

## TOWARDS A COMMON UNDERSTANDING OF THE LOWLAND DECIDUOUS FORESTS OF TROPICAL ASIA: SOUTH ASIA AND INDO-BURMA COMPARED

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### ABSTRACT

The classification of the lowland forests of South Asia, originally presented by H. G. Champion, is now well accepted there; but its application to the east, in Indo-Burma, has been inconsistent and fraught with controversy. The reasons for that are discussed here, and reconciliation proposed. I conclude, first, that the composition of the woody flora should be the definitive criterion for classification of the deciduous forests of tropical Asia, and specifically the presence of characteristic species. Second, I conclude that Champion's Dry Deciduous forest is currently confined in Indo-Burma to the upper Irrawaddy plain, although the presence in Indo-Burma of a more widespread characteristic species, *Cochlospermum religiosum*, implies that Dry Deciduous forests, now degraded or converted, once also existed on the northern plains and adjacent foothills from the Chao Phraya to Mekong valleys.

Keywords: deciduous forests, tropical Asia, classification harmonisation

### BACKGROUND

The classification of the forests of South Asia and Burma (Myanmar) presented by H. G. CHAMPION (1936), later further elaborated for India with S. K. Seth (CHAMPION & SETH, 1968), has proven its worth in South Asia by its continued acceptance. It was soon also applied by foresters in Thailand, but there with continuing controversy and inconsistent use by them, and by ecologists (OGAWA *ET AL.*, 1961; SANTISUK, 1988; MAXWELL, 2004; MCSHEA *ET AL.*, 2011), while alternative classifications were adopted in the Indo-Chinese nations that are still in use (e.g. VIDAL, 1956, 1958).

The reason for this continuing controversy lies in major differences between the overall geomorphology and consequent dominant landscapes of the two regions. Those parts of South Asia formerly or still covered by deciduous forests are ancient stable surfaces over metamorphosed rocks of the Indian tectonic plate or its extensive associated basalt trap, lacking rugged sharp topography. Indo-Burma is vastly heterogeneous by contrast: mostly sedimentary (turbidite) but with ranges of granite and widespread karst limestone, the whole steeply folded by pressure from the continuing onward transit of the South Asian plate, inexorably nudging it north-eastwards. The sharp turbidite ranges bear clay loam soils over their shale slopes, whereas their ridges are much supported by sandstone, with shallower freely draining soils; while granite and metamorphosed rocks yielding siliceous soils are also widespread.

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Received 30 July 2015; accepted 8 March 2016.

In particular, in South Asia the regions of siliceous soils occupy a vast and continuous area over the ancient granite and its metamorphosed derivatives, and an equally continuous albeit narrow Himalayan foothill band, the terai; whereas in Indo-Burma siliceous soils dominate at best relatively small areas over the sandstones of the Khorat Plateau and Cardamoms, and core granite exposures, otherwise being confined to ridge and dip-slope fragments in a sea of loams over the prevailing turbidite. Distinctive drought-prone soils do occur though over the archipelagoes of karst summits. Besides, whereas much of South Asia experiences at least six and one half dry months annually, such a dry climate is confined in Indo-Burma to the northern Irrawaddy Plain, and to the plains and foothills of north-east Thailand and adjacent Laos. Further complicating comparison, the frontier ranges of India and Burma, clothed in seasonal evergreen forest, act as a major plant geographic barrier to the migration of deciduous forest elements, recognized by me (ASHTON, 2014) as Chatterjee's Partition. The deciduous tree flora is markedly richer to the east, with many species unknown in South Asia, although a few occur in semi-evergreen forest in the north-east (Table 1).

Table 1. Range of species in two large genera of deciduous forests in the wet seasonal tropics of Asia. Abbreviations: DDif = deciduous dipterocarp forest, E = eastern, N = northern, NE = north-eastern, NW = north-western, S = southern, SE = south-eastern.

