines the distribution of these two broad categories of forest type.

In seasonally-dry, tropical environments, trees shed their leaves to survive drought during the dry season. Evergreen forests grow where soil moisture is sufficient to meet the transpiration needs of the trees throughout the year, whereas deciduous forests grow where soil moisture falls below that needed to maintain transpiration during the dry season.

Within all plants, there is usually a constant, upward flow of water, transporting nutrients from the roots to the leaves. This is transpiration and it is driven by evaporation of water from cells within the leaves and diffusion of water vapour into the atmosphere via pores in the leaves' surfaces, called stomata. When soil moisture falls below the level needed to support transpiration for long periods, trees may shed their leaves. This prevents water loss and retains sufficient water within roots, trunks and branches to maintain basic metabolism, until the rains replenish soil moisture.

Therefore, the amount of moisture retained in the soil by the beginning of the dry season is the critical factor that determines whether a forest is evergreen or deciduous - and that, in turn, is primarily determined by elevation. Trees cannot respond directly to elevation, but they do respond to the impact of elevation on soil moisture.

Rainfall increases with increasing elevation. As warm air (which can hold a lot of water vapour) passes over mountains, it is forced up into cooler air. Since cool air can hold less water vapour than warm air, some of the vapour must condense out as rain (orographic precipitation). In contrast, temperatures fall with increasing elevation (approximately -0.6 □ C for every 100 metres ascended) and consequently, losses of water from the soil and through the vegetation by evaporation also decline. So, at high eleva-tions, more water enters the soil from rainfall and less is removed by evaporation.

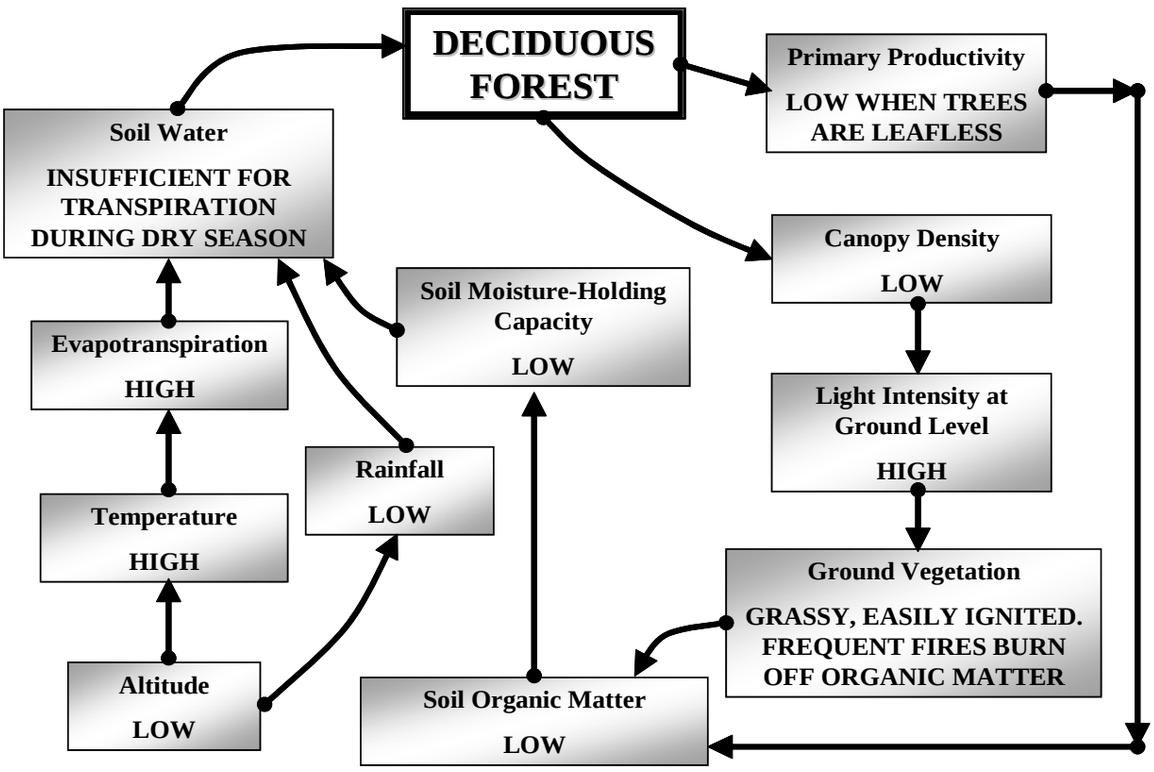


Furthermore, evergreen forest soils are rich in organic matter (due to a continuous rain of leaf litter from the highly productive trees). High organic matter content greatly enhances the moisture-holding capacity of the soil. In evergreen forests, "field capacity" (the maximum amount of water that can be held within 1 gm of dry soil) averages typically about 0.35 gm water per gm of dry soil; enough to feed the transpiration needs of the trees throughout the dry season. Therefore, most of the tree species at higher elevations can retain dense foliage all year round, without drying out.

In the lowlands, everything is reversed. Less water enters the soil (due to lower rainfall); evaporation is higher (due to higher temperatures) and soil field capacity is lower (averaging only about 0.20 gm water per gm of dry soil), especially if fire burns off organic matter. Therefore, even if the soil reaches field capacity by the end of the rainy season, it retains insufficient moisture to maintain transpiration of the trees throughout the dry season. The trees shed their leaves, effectively shutting down transpiration and conserving water for survival.

Superimposed on the effects of elevation, disturbances caused by humans have a modifying effect on the distribution of forest types. Such disturbances also exert their effects mostly by reducing soil moisture. Tree felling, browsing by cattle and agricultural activities open up the forest canopy, causing the soil to dry out, leading to soil erosion and reduced plant growth. Fire burns off soil organic matter, whilst reduced primary production reduces inputs of organic matter into the soil. Reduced soil organic matter content inevitably leads to reduced soil moisture-holding capacity, opening the way for deciduous trees to invade areas above 1,000 m, previously occupied by evergreen forest. Conversely, evergreen forests can sometimes spread down to lower elevations, along streams or wherever soil moisture is high. However, due to logging in the past, lowland evergreen forests have been completely eliminated from northern Thailand.

Other factors such as bedrock, aspect and slope can also affect the distribution of forest types, but none of these is as influential as soil moisture.



SECTION 2 – RECOGNIZING EVERGREEN FOREST

Whilst evergreen forests in northern Thailand are fairly uniform, deciduous forests can be divided into at least 3 distinct types. In Sections 2 & 3, we present a summary of the most characteristic features of northern Thailand's main forest types, adapted from Maxwell and Elliott's (2001) analysis of the vegetation of Doi Suthep-Pui National Park (see also Maxwell, 2004).

What are the distinguishing characteristics of evergreen forest (EGF)?

In northern Thailand, evergreen forest (EGF) grows above 1,000 m elevation or slightly lower along streams. Floristically, EGF is quite uniform, and cannot be divided into sub-types, up to the maximum elevation in the region (Doi Inthanon summit 2,565 m).

EGF is quite distinct from the various deciduous forest types. The main canopy, often with emergent tree crowns, is much higher and denser than that of deciduous forests, often exceeding 30 m in height. This creates dense shade at ground level. Beneath the main canopy, the lower story is comprised of young trees, treelets and shrubs. Woody climbers and fig trees are common.

A high abundance of epiphytes is an obvious feature of EGF. In addition to vascular plants, algae, bryophytes and lichens often encrust tree trunks and branches.

The ground flora is often dense and consists of tree seedlings and herbs, including several with a saprophytic or parasitic way of life. Grasses can occur in disturbed areas, but tall bamboos are absent.

Fires are less common in EGF than in deciduous forests, but when fire does occur, it is much more damaging, since EGF trees lack the resilience of deciduous forest trees. After a fire, shrubs, the ground flora and populations of ground-dwelling small mammals and birds may take many years to recover.

High biodiversity is a feature of EGF. More tree species grow there than in any other forest type (at least 250 have been recorded so far). Although no tree species or genus dominates, several families tend to be better represented in EGF than in the deciduous forest types *e.g.* Lauraceae, Fagaceae, Theaceae, Moraceae, Magnoliaceae, *etc.* Most of the canopy trees are evergreen. Characteristic ones include *Lindera caudata* (Nees) Bth. and *Phoebe laceolata* (Wall. *ex* Nees) Nees (both Lauraceae), *Artocarpus lanceolata* Trec. and several gigantic "strangling" figs, *e.g. Ficus altissima* Bl. and *F. benjamina* L. (Moraceae). Of the oaks (Fagaceae), *Quercus vestita* Rehd. & Wils., *Q. glabricupula* Barn., *Q. incana* Roxb. and *Q. lineata* Bl. are all highly characteristic. Other characteristic evergreen trees include *Pyrenaria garrettiana* Craib (Theaceae), *Garcinia mckeaniana* Craib (Guttiferae), *Casearia grewiifolia* Vent. (Flacourtiaceae), *Chionanthus sutepensis* (Kerr) Kiew (Oleaceae), *Elaeocarpus prunifolius* Wall. *ex* C. Muell. (Elaeocarpaceae), *Dysoxylum excelsum* Bl. (Meliaceae), *Ostodes paniculata* Bl. (Euphorbiaceae) and *Diospyros marlabarica* Cl. (Ebenaceae).

