Know Your Reference Forest

The reference ecosystem is a central concept of restoration science. It defines the target, at which restoration is aimed. International restoration guidelines define it as “… *the condition of the ecosystem as it would be had it not been degraded, adjusted as necessary to accommodate changed or predicted change in biotic or environmental conditions (e.g., climate change)”* (Gann et al., 2019).

Restoration aims to set ecological succession on a trajectory reference forest levels of i) biomass (and carbon), ii) structural complexity, iii) biodiversity and iv) ecological functioning. Therefore, it is necessary to measure these attributes in reference forest. They should be measured in the reference forest at the start of a restoration project. The information from such surveys is an essential component of any restoration plan.

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| **Attribute** | **Measured by** | **Instructions** |
| Biomass | Circular sample plots – allometric equations | https://www.forru.org/advice/biomass-carbon-accumulation-climate-change |
| *Carbon* |
| Structural Complexity | Profile diagrams | https://www.dropbox.com/s/2bc5emi8bcdl629/Forest%20Structure.pdf?dl=0 |
| Biodiversity |  |  |
| *Trees* | Circular sample plots – rarefraction curves, diversity indices | https://www.forru.org/advice/biodiversity |
| *Ground flora* |
| *Birds* | McKinnon’s list method |
| *Mammals* | Camera traps |

**Forest types**

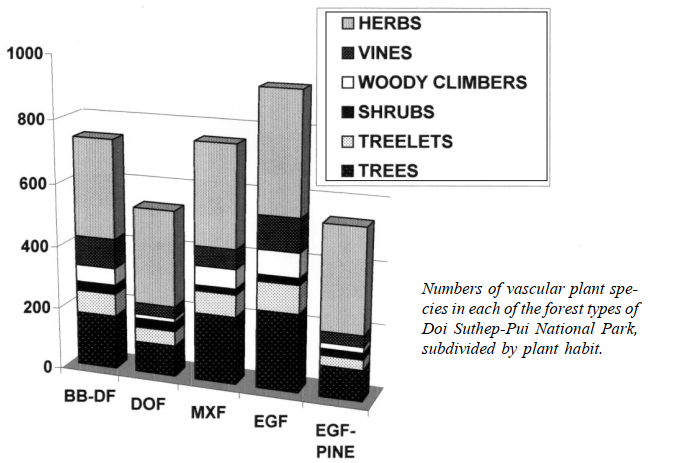
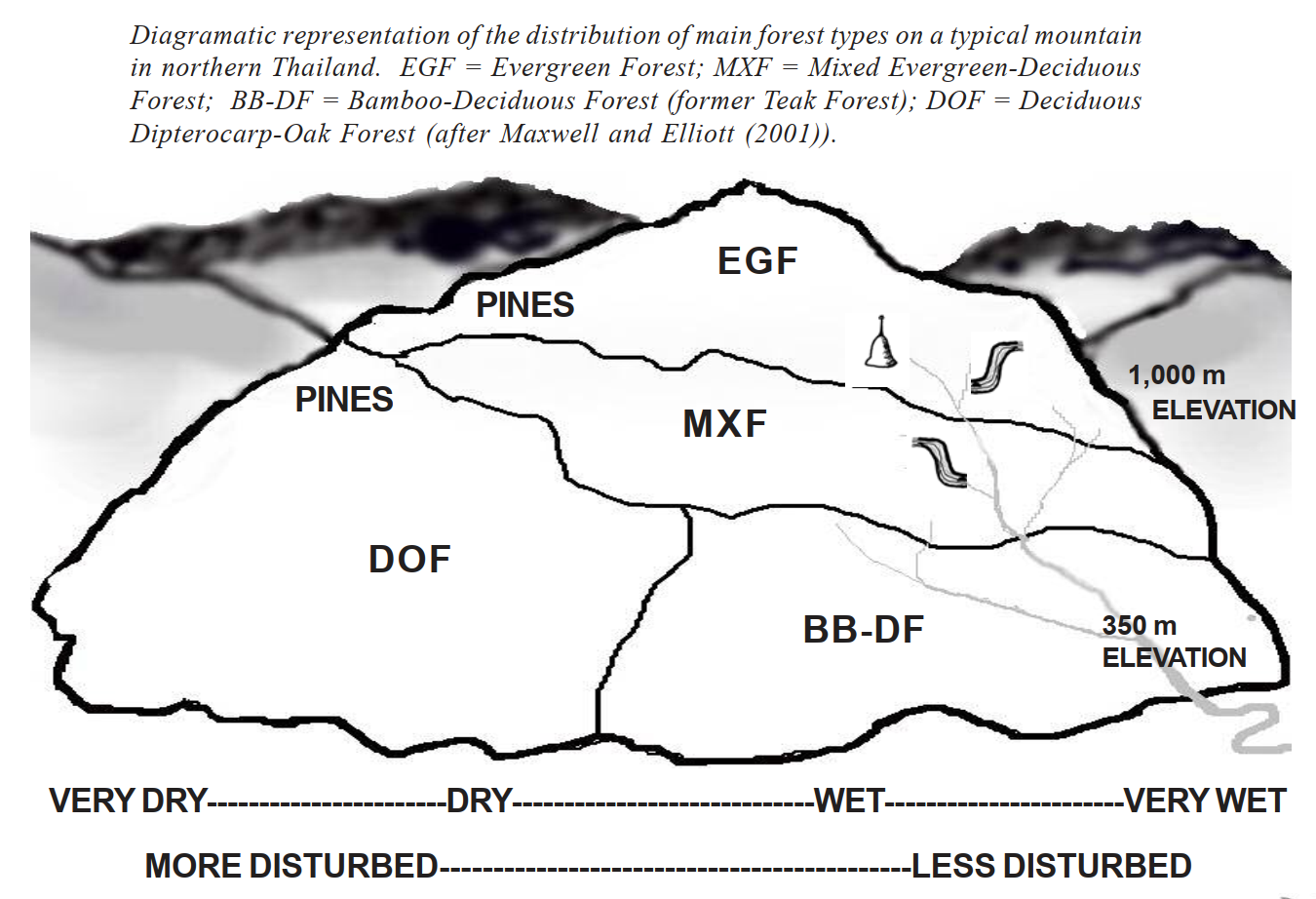
Two broad categories of forest ecosystem dominate northern Thailand and Lao PDR: deciduous forest TYPES (from the lowlands up to about 1,000 m above sea level) and evergreen forest types (above about 1,000 m above sea level).