Name	India	Indo-Burma
<b><i>Dalbergia</i></b>		
<i>sissoo</i>	NE	-
<i>latifolia</i>	S, N	-
<i>rimosa</i>	NE	NW Burma
<i>ovata</i>	-	Wide
<i>cultrata</i>	-	Wide
<i>lanceolaria</i>	Wide	Wide
<i>assamica</i>	NE	North
<i>kurzii</i>	-	DDiF, wide
<i>cana</i>	-	Wide
<i>sericea</i>	NE	-
<i>oliveri</i>	-	Wide
<i>frazieri</i>	-	NW Burma
<i>wattii</i>	Manipur	-
<i>reniformis</i>	NE	Burma
<i>burmanica</i>	-	Burma
<i>collettii</i>	-	Burma
<i>henryana</i>	-	NW Burma
<i>kingiana</i>	-	NW Burma
<i>lacei</i>	-	Burma, wide
<i>obtusifolia</i>	-	Burma, wide
<i>peguensis</i>	-	Wide
<i>pinnata</i>	-	Burma, wide
<i>prainii</i>	-	Burma, wide

Table 1 (continued).

<b>Name</b>	<b>India</b>	<b>Indo-Burma</b>
<i>cochinchinensis</i>	-	SE
<i>darlacensis</i>	-	SE
<i>malabarica</i>	Peninsular India	N Thailand
<i>parviflora</i>	-	Peninsular
<i>junghuhnii</i>	-	Peninsular
<i>suthepensis</i>	-	N Thailand
<b><i>Lagerstroemia</i></b>		
<i>indica</i>	Wide, Japan	Wide
<i>speciosa</i>	Wide	Wide
<i>lanceolata</i>	Peninsular India	-
<i>thomsonii</i>	Peninsular India	-
<i>rottleri</i>	Peninsular India	-
<i>parviflora</i>	Peninsular India	N Burma, Andamans
<i>calyculata</i>	-	Wide
<i>cochinchinensis</i>	-	E
<i>crispa</i>	-	Wide
<i>duperreana</i>	-	Wide
<i>huomotensis</i>	-	Thailand
<i>langkawiensis</i>	-	Thailand
<i>loudonii</i>	-	E
<i>macrocarpa</i>	-	Wide
<i>noei</i>	-	E
<i>ovalifolia</i>	-	E, Java
<i>spireana</i>	-	Laos, Thailand
<i>subangulata</i>	-	Thailand
<i>tomentosa</i>	-	Wide
<i>venusta</i>	-	E
<i>villosa</i>	-	Wide, Sunda

### THE PRINCIPLES BEHIND CHAMPION'S CLASSIFICATION

Champion's classification has been generally accepted because it is based on field reality: the physiognomy and structure, and associated overall species composition actually prevailing in individual studied forests; with their climatic and geologic-edaphic conditions. To quote:

"A classification of forest types is put forward based on four temperature zones, tropical, subtropical, temperate and alpine, each subdivided on available moisture as reflected by the relative importance of evergreen, deciduous and thorny trees."

Such a classification and its associated forest type nomenclature does, though, present a difficulty already recognized by ecologists at that time, that it cannot be valid to classify

or name forest types according to some physical environmental factor on which they are assumed to be dependent, but hardly proven, on the basis of correlation alone. A classification of vegetation must stand on the basis of its own characteristics alone, as also its nomenclature.

CHAMPION (1936) addressed available moisture as a factor in his introduction as follows:

“Total annual rainfall may be an important factor in determining the nature of vegetation, but its seasonal distribution exists as at least an equally far-reaching influence.”

“The most important aspect of soil in the present connection is the efficiency with which it acts as intermediary in retaining and transferring the rainfall or subsoil water to tree growth”

“... moisture conditions during the growing season are evidently the most important item in determining the type of vegetation which can exist – the climatic climax in fact; but neither rainfall alone nor even atmospheric humidity indicates the availability of the moisture for growth, many other factors among which the soil is predominant coming into play.”

But CHAMPION & SETH (1968) were explicit:

“As an edaphic climax, it [i.e. Dry Deciduous Forest] is met with in areas of varying extent through much of the moist deciduous type affecting such sites as south facing hill sides, flat hill tops, eroded ground and high intensively drained gravel terraces.”