Despite the name of this forest type, about 27% of its tree species are deciduous, although many of these are also shared with MXF. A few of the larger deciduous canopy species include *Manglietia garrettii* Craib and *Magnolia baillonii* Pierre (both Magnoliaceae), *Melia toosendan* Sieb. & Zucc. (Meliaceae) and *Morus macroura* Miq. (Moraceae). Some deciduous trees, restricted to evergreen forest, include *Acrocarpus fraxinifolius* Wight *ex.* Arn. (Leguminosae, Caesalpinioideae), *Litsea zeylanica* (Nees) Nees (Lauraceae) and the rather rare *Hovenia dulcis* Thunb. (Rhamnaceae),

The understorey is denser than that of deciduous forests and is very diverse in stream valleys. Understorey trees include: *Phoebe lanceolata* (Nees) Nees (Lauraceae), *Acronychia pedunculata* (L.) Miq. (Rutaceae), *Sarcosperma arboreum* Bth. (Sapotaceae) and *Diospyros glandulosa* Lace (Ebenaceae). Deciduous representatives include *Engelhardia spicata* Lechen. (Juglandaceae) and *Spondias axillaris* Roxb. (Anacardiaceae).

Treelets and shrubs (91 and 22 recorded species, respectively) are numerous. Characteristic treelets include *Vernonia volkameriifolia* DC. (Compositae), *Glochidion kerrii* Craib (Euphorbiaceae), *Debregeasia longifolia* (Burm. f.) Wedd. (Urticaceae), *Archidendron glomeriflorum* (Kurz) Niels. (Leguminosae, Mimosoideae) and *Litsea cubeba* (Lour.) Pers. (Lauraceae). Characteristic evergreen shrubs include *Psychotria ophioxyloides*

Wall. (Rubiaceae) and *Phlogacanthus curviflorus* (Wall.) Nees (Acanthaceae). Pandans and banana plants (*e.g. Pandanus penetrans* St. John (Pandanaceae) and *Musa itinerans* Cheesm. (Musaceae)) are characteristic of shaded, stream valleys.

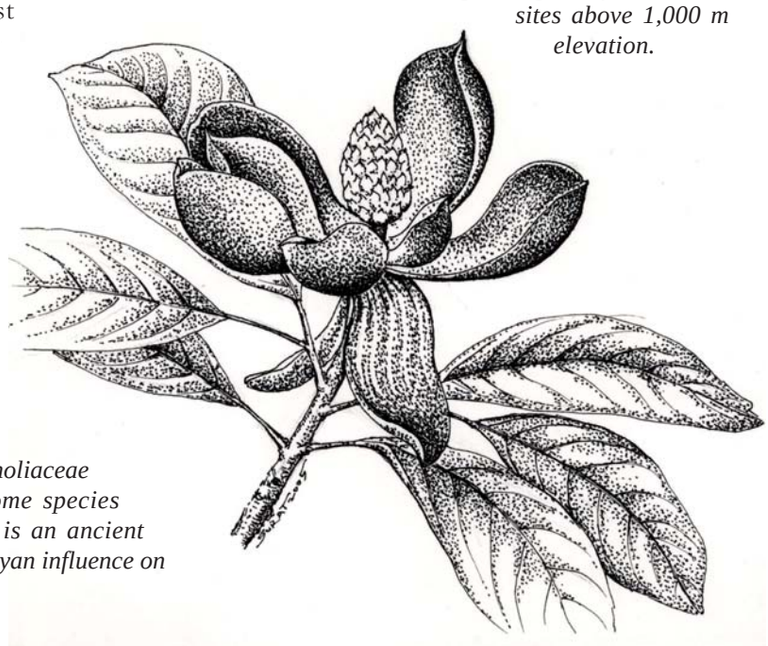
A high diversity of woody climbers (78 recorded species) is a notable feature of evergreen forest. Some characteristic evergreen examples include: *Toddalia asiatica* (L.) Lmk. (Rutaceae), *Ficus parietalis* Bl. (Moraceae), *Combretum punctatum* Bl. (Combretaceae) and *Uncaria macrophylla* Wall. (Rubiaceae). Also common are several species of *Tetrastigma* (*e.g. T. laoticum* Gagnep. and *T. obovatum* (Laws.) Gagnep. (Vitaceae)) and *Mucuna macrocarpa* Wall. (Leguminosae, Papilionoideae), which also occur in MXF. Rattan palms are characteristic, but fairly rare, in EGF *e.g. Calamus palustris* Griff. var. *cochinchinensis* Becc. and *Plectocomia kerrana* Becc.

Epiphytes abound in evergreen forest. The 82 species recorded there include trees, shrubs, vines and herbs. The trees include the so-called "strangling" figs, which begin life as epiphytes *e.g. Ficus superba* (Miq.) Miq. (Moraceae) and the very rare *Sorbus verrucosa* (Decne.) Rehd. (Rosaceae). Characteristic epiphytic shrubs include a rhododendron *(Rhododendron vietchianum* Hk. (Ericaceae)) and several hemiparasitic mistletoes (*e.g. Macrosolen cochinchinensis* (Lour.) Tiegh., *Viscum ovalifolium* Wall. *ex* DC. and *V. orientale* Willd. (Loranthaceae)). Epiphytic herbs are nearly all perennials and many are deciduous. Species particularly characteristic of evergreen forest include ferns (*e.g. Lepisorus nudus* (Hk.) Ching (Polypodiaceae) and *Davallodes membranulosum* (Hk.) Copel. (Davalliaceae)); gingers (*e.g. Hedychium ellipticum* Ham. *ex* J. Sm.); orchids (*e.g. Bulbophyllum bittnerianum* Schltr., *Coelogyne schultesii* Jain & Das. and *Trichotosia dasyphylla* (Par. & Rchb. f.) Krzl. and gesnerids (*e.g. Didymocarpus wattianus* Craib and *Aeschynanthus hosseusii* Pell. (Gesneriaceae)).

The herbaceous ground flora (321 recorded species) is very diverse. Characteristic ferns in shaded undisturbed areas include *Arachnoides henryi* (Christ) Ching and *Tectaria herpetocaulos* Holtt. (both Dryopteridaceae), *Thelypteris subelata* (Bak.) K. Iw. (Thelypteridaceae) and *Diplazium dilatatum* Bl. (Athyriaceae). Common flowering herbs in EGF include: *Impatiens violaeflora* Hk. f. (Balsaminaceae), *Opiorrhiza trichocarpon* Bl. and *Geophila repens* (L.) I.M. John. (both Rubiaceae) and *Pilea trinervia* Wight (Utricaceae). Gingers such as *Globba kerrii* Craib, *G. villosula* Gagnep. and *Zingiber smilesianum* Craib (Zingiberaceae) are also common.

Some plants in the ground layer of EGF lack the need for light for photosysnthesis because they have evolved a parasitic or saprophytic way of living. For example *Balanophora* species superficially resemble fungi (*e.g. B. abbreviata* Bl. and *B. fungosa* J.R. & G. Forst.) but are parasitic on tree roots. *Sapria himalayana* Griff. (Rafflesiaceae) is the most spectacular parasite, with bright red flowers, the size of saucers, with yellow spots. It parasitizes the roots of woody climbers in the genus *Tetrastigma* (Vitaceae).

Manglietia garrettii *Craib (Magnoliaceae) is a framework tree species, recommended for including in forest restoration plantings on former EGF sites above 1,000 m elevation.*



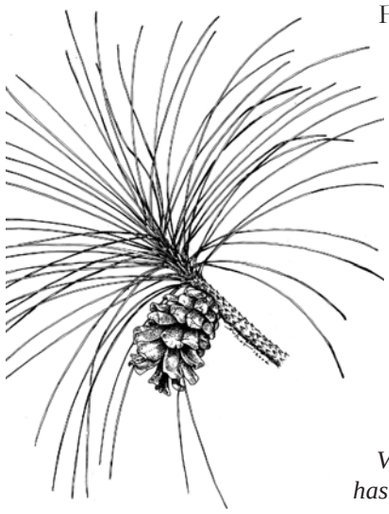
The tree and shrub family Magnoliaceae is typical of EGF (although some species occasionally grow in MXF). It is an ancient family and represents the Himalayan influence on northern Thailand's flora.