For full descriptions of forest types see Chapter 3 of Forest Restoration Research Unit (2005):

<https://www.forru.org/library/0000153>

…and Maxwell, J. F. & S. Elliott, 2001

<https://www.forru.org/library/0000027>

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**Distinguishing characteristics of teak forest or bamboo-deciduous forest (BB-DF)**

Most former teak forest have been replaced by bamboo-deciduous forest following logging. Such forest grows on fertile soils from 300 to 900 m above sea level, with tall trees (20-30 m tall) producing a patchy canopy, which becomes sparse in the dry season. Remnant teak trees and an understorey, dominated by bamboos are indicative. A dense shrub layer is 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 mixed herbs and grasses, the latter especially where fires occur. At least 180 tree species occur 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*, *Dalbergia cultrata*, *Pterocarpus* *macrocarpus*, *Lagerstroemia cochinchinensis*, *Chukrasia* *tabularis* and *Afzelia xylocarpa*. Woody climbers (lianas), often quite large, are a notable feature of this forest type (*Millettia*, *Combretum, Congea* spp). Bamboos are abundant, especially in more disturbed areas e.g., *Bambusa* and *Dendrocalamus* species. The ground is mostly bare during the dry season. The first herbs to appear are gingers (e.g., *Globba* and *Kaempferia* species, orchids and aroids (e.g., *Amorphophallus* species) which tend to flower in April before their leaves appear. As the rainy season starts, more species appear and flower e.g., *Curcuma parviflora, Geodorum recurvum, Habenaria thailandica and Peristylus constrictus*. By about July, ferns and their allies begin to proliferate, such that by August, the ground is covered with a diverse herbaceous vegetation, which dies back and later burns with the onset of the following dry season.