The criteria cited by Champion to distinguish his major classes of lowland vegetation, and their environmental correlates, are summarized in Table 2. His definition of both individual forest types and the higher categories of his classification are loosely grounded in their floristics, of shrub and herb as well as tree species. However, no species are earmarked as diagnostic, and the user needs to infer which are by using the lists in combination with personal field experience. It is clear that the main reason for this lack of diagnostic species is the continuous ecotonal nature of variation among continental Asian deciduous forests, substantially enhanced by human influences. But might it be possible to identify characteristic species for the higher categories?

Champion's forest types presuppose primary or near-primary status, a condition which hardly survives, even in sanctuaries. Champion, especially with Seth later, considered secondary seres, but the subject was greatly elaborated by the team at the French Institute, Pondicherry (GAUSSEN, 1959, 1978; LEGRIS, 1963) and others. Increase in fire frequency, and grazing and browsing by domestic cattle, first retards the primary forest type to late succession, then reduces its structure and physiognomy towards the next “drier” category. Evergreen species become increasingly eliminated, canopy stature is reduced and becomes more diffuse, stand density declines, and the woody or tall herbaceous field layer is replaced by grass. Overall, the woody flora especially is impoverished. Human influence therefore greatly complicates the application of a consistent forest classification. Notably though, it appears that no species characteristic of “drier” forest types have been recorded to invade degraded succession of “moister” types.

## REALITY ON THE GROUND

Champion's two major classes of forest vegetation, lowland and montane, respectively correlated with temperature and moisture gradients, are based on axes in which stature and physiognomy (deciduousness) are also combined with climate: first mean annual temperature, then mean annual rainfall and its seasonality (climatic dryness); and this is reflected in the

Table 2. Ecological characteristics of primary lowland deciduous and evergreen forest formations of India and Burma, as defined by CHAMPION (1936).

Forest types along dryness continuum	(Dry) Short deciduous forest	(Moist) Tall deciduous forest	Semi-evergreen forest	Seasonal (wet) evergreen forest
<b>Climate</b>	6.6–8.5 dry months	5.0–6.5 dry months	5.0–6.5 dry months	2.0–4.9 dry months
<b>Phenology</b>	All woody plants deciduous	Canopy overwhelmingly deciduous, subcanopy partly evergreen	Canopy deciduous and evergreen mixed, subcanopy evergreen except in succession	Canopy and subcanopy overwhelmingly evergreen
<b>Pioneers</b>	No pioneer tree species	Pioneer tree species usually absent	Pioneer tree species few but some common	Pioneer species many, abundant
<b>Stature</b>	Canopy trees <20 m, short, even, without buttresses	Canopy trees >20m, even to heterogeneous but lacking emergents, some buttressed	Canopy trees >20 m, even to heterogeneous, often with scattered emergents; many buttressed	Canopy 30 m (–45m), heterogeneous, usually with many emergents, most buttressed, supra-annual regeneration
<b>Regeneration</b>	Coppicing dominant; seed dormancy (sal excepted)	Supra-annual regeneration: deciduous species mostly with seed dormancy, evergreen often without	Supra-annual regeneration, most lacking dormancy pioneers and some deciduous species excepted	Few species with seed dormancy, pioneers excepted
<b>Field layer</b>	Field layer predominantly grassy, no palm; <i>Dendrocalamus strictus</i> (local)	Bamboo ( <i>Dendrocalamus strictus</i> on siliceous soils), Zingiberaceae; grassy on dry sites, frequent burning	Field layer subordinate to woody regeneration, shrubs	Field layer subordinate to woody regeneration, shrubs few
<b>Prevalent taxa</b>	<i>Acacia</i> , <i>Anogeissus latifolia</i> , <i>Chloroxylon</i> , <i>Cochlospermum</i>	<i>Terminalia</i> , <i>Lagerstroemia</i> , <i>Syzygium</i>	<i>Holigarna</i> , <i>Lamarckia</i> , <i>Tetrameles</i>	Dipterocarps, <i>Terminalia</i> , <i>Lagerstroemia</i> , <i>Syzygium</i> , <i>Lamarckia</i> , <i>Tetrameles</i>
<b>Fire</b>	Crown fires frequent	Ground fires predominant, formerly 1/10 years	Crown fires absent, ground fires formerly rare	Fire resistant
<b>Browsing</b>	Browsing ubiquitous, seasonal	Browsing variable, now more frequent /continuous	Browsing present, patchy	Browsing sparse where top predators present