What are the distinguishing characteristics of pine forest (EGF-PINE)?

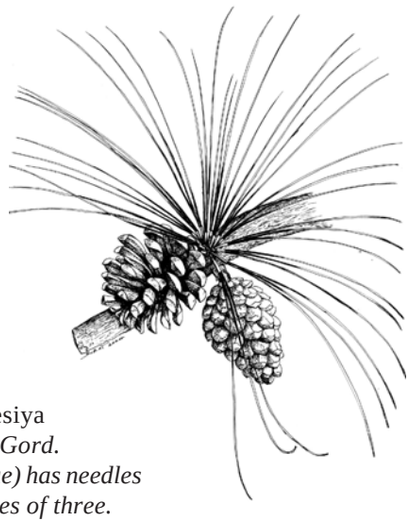
On fire-prone, exposed ridges at elevations of about 950-1,800 m the pine tree, *Pinus kesiya* Roy. *ex* Gord. (Pinaceae) may grow in abundance, amongst other EGF tree species; in some places dominating the forest. At the lower elevation limits of EGF, Thailand's other, much less common pine species, *Pinus merkusii* Jungh & De Vriese may also grow.

The canopy of evergreen forest with pine (EGF-PINE) is more open than that of EGF without pine. Several oak or chestnut species (Fagaceae) are characteristically associated with pines, including *Castanopsis argyrophylla* King *ex* Hk. f., *Quercus brandisiana* Kurz, *Q. leticellata* Barn. and *Lithocarpus craibianus* Barn (Fagaceae). Other tree species, associated with pines (mostly due to the lower pH of the soil), include *Viburnum inopinatum* Craib (Caprifoliaceae), *Helicia nilagirica* Bedd. (Proteaceae) and *Myrica esculenta* B.-H. *ex* D. Don (Myricaceae).

Where fires are particularly frequent, trees more characteristic of deciduous dipterocarp-oak forest can spread up into EGF-PINE and grow at much higher elevations than is typical (*e.g. Craibiodendron stellatum* (Pierre) W. W. Sm. and *Vaccinium sprengelii* (D. Don) Sleum. (both Ericaceae), *Anneslea fragrans* Wall. (Theaceae) and *Aporusa villosa* (Lindl.) Baill. In such areas, oaks and chestnuts become particularly common (*e.g. Castanopsis armata* (Roxb.) Spach, *C. tribuloides* (Sm.) A. DC., *Lithocarpus elegans* (Bl) Hatus. *ex* Soep., *L. fenestratus* (Roxb.) Rehd. and *Quercus vestita* Rehd. & Wils (all Fagaceae). A total of 99 tree species have been recorded in EGF-PINE. Shrubs and woody climbers are less prominent in EGF-PINE, compared with EGF without pine.



Pinus merkusii *Jungh. et de Vriese (Pinaceae) has needles in pairs.*



Pinus kesiya *Roy. ex Gord. (Pinaceae) has needles in bunches of three.*

Characteristic vascular epiphytes (86 recorded species) include ferns, orchids, gesnerids and hemiparasitic mistletoes (Loranthaceae and Viscaceae). Common epiphytic ferns include *Drynaria propinqua* (Wall. *ex* Mett.) J. Sm. *ex* Bedd., *Lepisorus subconfluens* Ching and *Polypodium argutum* (J. Sm. *ex* Hk. & Grev.) Hk. (all Polypodiaceae).

Epiphytic orchids are represented by many genera (*e.g. Bulbophyllum suavissimum* Rol., *Cleisostoma fuerstenbergianum* Krzl., *Coelogyne trinervis* Lindl., *Dendrobium heterocarpum* Lindl., *Diploprora championi* (Lindl.) Hk. f., *Oberonia pachyphylla* King & Pantl., *Pholidota articulata* Lindl. and *Trichotosia dasyphylla* (Par. & Rchb. f.) Krzl.).

Hemi-parasitic mistletoes are common, including *Macrosolen avenis* (Bl.) Dans. and *Scurrula ferruginea* (Jack) Dans. (Loranthaceae) and *Viscum ovalifolium* Wall. *ex* DC. (Viscaceae). Gesnerids, typical of EGF-PINE, include *Didymocarpus kerrii* Craib and *D. aureoglandulosus* Cl. (Gesneriaceae).

The ground flora includes 263 recorded herb species, both annuals (32%) and perennials (68%). Annual herbs include: *Blumeopsis flava* (DC.) Gagnep. and *Anaphalis margaritacea* (L.) Bth. & Hk. f. (both Compositae), *Lobeia nicotianaefolia* Roth *ex* Roem. & Schult. (Campanulaceae) and *Exacum pteranthum* Wall. *ex* Colebr. (Gentianaceae). Typical deciduous, perennial herbs include *Inula cappa* (Ham. *ex* D. Don) DC. (Compositae), *Pratia begoniifolia* (Wall. *ex* Roxb.) Lindl. (Campanulaceae), *Anthogonium gracile* Wall. *ex* Lindl. (Orchidaceae), *Oleandra undulata* (Willd.) Ching (Oleandraceae) and *Kuniwatsukia cuspidata* (Bedd.) Pic.-Ser. (Athyriaceae).

What are the challenges when restoring EGF and EGF-PINE?

Because EGF supports more tree species than the other forest types (see Box 2.5), tree planting should aim to include as many species as possible, within practical limits, to "kick-start" biodiversity recovery. A large proportion of evergreen forest trees have large seeds, which are dispersed by large animals *e.g.* rhinos, elephants, wild cattle *etc.* Most such large animal species have been extirpated from northern Thailand or remain only as tiny, isolated populations. Therefore, including tree species with large fleshy fruits amongst those planted can help to conserve such tree species, which now have very limited natural opportunities for seed dispersal.

Deciduous trees, which grow in evergreen forest, often make the best framework species for accelerating biodiversity recovery after planting (*e.g. Acrocarpus fraxinifolius, Erythrina subumbrans, Gmelina arborea, Hovenia dulcis, Melia toosendan, Spondias axillaris*). Their deciduous habit makes them resistant to drought-induced stress during the first hot-dry season after planting. Therefore, they usually have high survival rates.

Soils at EGF sites are usually richer in nutrients than deciduous forest soils are, so less fertilizer may be required after tree planting. In contrast, weed growth tends to be more rapid. Weeding may, therefore, have to be carried out more frequently than in deciduous forest sites, with correspondingly higher labour costs. EGF sites at higher elevations may be above the spring line. This makes watering the trees after planting unfeasible, since access to the planting sites by water tankers is also likely to be difficult. Planting must therefore be delayed until rainfall is reliable.

To restore EGF-PINE, pines, oaks and chestnuts, suited to the elevation of the planting site, should be included amongst framework tree species planted, since they are characteristic of this forest type. Since EGF-PINE occurs in fire prone areas, particular attention must be paid to fire prevention after planting.

Box 2.1 - Looking at Thailand's two indigenous pine species

Thailand's two native pine species are easily distinguished by their leaves. The needle-like leaves of *Pinus merkusii* Jungh. de Vriese grow in pairs, whereas those of *P. kesiya* Roy. *ex* Gord. grow in bundles (fascicles) of three.

In northern Thailand, *P. merkusii* tends to grow at lower elevations (300-1,200 m) than *P. kesiya*, more commonly in DOF but sometimes at the lower limits of EG-PINE. In the lowlands it is now rare due to over-exploitation for its resin and timber. *P. kesiya* is commoner and is characterstic of EG-PINE, but it also grows at the upper limits of DOF; from 950 to 1,800 m elevation.

Both species are light demanding and fire resilient. Both are exploited for resin, but *P. merkusii* produces the highest yield (large trees up to 40 kg of pure resin per year). Damage to pines by hacking at their trunks, to remove resin-soaked slivers of wood for fire lighters, is common. It weakens the trees and eventually kills them. This practice has now beome a serious threat to pines throughout northern Thailand.