**Factors limiting restoration of BB-DF?**

Bamboos are aggressive competitors. Their dense root systems fully exploit the soil and, in the dry season, they smoother nearby tree seedlings with a dense layer of leaf litter. Consequently, trees planted near large bamboo clumps cannot compete and gradually fade away. Therefore, controlling the spread of bamboo is essential for the successful restoration of bamboo-deciduous forest. Luckily bamboo canes and bamboo shoots are useful local products, so local people can usually be encouraged to harvest them and help to give planted trees a better chance to survive. Bamboos and smaller grasses also constitute a serious fire hazard. Weeding, firebreaks and an effective fire prevention programme are therefore particularly important when restoring this forest type.

**Distinguishing characteristics of deciduous dipterocarp-oak forest (DOF)**

DOF grows in very dry or degraded areas, from the lowlands up to about 800-900 m elevation, along dry ridges with little or no top soil, alternating with BB-DF in the moister gullies. 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. 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 “only” around 100 tree species, of which 24 are common or abundant, deciduous dipterocarp-oak forest has a relatively low tree species richness compared with the other forest types.

With their huge leaves and massive winged fruits, the dipterocarps are easily recognised and are characteristic in this forest type (*Dipterocarpus tuberculatus*, *D. obtusifolius* etc.) Other common tree species of the Dipterocarpaceae include *Shorea* and *Hopea* species. Oaks and chestnuts, members of the family Fagaceae, are the next most easily recognised group of tree species, especially when they are in fruit, *Quercus, Lithocarpus* and *Castanopsis* spp*.* Where fires are frequent, oaks and chestnuts may be rare or absent, but if such areas are protected from fire from 30 years or more, they can slowly re-establish themselves, provided mature, seed-producing trees survive nearby. The small, fire-resistant palm *Phoenix* *loureiri*, so-called because it sprouts new leaves after fire from a woody stem, is an easily recognized indicator species of this forest type. Deciduous dipterocarp-oak forest supports only 14 species of woody climbers, but the deciduous species *Spatholobus parviflorus* and *Celastrus paniculatus* are characteristic as is the epiphytic vine *Dischidia major* (Asclepiadaceae), which supports ants’ nests in its specialised bladder-like leaves. The ground layer is dominated by grasses and sedges which dry out in the hot season providing very combustible fuel materials for fires. Amongst the grasses species of the ginger family (Zingiberaceae) are quite common, including *Curcuma*, *Globba* and *Kaempferia* species*.* In burnt areas at the upper elevational limit of this forest type, pine (*Pinus kesiya*) sometimes grows amongst the dipterocarps.

**Factors limiting restoration of 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 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 or using polymer gels, when planting trees, can help reduce immediate post-planting mortality. Watering the trees immediately after planting can also help increase 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.

**Distinguishing characteristics of mixed evergreen-deciduous forest (MXF)**

In a narrow band at mid-elevations (about 800-1,000 m elevation or from 600 m in permanent stream valleys) a transitional zone between evergreen and deciduous forest types occurs. Mixed evergreen-deciduous forest consists of a diverse community of tree species from both evergreen and deciduous forest types, but it also supports many species, which do not occur in any of the other forest types. In general, canopy height varies from 20 to 30 m but emergent trees, exceeding 30 m, are common. Canopy cover is usually complete, though less dense than in evergreen forest. Woody climbers are a major feature. 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 rarely dominate the ground layer, except where fire has occurred.

More than 200 tree species grow in MXF, of which only about 43 % are deciduous. There are strong similarities 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* and *D. turbinatus*, but these trees appear very different to the large-leaved dipterocarps of DOF. With their massive grey trunks, small leaves and dense, broad crowns they resemble giant sticks of broccoli.