forest nomenclature (Table 2, for lowland forests). I infer that this combination of biological and climatic criteria is the primary cause of the difficulties posed when trying to apply Champion's classification to Indo-Burmese forests, for two reasons.

First, forests on clay loam soils tend to have less evergreen subcanopies than those on siliceous soils. Champion distinguished between Moist Deciduous forests which are tall, and with partially evergreen subcanopy, from Dry Deciduous forests which are short and entirely deciduous. Often though, particularly where the subcanopy is dominated by a gregarious bamboo which, following synchronous flowering and fruiting, dies and becomes the tinder for extensive hot fire, such "moist deciduous forests" may be wholly deciduous.

Second, Champion applied the term "dry" primarily to climatic dryness, but also discussed edaphic dryness, albeit not citing forest examples in his classification. Whereas, in South Asia, application of the classification to major divisions of forest types has always been climatic and therefore regional in scale, in Indo-Burma its current application it is both regional and, particularly, topographic and edaphic, therefore at local landscape scale. There, landscapes are widespread in which semi-evergreen forest forms a riparian fringe behind which is an ecotone to semi-evergreen forest on lower slopes, "moist deciduous forest" above, and putative "dry deciduous forest" on ridges. Canopies may reach 40 m on lower slopes, while others at most 10 m tall may clothe siliceous dip slopes, or those sheltered from the south-west monsoon and ridges above; all within a climate which, in India, would support semi-evergreen forest. Are these Indo-Burmese forest types truly analogous to their South Asian counterparts?

Two higher categories of deciduous forests were recognized by Champion, "moist" and "dry". They are distinguished by physiognomic, dynamic and structural characteristics, and major floristic differences as a consequence. Each is provided with a table citing rainfall stations for specific forests, in which the range of the length of the dry season is distinct and quite narrow (Table 2). No Dry Deciduous forests are cited with Moist Deciduous forest rainfall.

Within the "moist" class, the distinction between Moist Deciduous and Semi-evergreen forests is essentially dynamic over most of the range of the two types which, in this case, overlap within the same rainfall seasonality regime. The distinction is mediated by the frequency of catastrophe, either of fire as can be seen at Mudumalai Wildlife Sanctuary, Tamil Nadu or, especially in Indo-Burma and the Andamans, cyclonic storms. The two forest formations therefore share the same flora except towards their climatic extremes. Moist Deciduous forest is distinguished by the widespread subcanopy dominance of various single species of bamboo.

Champion again, in respect of his Moist Deciduous forest:

"The soil cover should also consist mainly of more or less evergreen shrubs with little grass, but the fires result in the spread of grass which is often heavy and continuous especially where the canopy is open. The absence of small trees and saplings is often marked and is also ascribable to repeated burning and grazing."

Of his Northern Tropical Moist Deciduous forest, the term he uses for sal (*Shorea robusta*, a deciduous dipterocarp confined to India) dominated "moist" forest, he states "...broken up by more pronouncedly deciduous forests which usually appear to owe their presence to soil conditions unfavourable to the regeneration of sal"; but without discussion, he does not classify these as comprising outliers of Dry Deciduous forest. Similarly MOONEY (1938), in his classical study of the forests of Singbhum, Odisha, recognises the presence of both Moist and Dry Deciduous forests there, but correlated with differences of rainfall, not substrate or topography:

“It is the aspect and lack of moisture that have the chief influence of its [Dry Deciduous forest] distribution, rather than the geological formation or soil per se”.