Pine seeds are wind-dispersed. Where remnant trees remain, seedlings establish easily on disturbed soil, but are intolerant of dense weeds and fire. Where pines once grew, but have been completely eliminated, consider planting them, along with framework tree species. Do not grow plantations of pure pine. They are poor wildlife habitat. Obtain pine saplings from nuseries, but make sure they have been grown from seeds from local forest (not plantations). Never select saplings of exotic pines, such as *P. carribea.* To grow pines yourself, carefully cut green or brown cones, just before they open, from local forest trees, without damaging the twigs. Store the immature green cones in shade, until they turn brown. Then, sun-dry them until they open. Shake out the seeds, remove the wings and sow seeds in germination trays in sand. Transfer 3-5 cm-tall seedlings into containers and grow them on for 1-1.5 years. Alternatively, harvest 5 to 10-cm-tall seedlings from forest, during the rainy season and grow them on in containers (Box 6.1). Dried seeds remain viable for several years.

Section 3 – Recognizing Deciduous Forest Types

Three deciduous forest types are easily recognised. Mixed evergreen-deciduous forest (MXF) is a distinct zone between upland evergreen and lowland deciduous forests. Bamboo-deciduous forest (BB-DF) has largely replaced formerly dominant teak forests, due to logging, whilst deciduous dipterocarp-oak forest (DOF) grows on the driest or most disturbed lowland sites.

What are the characteristics of mixed evergreen-deciduous forest (MXF)?

In a narrow elevational band from 800 to 1,000 m (or from 600 m in stream valleys), a distinct zone occurs in between EGF and BB-DF. Mixed evergreen-deciduous forest (MXF) consists of a diverse mix of tree species from both these forest types, but it also supports many species, that grow only in this forest type.

Canopy height varies from 20 to 30 m, but emergent trees, taller than 30 m, are common. Canopy cover is usually complete, though it is less dense than in evergreen forest. Woody climbers are prominent. Epiphytes are common. Bamboos are present, but are less prevalent than in BB-DF. There is usually a dense ground layer of herbs and tree seedlings. Grasses are rare, except where fire has occurred.

Of the 217 tree species, recorded in MXF on Doi Suthep, only 43% are deciduous. There is a very strong similarity between the tree floras of MXF and BB-DF. Of the 38 tree species that are common or abundant in the former, 21 (55%) are shared with the latter. The most easily recognized evergreen canopy tree species, characteristic of this forest type, are the tall, emergent, evergreen, dipterocarps: *Dipterocarpus costatus* Gaertn. f. and *D. turbinatus* Gaertn. f. (Dipterocarpaceae). With their massive trunks, relatively small leaves and broad, umbrella-shaped crowns, these trees appear very different to the large-leaved dipterocarps of DOF.

Other common tree species in MXF include *Irvingia malayana* Oliv. *ex* Benn. (Irvingiaceae), *Mangifera caloneura* Kurz (Anacardiaceae), *Eugenia albiflora* Duth. *ex* Kurz (Myrtaceae), *Lagerstroemia cochinchinensis* Pierre (Lythraceae), *Spondias pinnata* (L. f.) Kurz (Anacardiaceae), *Terminalia mucronata* Craib & Hutch. (Combretaceae) and *Engelhardia serrata* Bl. (Juglandaceae). Common evergreen understorey trees include *Garcinia speciosa* Wall. (Guttiferae) and *Scleropyrum pentandrum* (Denn.) Mabb. (Santalaceae).

More than 60 species of woody climbers have been recorded in MXF. Characteristic ones include *Securidaca inappendiculata* Hassk. (Polygalaceae), *Tetrastigma* aff. *harmandii* Planch. (Vitaceae) and *Parameria laevigata* (Juss.) Mold. (Apocynaceae). Characteristic epiphytes include orchids (*e.g. Bulbophyllum congestum* Rol. and *B. propinquum* Krzl.), hemiparasitic mistletoes (*e.g. Helixanthera pulchra* (DC.) Dans. and *Dendrophthoe pentandra* (L.) Miq. (Loranthaceae) and ferns (*e.g. Polypodium subauriculatum* Bl. and *Pyrrosia porosa* (Wall. *ex* Presl) Hoven. (Polypodiaceae)).

The ground flora includes at least 278 herb species, as well as seedlings and saplings of trees and shrubs. Most of these species are shared with EGF or BB-DF. The few that are unique to MXF include two ground orchids (*e.g. Tainia hookeriana* King & Pantl. and *Tropidia pedunculata* Bl.), a few ferns (*e.g. Microlepia puberula* v. A. v. Ros. (Dennstaedtiaceae)), *Asplenium excisum* Presl (Aspleniaceae) and *Tectaria impressa* (Fee) Holtt. (Dryopteridaceae) and the parasite, *Balanophora laxiflora* Hemsl (Balanophoraceae) on tree roots.

What are the special challenges when restoring MXF?

MXF sites are often located on steep slopes, so access to them can present problems. As with BB-DF, large bamboos can inhibit growth and survival of planted trees, so some control of them may be necessary to allow tree establishment. Most MXF sites are near permanent streams, so watering trees after planting is usually feasible. The large dipterocarps, characteristic of this forest type, have wind-dispersed seeds. Where remnant mature trees survive, there is usually no need to plant them. However, where they are absent, consider adding indigenous dipterocarp species to the mix of framework tree species planted, to maintain the distinctive structure of MXF. Dipterocarp seedlings grow very slowly in nurseries, so start collecting seeds at least 2 years in advance.

Mixed Evergreen Deciduous Forest (MXF)

Above - A massive Dipterocarpus costatus *Gaertn. f. (Dipterocarpaceae) tree, towering over the main forest canopy: a characteristic feature of MXF.*

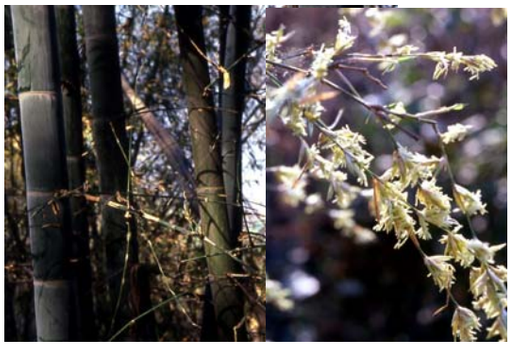
Right - Understorey tree, Bauhinia variegata *L. (Leguminosae, Caesalpinioideae) flowers January to March, when leafless.*

Below - With no green leaves for photosynthesis, Aeginetia indica *Roxb. (Orobanchaceae) is parasitic on plant roots.*

Below - Shade-tolerant herb, Gomphostemma strobilinum *Wall. ex Bth. (Labiatae). Variegated leaves lie flat against the soil surface.*

Bamboo-Deciduous Forest (BB-DF)

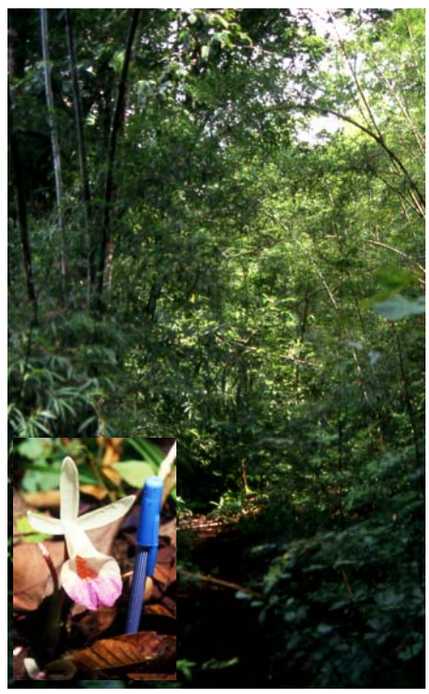
Below - Planted teak, CMU campus, nearly leafless in February.



Below- Afzelia xylocarpa *(Kurz) Craib (Leguminosae, Caesalpinioideae), a valuable timber tree in ex-teak forest.*

Insert right - Boesenbergia longiflora *(Wall.) O. K. (Zingiberaceae) adds colour to the ground flora of BB-DF, August.*

Left - Where teak has been removed, bamboos take over. Several species flower gregariously over their entire ranges.



Above - BB-DF along the lower Mae Soi Valley near Chom Thong. Typical of logged over, former, teak forest.

Deciduous Dipterocarp-Oak Forest (DOF)

Left - DOF canopy, changing colour in January. Above centre - A young sapling of Dipterocarpus tuberculatus *(Dipterocarpaceae), flushing out in March; typical of dry or highly degraded sites. Above right - fallen flowers of* D. obtusifolius.

Right - Flattened acorn of Quercus kerrii *Craib (Fagaceae) a characteristic oak of DOF.*

Epiphytes of DOF: Far left - Dischidia major *(Vahl) Merr. (Asclepiadaceae) has a symbiotic relationship with ants. Ants nest in cavities formed by its bladder leaves. Adventitious roots grow into these cavities to extract moisture and nutrients from the ants' nests (centre left). Ants are also commonly found amongst the more conventional leaves of* D. nummularia *R. Br. (left).*

Ground flora species of DOF: Far left - Arundina graminifolia *(D. Don) Hochr. (Orchidaceae), September; Centre -* Platostoma coloratum *(D. Don) A.J. Platon (Labiatae), May; Above - the parasitic* Aeginetia pendunculata *Wall. (Orobanchaceae), flowering after fire in March.*

What are the characteristics of bamboo-deciduous forest (BB-DF)?