Other tree species common in this habitat include *Duabanga* *grandiflora*, *Irvingia* *malayana*, *Mangifera caloneura* and *Eugenia albiflora*. Common deciduous canopy trees include *Lagerstroemia cochinchinensis* and *L. tomentosa*, *Spondias* *pinnata*, *Terminalia mucronata* and *Engelhardia serrata*. More than 60 species of woody climbers have been recorded in MXF, including *Combretum, Ventilago,* and *Tetrastigma* species. Epiphytes are also diverse, including fig trees, orchids, ferns, Gesneriaceae and Loranthaceae. The ground flora is also diverse and includes at least 278 herb species as well as seedlings and saplings of the trees and shrubs.

**Factors limiting restoration of 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.

**Distinguishing characteristics of evergreen forest (EGF)**

Evergreen forest is quite distinct from the deciduous forest type. The main canopy is higher and denser, often exceeding 30 m in height. Emergent trees sometimes occur and, beneath the main canopy, there is usually a lower story, comprised of smaller trees, treelets and shrubs. Woody climbers are common. The high abundance of epiphytes is an obvious feature of evergreen forest. In addition to vascular plants, bryophytes and lichens often encrust tree trunks and branches. Tall bamboos are scarce. The ground flora is often dense and consists of tree seedlings and herbs, including several with a saprophytic or parasitic way of life. Grasses occur only in disturbed areas. Fires are less common in evergreen than in deciduous forests, but evergreen forest is less resilient of fire damage than deciduous forest. In particular, shrubs and the ground flora take many years to recover after burning.

Evergreen forest supports more tree species than any other forest type, 250 have been recorded. Although no species or genus dominates, several families tend to be better represented there than in the deciduous forest types e.g., Lauraceae, Fagaceae, Theaceae, Moraceae, Magnoliaceae, etc. The understorey is denser than that of forests at lower elevations and is especially diverse in stream valleys. A high species richness of woody climbers (78 species) is a notable feature of evergreen forest from several families: Rutaceae, Moraceae, Combretaceae and Rubiaceae. Also common are several species of *Tetrastigma* (e.g., *T. laoticum* and *T. obovatum* (Vitaceae)) and *Mucuna macrocarpa* (Leguminosae, Papilionoideae), as well as rattans (Palmae) e.g., *Calamus kerrianus* and *Plectocomia kerrana*.

Epiphytes abound in evergreen forest. The 82 species recorded there include trees, shrubs, vines and herbs, including several species of "strangling" fig tree, which begin life as epiphytes e.g., *Ficus superba*.

The herbaceous ground flora (>300 species) is very diverse. Two of the most characteristic ferns of this forest type are *Brainea insignis* and *Dicranopteris linearis*, in open, fire-damaged places; whilst *Arachnoides henryi* and *Tectaria herpetocaulos*, *Thelypteris subelata* and *Diplazium* *dilatatum* grow in shaded, more pristine areas. Gingers and aroids are frequent. Parasitic or saprophytic members of the ground flora include several *Balanophora* species: *Sapria himalayana* and several rare orchids e.g., *Epipogium roseum.*

**Factors limiting restoration of EGF**

Because EGF supports more tree species than the other forest types, tree planting should aim to include as many species as possible, within practical limits, to kickstart 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* etc.). 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.

**Reading**

Forest Restoration Research Unit, 2005. How to Plant a Forest: The Principles and Practice of Restoring Tropical Forests. Compiled by Elliott, S., D. Blakesley, J.F. Maxwell, S,, Doust & S. Suwannaratana. Biology Department, Science Faculty, Chiang Mai University, Thailand, 200 pp.  Chapter 3. <https://www.forru.org/library/0000152>

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Maxwell, J. F. & S. Elliott, 2001. Vegetation and Vascular Flora of Doi Sutep–Pui National Park, Chiang Mai Province, Thailand. Thai Studies in Biodiversity 5. Biodiversity Research & Training Programme, Bangkok. 205 pp. <https://www.forru.org/library/0000027>

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