Mooney also recognizes a high level [“moist”] sal: “This community covers a large area in all divisions and is especially typical of the sharp shale ridges...”. Among species present, he cites the evergreen *Syzygium cumini* (as its synonym *Eugenia caryophyllifolia*). Other evergreens, such as *Wendlandia tinctoria*, may occur on valley slopes at their altitude, which may reach 1000 m.

Champion otherwise distinguishes Dry from Moist Deciduous forest by the dominance in Dry Deciduous forest of grass in the field layer, except where fire is infrequent when deciduous shrubs, or *Lantana*, may become abundant.

Again, Champion in 1936:

“It is well established that whereas with favourable moisture conditions, the rock and soil may not greatly influence the nature of the vegetation, they become increasingly important as the rainfall drops off until abrupt changes may occur with a change of geological formations (STAMP, 1924: 17)”

This last statement is now tempered by the realisation, on the one hand, that one third or more of the tree flora changes between loam and sandy soils in the perhumid Far East, whereas only a few other species besides the dominant teak and sal consistently do so in the Dry Deciduous forests of South Asia (ASHTON, 2014). CHAMPION (1936) cites the absence of palms or bamboos as a characteristic of dry deciduous forest, although the presence of the bamboo *Dendrocalamus strictus* is cited in many of the forests listed as examples. *Dendrocalamus strictus* is of particular interest, because he also much cited it in examples of sal forests, notably Northern Tropical Moist Deciduous Forests, that is South Asian forests overlying siliceous substrates.

## INDO-BURMESE FORESTS

Champion also distinguished, as a grassy subtype of moist deciduous forest, Chittagong Moist Deciduous Forest, “a specialised xerophytic type on steeper cliffy sections”, on the northern ranges of the Burmese Arakan (now Rakine) Yoma, over sedimentary rocks whose soils rapidly dry during the quite short 4 month dry season. Forest stature is not quoted.

Champion again:

“In Burma it [Dry Deciduous Forest] is characteristically developed only in the central drier tract extending into regions of higher rainfall only as an edaphic climax.”

From these statements I infer that Champion, unlike the dynamic distinction between his Semi-evergreen and Moist Deciduous Forests, originally regarded stands in “moist” forested landscapes with some of the attributes of his Dry Deciduous Forest, notably grassy field layer, as being a specialized xerophytic type of Moist Deciduous Forest. This is important, because the Indo-Burmese landscape widely differs from the Peninsular Indian in that shallow, drought prone soils exist on ridges and spurs in close mosaic with deeper loam soils, some of which are calcareous. The forest floristic communities on these soils appear to be those of adjacent deeper soils, therefore “Moist” Deciduous forest, and may often lack a deciduous dipterocarp component. It is possible that the frequent presence of a grassy field layer has resulted from

centuries of cattle grazing. On what criteria did Champion reach his 'moist' categorization? I infer that it must primarily be floristic.

Indo-Burma differs from South Asia in the presence of two *Shorea*, *S. siamensis* and *S. obtusa*, and three *Dipterocarpus*, *D. intricatus*, *D. obtusifolius*, and *D. tuberculatus*, canopy dipterocarps which form an otherwise floristically variable forest type characteristic of edaphically dry sites, mostly with sandy but sometimes freely draining sandy loam soils (BUNYAVEJCHEWIN, 1983a, b). It shares the Burmese name Indaing, while it is termed Deciduous Dipterocarp Forest in Thailand. Champion recognized Indaing as "a subsidiary edaphic type of dry tropical forest. He recognized three types, differing in stature, and in habitat. All share *Dendrocalamus strictus*; the palm *Phoenix acaulis*, and the endemics *Cycas siamensis*, *Strychnos nux-blanda* and *Gardenia erythroclada* are also cited.