Before the latter decades of the 19th century, much of northern Thailand's lowlands were covered by vast forests, dominated by teak (*Tectona grandis* L. f. (Verbenaceae)) from valley bottoms up to 900 m elevation. However, the relentless exploitation and international trade of this highly valuable timber tree, first by foreign companies and then by Thai logging firms, changed the character of these forests. Although remnants of teak forest can still be found in a few national parks, wild teak has now become rather rare and has largely been replaced by other tree species that were formerly present in teak forest. In addition bamboos have become much more dominant. Bamboo-deciduous forest (BB-DF) is therefore a form of degraded teak forest.

To recognize former teak forest or BB-DF, look for tall trees, producing a patchy canopy, growing on fertile soils within the elevation range 300-900 m. In the dry season, canopy cover is sparse, since most trees drop their leaves. Remnant teak trees are indicative (see Box 2.2). An understorey, dominated by dense thickets of bamboos, is also characteristic. A dense shrub layer is also usually present. Woody climbers are common and epiphytic orchids and ferns grow frequently on the trunks or main branches of the larger trees. The ground layer consists mostly of deciduous herbs and grasses, the latter especially common where fires have occured. Fires are common.

In BB-DF, main canopy trees can grow up to 20-30 m tall. At least 180 tree species have been recorded in such forest, of which more than 70% are deciduous, but none approaches the former dominance of teak. Some of the more characteristic ones include valuable commercial tree species such as *Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) Niels. (Leguminosae, Mimosoideae), *Dalbergia cultrata* Grah *ex* Bth., *Pterocarpus macrocarpus* Kurz (both Leguminosae, Papilionoideae), *Lagerstroemia cochinchinensis* Pierre (Lythraceae), *Chukrasia tabularis* A. Juss. (Meliaceae) and *Afzelia xylocarpa* (Kurz) Craib (Leguminosae, Caesalpinioideae). Logging has favoured other less valuable species. Particularly characteristic are *Colona flagrocarpa* (Cl). Craib (Tiliaceae), *Schleichera oleosa* (Lour.) Oken (Sapindaceae), *Terminalia chebula* Retz. var. *chebula, T. mucronata* Craib & Hutch. (Combretaceae) and *Sterculia pexa* Pierre (Sterculiaceae). Common understorey trees include: *Vitex canescens* Kurz and *V. limoniifolia* Wall. *ex* Kurz (both Verbenaceae), *Cassia fistula* L. (Leguminosae, Caesalpinioideae), *Antidesma acidum* Retz., *Phyllanthus emblica* L. (both Euphorbiaceae), *Stereospermum neuranthum* Kurz and *Oroxylum indicum* (L.) Kurz (both Bignoniaceae).

Woody climbers (lianas), often quite large, are a notable feature of this forest type. A total of 55 species have been recorded, of which 65% are deciduous. Some of the typical species include *Millettia cinerea* Bth. and *M. extensa* (Bth.) Bth. *ex* Bak. (Leguminosae, Papilionoideae), *Combretum latifolium* Bl. (Combretaceae) and *Congea tomentosa* Roxb. var. *tomentosa* (Verbenaceae).

Thirty shrub species have been recorded in BB-DF on Doi Suthep, of which 63 % are deciduous. Some typical species include *Helicteres elongata* Wall. *ex* Boj. and *H. hirsuta* Lour. (Sterculiaceae), *Desmodium gangeticum* (L.) DC. and *D. velutinum* (Willd.) DC. ssp. *velutinum* (Leguminosae, Papilionoideae), *Sericocalyx quadrafarius* (Wall. *ex* Nees) Brem. (Acanthaceae), *Phyllanthus sootepensis* Craib and *Sauropus hirsutus* Beille (both Euphorbiaceae).

Bamboos (Gramineae, Bambusoideae), are abundant, especially in more disturbed areas. The more characteristic species include *Dendrocalamus membranaceus* Munro, *D. nudus* Pilg and *Bambusa tulda* Roxb.

At least 38 species of epiphytes have been recorded in BB-DF on Doi Suthep. They mostly belong to 3 groups: Moraceae (figs, many of which begin their lives as epiphytes), Orchidaceae, (orchids) and Pteridophytes (ferns). Particularly characteristic species include: *Ficus microcarpa* L.f. (Moraceae), an evergreen tree; *Cymbidium aloifolium* (L.) Sw. (Orchidaceae), a succulent evergreen herb and the ferns, *Platycerium wallichii* Hk. and *Drynaria bonii* C. Chr. (both deciduous Polypodiaceae). The evergreen hemiparasitic epiphyte, *Scurrula atropurpurea* (Bl.) Dans. (Loranthaceae) is restricted to bamboo-deciduous forest.

The ground is mostly bare during the dry season (November-April). The first herbs to appear are gingers (*e.g. Globba nuda* K. Lar. and *Kaempferia rotunda* L. (Zingiberaceae)), orchids

Box 2.2 - Looking at Teak

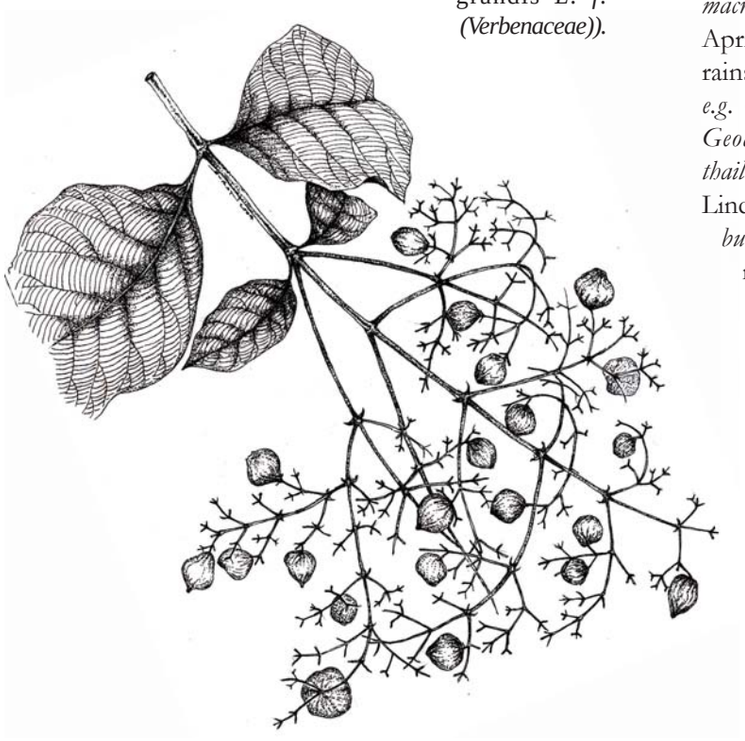
Teak is perhaps Thailand's most famous tree species. Easily recognized by its sandy brown bark, with shallow, longitudinal fissures, and a crown of large leaves, this deciduous tree once dominated much of northern Thailand's lowland forests - but not any longer.

Its downfall was its timber. Incredibly durable, easy to carve and beautiful to look at, teak wood is excellent for house beams, flooring, furniture, ornaments, boats and bridges. Begining in the 19th century, first foreign and then Thai timber companies ruthlessly exploited northern Thailand's teak forests so that now, large, natural teak trees are a very rare sight, except in a few national parks such as Mae Wong and Mae Yom.

Teak has remarkable powers of natural regeneration and, where even just a few mature teak trees remain, teak seedlings readily establish naturally, especially on moister sites. Teak is not considered to be a framework species, since it does not attract seed-dispersing animals but, where it is absent, forest restoration plantings to rehabilitate BB-DF, would be incomplete without including it on the list of tree species planted. Teak may also be planted where it is desirable to re-establish a forest with high future economic value, but try not to create mono-species teak plantations.

Since this species is valuable, many tree nurseries grow it, but selective breeding has begun to "domesticate" the species, so make sure that any seedlings obtained from nurseries are grown from local, *wild* seed sources.

Alternatively, collect seeds from beneath local forest trees that are older than 20 years (not plantations). Air dry the fruits for 2-3 days and remove the thin, inflated calyx. Soak fruits over night; then sun-dry them by day. Repeat this cycle for 1-2 weeks. Sow seeds sparsely in germination trays in full sunlight, making sure that fully germinated seedlings do not shade germinating seeds. Germination starts after 10 days and continues for about 90 days. Total germination per cent usually exceeds 50%. Grow-on seedlings in containers in light shade. Saplings are usually ready for planting within a year after seed collection.



*Teak foliage and fruits (*Tectona grandis *L. f. (Verbenaceae)).*

(*e.g. Geodorum siamense* Rol. *ex* Dow., *Nervilia aragoana* Gaud. and *N. plicata* (Andr.) Schltr. (Orchidaceae)) and aroids *e.g. Amorphophallus macrorhizus* Craib (Araceae), which flower in April, before the leaves appear. After the first rains have fallen in May, more species flower *e.g. Curcuma parviflora* Wall. (Zingiberaceae), *Geodorum recurvum* (Roxb.) Alst., *Habenaria thailandica* Seid. and *Peristylus constrictus* (Lindl.) Lindl. (all Orchidaceae) and the vine *Stemona burkillii* Prain (Stemonaceae). By mid-July, many other herbs have matured, including many fern allies, *e.g. Selaginella ostenfeldii* Hier. (Selaginellaceae) and ferns such as *Anisocampium cumingianum* Presl, *Kuniwatsukia cuspidata* (Bedd.) Pichi-Ser. (both Athyriaceae) and *Dryopteris cochleata* (D. Don) C. Chr. (Dryopteridaceae), with its bimorphic fronds. By August, the ground is covered with a dense and diverse herbaceous vegetation, which dies back and subsequently burns with the onset of the dry season.

What are the special challenges when restoring BB-DF?

The greatest problem with restoring BB-DF are the bamboos. Bamboos are giant grasses and like other grasses, they are highly aggressive competitors. Their dense root systems fully exploit the soil; they cast dense shade and, in the dry season, they smother nearby tree seedlings with a dense layer of leaf litter. Consequently, any trees planted near large bamboo clumps cannot compete and gradually fade away. Therefore, controlling (but not eliminating) the spread of bamboos is essential for successful tree establishment in BB-DF (see Box 2.3). Luckily bamboo canes and bamboo shoots are useful products, so local people usually need no encouragement to harvest them, to give planted trees a higher chance of survival.

Smaller grasses characteristic of BB-DF include *Oryza meyeriana* (Zoll. & Mor.) Baill. var. *granulata* (Watt) Duist. (Gramineae), *Microstegium vagans* (Nees *ex* Steud.) A. Camus and *Panicum notatum* Retz.(both Gramineae). Together with the bamboos, they constitute a serious fire hazard. Consequently, weeding, firebreak construction and an effective fire prevention program are all particularly important when restoring this forest type.

Box 2.3 - Looking at Bamboos

Bamboos are giant 'woody' grasses in the family Gramineae, sub-family Bambusoideae. More than 1,400 species grow mostly in the tropics and sub-tropics, with more than 25 species found in northern Thailand. Some giants grow up to 15 m tall and reach 30 cm in diameter. They are the world's fastest-growing woody plants and are among the most useful.

A bamboo plant consists of a system of underground rhizomes (stems), from which aerial shoots (culms) grow. The culms have annular nodes and hollow internodes. Branching occurs at the nodes, and leaves grow from the branches. The hollow, rigid woody structure of larger bamboos makes them very strong, whilst thinner canes have great flexibility: properties that make bamboo a versatile construction and craft material. The canes are used for all kinds of temporary construction and furniture and are split and woven to make mats and baskets. Young culm buds ("bamboo shoots") are a popular vegetable in oriental cuisine.

Some bamboo species are renowned for their gregarious flowering habits *i.e.* after perhaps decades of vegetative growth, all individuals of a species flower and then their culms die back simultaneously over their entire ranges, producing masses of seeds. Seed predators are unable to eat all the seeds so some survive to grow into the next generation of bamboo plants.

Bamboos are classified into two types: monopodial (or clumping); and sympodial (or scrambling).

Clumping bamboos produce a series of culms close together, in a single clump. These plants tend to produce stronger culms than scrambling bamboos and are, therefore, more widely used for light construction.

In contrast, scrambling bamboos produce very long, rhizomes, which can spread considerable distances underground. Each node of the rhizomes can produce a new shoot, from which a new rhizome system can develop. Whilst this characteristic is sometimes beneficial *e.g.* for controlling soil erosion, it also enables these plants to become highly invasive and to suppress tree establishment and growth.

If forest restoration is threatened by invasive bamboos, the bamboos must be controlled. Cutting back the shoots may be effective, but if it is not followed up rigorously, it actually stimlates spread of the rhizomes. Therefore, a systemic herbicide such as glyphosate (Roundup) can be applied to the cut culm stumps to kill the rhizomes. Bamboos are characteristic of BB-DF, so be careful not to completely eliminate them.

What are the distinguishing features of deciduous dipterocarp-oak forest (DOF)?

Typically, DOF grows in the driest or most degraded areas, from valley bottoms up to 800-900 m, often along ridges with little or no top soil, alternating with BB-DF in moister gullies. It is a secondary forest, in which frequent fires, eroded soils and other disturbing factors prevent the forest from developing into BB-DF and ultimately into teak forest.

To recognize this forest type, look for short trees (rarely exceeding 20 m) forming an open or irregular canopy. A ground layer, dominated by grasses and sedges, is characteristic. Woody climbers are rare and the shrub layer consists mainly of the saplings of the common tree species. Large bamboos are absent.

In DOF, more than 80% of tree species are completely deciduous, shedding their leaves in the dry season and flushing green again, usually before the onset of the rainy season. With around 100 tree species, of which 24 are common or abundant, DOF has a relatively low tree species richness, compared with the other forest types.

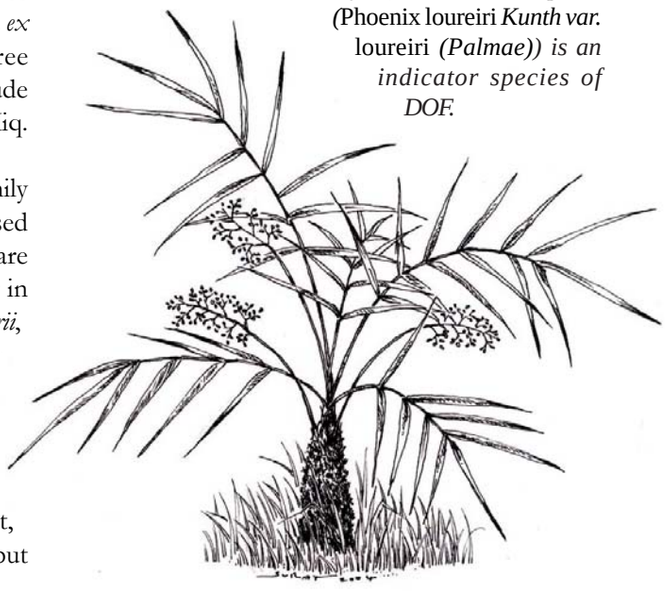
With their huge leaves and massive fruits with wings derived from the calyx, the *Dipterocarpus* species are undoubtedly the most easily recognised and characteristic tree species in this forest type. In many of the most degraded areas, especially along ridge crests, *Dipterocarpus tuberculatus* Roxb. var. *tuberculatus* (Dipterocarpaceae) approaches dominance, but on gentle slopes or in slightly moister areas, this species tends to be replaced by *D. obtusifolius* Teijsm. *ex* Miq. var. *obtusifolius*. Other dominating tree species of the Dipterocarpaceae family include *Shorea obtusa* Wall. *ex* Bl. and *S. siamensis* Miq. var. *siamensis.*

Oaks and chestnuts, members of the family Fagaceae, are the next most easily recognised group of tree species, especially when they are in fruit, although many of them also occur in other forest types. *Quercus kerrii* Craib var. *kerrii*, *Q. aliena* Bl., *Q. brandisiana* Kurz, *Lithocarpus elegans* (Bl.) Hatus. *ex* Soep., *Castanopsis diversifolia* King *ex* Hk. f. and *C. argyrophylla* King *ex* Hk. f. (the last is one of the very few evergreen tree species in DOF) are especially common. Where fires are frequent, oaks and chestnuts may be rare or absent, but if such areas are protected from fire for 30 years or more, they slowly re-establish themselves, provided mature, seed-producing trees survive nearby (Kafle, 1997 and Meng, 1997).

The small palm, *Phoenix loureiri* Kunth var. *loureiri* (Palmae), so-called because it sprouts new leaves after fire from a woody stem, is an easily recognized indicator species of this forest type. Other common characteristic tree species include *Gluta usitata* (Wall.) Hou and *Buchanania lanzan* Spreng. (both Anacardiaceae), *Craibiodendron stellatum* (Pierre) W.W. Sm. (Ericaceae), *Strychnos nuxvomica* L. (Loganiaceae), *Tristaniopsis burmanica* (Griff.) Wils. & Wat. (Myrtaceae) and *Anneslea fragrans* Wall. (Theaceae).

DOF supports only 14 species of woody climbers, of which the deciduous species *Spatholobus parviflorus* (Roxb.) O.K. (Leguminosae, Papilionoideae), *Aganosma marginata* (Roxb.) G. Don (Apocynaceae) and *Celastrus paniculatus* Willd. (Celastraceae) are the most common.

Shrubs (29 species) and treelets (48 species) are abundant. Some common examples are: *Helicteres isora* L. (Sterculiaceae), *Grewia abutilifolia* Vent. *ex* Juss. (Tiliaceae); *Desmodium motorium* (Houtt.) Merr. and *Indigofera cassioides* Rottl. *ex* DC. (both Leguminosae, Papilionoideae); *Gardenia obtusifolia* Roxb. *ex* Kurz and *Pavetta fruticosa* L. (both Rubiaceae), *Strobilanthes apricus* (Hance) T. And. (Acanthaceae), *Premna herbacea* Roxb. (Verbenaceae) and *Breynia fruticosa* (L.) Hk. f., (Euphorbiaceae).



*Re-sprouting from the ashes after fire, the Phoenix palm (*Phoenix loureiri *Kunth var.* loureiri *(Palmae)) is an indicator species of DOF.*

Common vines in burnt areas include *Dunbaria bella* Prain (Leguminosae, Papilionoideae), *Solena heterophylla* Lour. ssp. *heterophylla* (Cucurbitaceae) and *Streptocaulon juventas* (Lour.) Merr. (Asclepiadaceae).

Of the 47 epiphytes, recorded in DOF on Doi Suthep, perhaps the most characteristic is *Dischidia major* (Vahl) Merr. (Asclepiadaceae), due to its extraordinary morphology and its association with ants. This plant grows bladder-like leaves, within which ants nest. Organic debris, brought in by the ants, supplies the plant with soil, moisture and nutrients. Several epiphytic orchid species also grow naturally in DOF, but some have disappeared due to over-collection for their ornamental value. Typical epiphytic orchids include: *Cleisomeria lanata* (Lindl.) Lindl., *Cleisostoma arietinum* (Rchb. f.) Garay, *Cymbidium ensifolium* (L.) Sw., *Dendrobium lindleyi* Steud., *D. porphyrophyllum* Guill., *D. secundum* (Bl.) Lindl., *Eria acervata* Lindl., *E. pannea* Lindl., *Rhynchogyna saccata* Seid. & Garay and *Vanda brunnea* Rchb. f. Two epiphytic ferns are also common in DOF: *Drynaria rigidula* (Sw.) Bedd. and *Platycerium wallichii* Hk. (Polypodiaceae).

The ground layer is dominated by grasses (Gramineae) and sedges (Cyperaceae), which dry out in the hot season, providing fuel for fires. Some of the common grasses include *Apluda mutica* L., *Arundinella setosa* Trin., *Eulalia siamensis* Bor, *Heteropogon contortus* (L.) P. Beauv. *ex* Roem. & Schult. and *Schizachyrium sanguineum* (Retz.) Alst. Sedges include *Carex continua* Cl., *Cyperus cuspidatus* Kunth, *Rhynchospora rubra* (Lour.) Mak. and *Scleria levis* Retz. Growing among the grasses, several ginger species (Zingiberaceae) are common *e.g. Curcuma zedoaria* (Berg.) Rosc., *Globba nuda* K. Lar. and *Kaempferia rotunda* L. Other common ground herbs include *Barleria cristata* L. (Acanthaceae), *Platostoma coloratum* (D. Don) A.J. Platon (Labiatae), *Striga masuria* (B.-H. *ex* Bth.) Bth. (Scrophulariaceae) and *Aeginetia indica* Roxb. (Orobanchaceae); the latter two are parasitic on plant roots. The fern ally, *Selaginella ostenfeldii* Hiern. (Selaginellaceae) and the ferns *Adiantum philippense* L., *A. zollingeri* Mett. *ex* Kuhn and *Cheilanthes tenuifolia* (Burm. f.) Sw. (all Parkeriaceae) are characteristic of the ground flora of DOF.

In burnt areas, at the upper elevational limits of DOF, pines (see Box 2.1) sometimes grow amongst the dipterocarps and oaks. This, rather rare, forest type is termed DOF+PINE.

What are the special challenges when restoring DOF?

Most DOF sites were originally disturbed by logging and have been subsequently degraded by decades of chopping for fire-wood, cattle browsing and frequent burning. The DOF sites that are currently available for restoration, are mostly those with soils too poor to have been completely cleared of trees and cultivated. They often retain some stunted trees or coppicing tree stumps of a few highly resilient (usually wind-dispersed) species. This means that the number of trees planted can be correspondingly reduced (often to as low as 200-300 per rai = 1,250-1,875 per hectare) to compensate for the density of trees or stumps remaining. Restoration usually focusses on enrichment planting, to i) increase the diversity of tree species present; ii) re-introduce fleshy-fruited tree species, attractive to wildlife and iii) improve soil conditions (*e.g.* by planting legumes).

In the lowlands, human population density is highest, so conflicts between forest restoration aims and human needs are intense. A high level of commitment from local communities is vital to cease disturbances that will endanger the planted trees. Education and public relations are, therefore, critical for successful restoration.

Dried grasses and leaf litter provide ideal fuel for fire. Therefore, fire prevention measures are particularly important at DOF sites. Soil conditions are very poor, with highly eroded, lateritic soils, with impeded drainage and low nutrient levels. Digging holes for tree planting in such soils is very hard work, so the labour costs for tree planting can be high. In the dry season, the upper soil layers quickly dry out, whilst in the rainy season, the soil becomes waterlogged due to poor drainage. This suffocates tree roots, killing the planted trees. Applying mulch and using polymer gels, when planting trees, can help reduce immediate post-planting mortality. Watering the trees immediately after planting can also help increase the survival of planted trees. Hire a water tanker if the site is accessible by road. Frequent fertilizer application is mandatory and soil amelioration measures before planting, *e.g.* green manure, should be considered. Weeds grow relatively slowly on DOF sites, so weeding may be needed less frequently than at EGF sites.

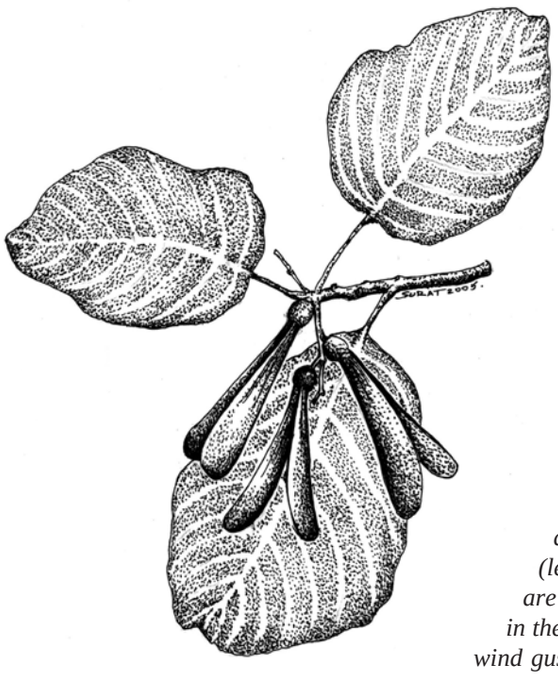
Box 2.4 - Looking at Dipterocarps

The tree family, Dipterocarpaceae, comprises nearly 600 species in 16 genera. Most species are native to South or South-East Asia. Less than 50 grow in tropical Africa and America. Within their South-East Asian stronghold, Dipterocarps dominate several forest types and are known for their diversity and abundance. The taller species feature prominently in international tropical timber markets, as well as meeting domestic timber demands.

Resins, oils and tannins are also valuable products obtained from Dipterocarps. Resin is extracted by hollowing out a bowl-shaped depression in the tree trunk and then scorching the wood above it to stimulate resin secretion. Solidified resins are called "*dammar*", whilst thin oils are called "*gurjun*". Liquid resin, which contains essential oils (oleoresins), is used as an ingredient in traditional medicinal remedies, as a liquid fuel and in the perfume industry. *Gurjun* is used as a substitute for linseed oil in paints and for making varnish. *Gurjun*, from *Dipterocarpus turbinatus*, is also used to make torches, ink and is mixed with *dammar* to caulk boats and to waterproof bamboo. Tannins, from the leaves and bark of *Dipterocarpus tuberculatus* are used to tan leather.

Even in the most severely degraded DOF, dipterocarps are usually strongly represented by re-sprouting tree stumps and remnant trees. Also, since their seeds are wind dispersed, there is usually no need to replant them. Most dipterocarps do not meet the criteria of framework species (Part 5). They grow slowly and they are unattractive to seed-dispersing wildlife, but they are a major component of both DOF and MXF. So, where they have become extirpated, planting them, along with framework species, can acclerate recovery of the original species composition of the climax forest type.

Dipterocarps are difficult to propagate from seed, because they flower unpredictably and their seeds are recalcitrant. Researchers have not yet developed a reliable technique to store viable seeds for longer than a few weeks. Harvesting wildlings is, therefore, often the most practicable way to grow saplings for planting (see Box 6.1). Vegetative propagation is an alternative, but it is relatively expensive and carries the risk of reducing genetic variability within species. Researchers have developed simple cutting techniques for several species, so seek professional advice to find the best method for the particular species you want to grow.



Tapping resin from this relatively young Dipterocarpus costatus *tree in MXF has almost killed it.*

Two dominant Dipterocarpus *species, characteristic of DOF in northern Thailand are notable for their large, broad, thick leaves and large nuts, which remain attached to wings derived from the calyx.* D. tuberculatus *(left) has the largest leaves and fruits. Although the nuts are winged, they are very heavy and do not fly very far except in the strongest gales. They are produced in April-May when wind gust speeds reach maximum velocity during pre-monsoon storms.* D. obtusifolius *has slightly smaller leaves and fruits.*

SECTION 4 - FOREST TYPE AND RESTORATION STRATEGY

How can the original forest type be determined?

Understanding which forest type you are dealing with will help you to decide which tree species to plant and which management strategy to apply after planting them. However, in areas, which have remained deforested for several decades, determining what the original forest type was can be difficult, especially where few original trees survive in the landscape. Under such circumstances, local knowledge becomes invaluable.

Ask elderly local people if they can remember which tree species originally grew on the site to be restored. Ask them to guide you around the sites and look for remnant trees or sprouting tree stumps, which may have survived since deforestation occurred. Collect specimens of leaves and flowers (if available) from the trees and get them identified by a botanist. On a map, identify the nearest area of forest, at the same elevation as the site to be restored. Survey the trees there, collect plant specimens and get them identified.

Once you are sure you have the correct scientific names of the trees you have observed, look them up in botanical text books (your national or local flora or internet resources) to discover which kind of forest type they usually grow in. Probably the best source for matching tree species with their preferred forest types in northern Thailand is Maxwell's published database of plant species and forest habitats of Doi Suthep-Pui National Park. This presents detailed descriptions of forest types that are typical of the northern mountains (up to 1,685 m elevation) and comprehensive species lists for each of them (Maxwell and Elliott, 2001). Similar publications are urgently needed for other regions.

Once a list of indigenous tree species has been compiled for the forest type to be restored, find out if any of them have been identified as framework species (see Part 9). Otherwise follow the steps in Part 5 to identify candidate species for testing as framework species. Find living examples in nearby forest and begin phenology studies and seed collection (Part 6). Grow them in a nursery and test them in field trials (Part 7).

Each forest type has particular conditions, which necessitate adjustments to management activities *e.g.* numbers and species of trees planted, planting methods, frequency of weeding and fertilzer application *etc.* These have been outlined in Sections 3 & 4. Once you have identified the forest type you are restoring, read Part 7 and modify the planting and maintenance strategy according to the forest type.

Are some forest types a higher priority for restoration than others?

Since forest restoration is primarily a tool to conserve biodiversity, forest types with high biodiversity and those which support rare or endangered species should receive the highest priority for restoration. The analysis presented in Box 2.5, shows that evergreen forest has the highest conservation value, both in terms of species richness, rare species and habitat-restricted species and should receive the highest priority for forest restoration. In addition, evergreen forest is a relatively rare forest type, since there is less land at higher elevations than at lower elevations. So, for maximum positive impact on biodiversity, restoration of evergreen forests should be a high priority.

However, other forest types should not be ignored. MXF is also a rare habitat, since it grows in a narrow elevation range and favours moist areas, often near running water. It also supports high biodiversity. Its tendency to grow in narrow corridors, along water courses, makes it particularly vulnerable to infrastructure development at mid-elevations. Dams, housing estates, resorts and golf courses all require water, and roads tend to follow valley bottoms, so MXF is often the first forest type to disappear from a landscape.

Although DOF supports lower biodiversity than the other forest types, it has a high degree of "uniqueness", with 28% of its plant species not able to grow in other forest types. Growing in the lowlands, where most people also live, this forest type is particularly threatened by cattle browsing, fire, charcoal making and firewood collection. So even this relatively species-poor forest type is worth restoring, if it is disappearing from the landscape.

Box 2.5 - Forest Types and Biodiversity

Doi Suthep-Pui in northern Thailand, was designated a national park in 1981, covering 261 sq km. Information about each of the >2,220 vascular plants found in the park (*e.g.* habit, habitat, elevation range *etc.*) were entered into a computer database. Analysis of this database allowed the conservation value of each of the forest types describe in this Part to be determined (Maxwell and Elliott, 2001).

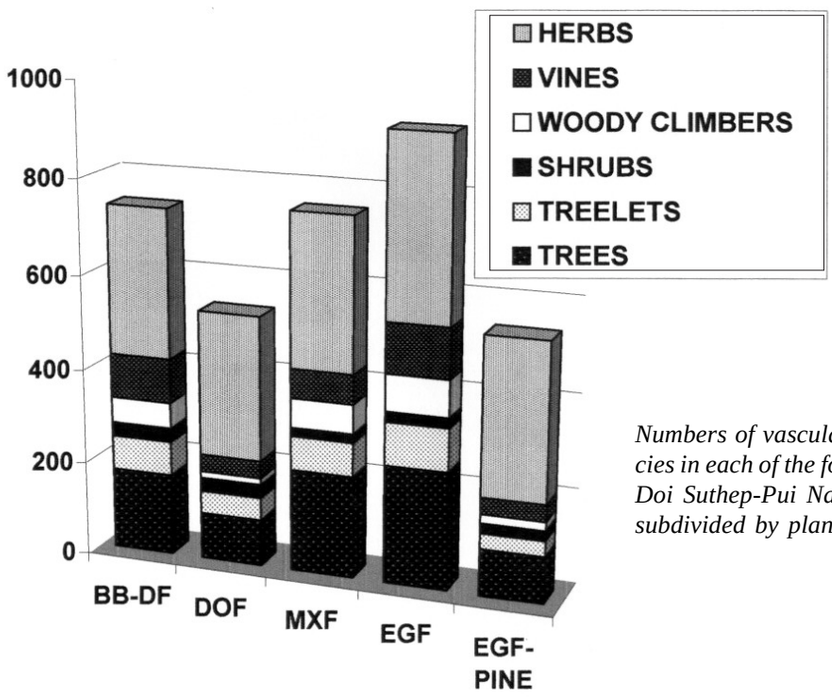
With 930 species, EGF has the highest species richness of vascular plants, compared with all other forest types. BB-DF and MXF are also highly diverse, with similar numbers of plant species (740 and 755, respectively). Habitats that are characteristic of disturbed or degraded areas generally support the fewest plant species, with DOF and EGF-PINE having "only" 533 and 540 species, respectively.

EGF also supports the highest number of vascular plant species that are "habitat-restricted". Therefore, further losses of evergreen forest would result in the extirpation of many plant species, which do not grow in any of the other forest types. In contrast, MXF supports the fewest habitat-restricted species, compared with the other forest types. The data also indicate that DOF is one of the most distinctive forest types, with 28 % of its plant species occurring in none of the other forest types.

EGF also supports far more rare or endangered plant species than any of the other forest types. Restoring EGF would therefore expand the habitat for large numbers of rare or endangered species and could help to save many of them from extinction.

Numbers of habitat-restricted vascular plant species and rare or endangered species in each forest type.

Forest Type	Number of species restricted to each forest type (% of habitat species richness)	Number of rare or endangered species (% of habitat species richness)
EGF	230 (25%)	314 (34%)
EGF-PINE	120 (22%)	141 (26%)
MXF	58 (8%)	147 (19%)
BB-DF	141 (19%)	153 (21%)
DOF	150 (28%)	121 (23%)



Numbers of vascular plant species in each of the forest types of Doi Suthep-Pui National Park, subdivided by plant habit.