But it is clear that his knowledge of Deciduous Dipterocarp forest was limited to drier climates in Burma. The deciduous dipterocarps may be considered analogous to sal; but whereas sal occurs in climates with from 5–9 dry months, unknown to Champion *S. siamensis* and *D. obtusifolius* occur in NW Peninsular Malaysia with only two dry months, on coastal limestone karst and sandy soils respectively. Further, whereas sal forests extend over vast tracts of undulating terrain and rolling hills bearing siliceous soils, different soils and topography are associated with different combinations of the Indo-Burmese species (ASHTON, 2014: Figs 3–22, 23). The species differ in their deciduousness, from *D. obtusifolius*, of freely draining sandy soils, which is barely fully deciduous therefore comparable to sal on moist sites, to *S. siamensis* which may be deciduous for five months on a wide range of sites but especially calcareous soils.

These forests, other than sharing one or more of these dipterocarps, further vary in several respects: from entirely deciduous to semi-evergreen, from c.10–40 m in stature, and from crooked boled and open canopied to straight boled and closed canopied. All can share the same landscape and climate, but not the same substrate and soils. Short statured Deciduous Dipterocarp forest is generally open-canopied, frequently with the lowland tropical pine *P. merkusii* present, and with a grassy field layer, thus resembling Dry Deciduous forest in structure. But it commonly has characteristic evergreen species in the understorey, including *Craibiodendron stellatum*, *Ternstroemia gymnanthera*, *Tristaniopsis merguensis* and *Vaccinium sprengelii*.

Although the presence of a distinct flora diagnostic to the type confirms that it is of ancient, pre-hominoid origin, many, perhaps most stands appear to represent a sere in the forest type that dominates the landscape in which they are set, be it "dry", "moist", semi-evergreen or evergreen. In this, the type cuts across the main axis of Champion's classification. Consistent exceptions are in the northern Irrawaddy plain, where the dry season exceeds 6.5 months, and on karst limestone in moist climates. Wherever stands of Deciduous Dipterocarp Forest abut other forest types, species characteristic of those types invade. At the moist extreme, juvenile or mature individuals or small clumps of deciduous dipterocarps, particularly *Dipterocarpus*, occur imbedded, even in semi-evergreen forest. For instance, within the Royal Thai Forest Department's forest dynamics plot in Huai Kha Khaeng UNESCO World Heritage forest, NW Thailand, there is a single *S. siamensis* and three small groups of *D. obtusifolius* of varying size (BUNYAVEJCHEWIN ET AL., 2009: Figs. 46, 49); while in the Mae Ping National Park forest, NW Thailand, and elsewhere in Burma, –35 m tall closed forest, patchily dominated by tall straight *D. tuberculatus* lacking any regeneration, occurs. All these species readily coppice. I infer that these dipterocarps are light demanders, as all require open sunny conditions on

the ground for successful regeneration, especially from seed. As with moist deciduous forest, it appears that Deciduous Dipterocarp forest of all kinds is replaced, in Moist Deciduous forest rainfall regimes, by adjacent forest types in the absence of fire, and fire is essential for providing conditions for Deciduous Dipterocarp forest establishment. And as with sal, their outer bark is thick and deeply fissured between the persistent flakes, which effectively protects trunks against hot fires. Nevertheless it seems unlikely that fire is always a prerequisite for regeneration from seed, especially on the karst limestone of wetter climates in which they occur.

In the dry zone of the northern Irrawaddy Plain, where there are 6.5–9 dry months, Champion did recognise Dry Teak Forest around its margins, a Dry Mixed Deciduous Forest and two floristically distinct Dry Deciduous Forests: *Diospyros* or Té Forest on dry sandy soil with the local endemics *Diospyros burmannica* and *Tectona hamiltoniana*, also the widely Indo-Burmese endemic *Shorea siamensis*; and Than-Dahat Forest on stiff clays, in which *T. hamiltoniana* is associated with the local endemic *Terminalia oliveri*. The forest types defined by this local endemic tree flora are unknown elsewhere.

#### TOWARDS AN OPTIMAL CLASSIFICATION OF THE DECIDUOUS FORESTS OF TROPICAL ASIA

Of the several criteria by which Champion classified the tropical deciduous forests of continental Asia, which can be consistently applied in Indo-Burma? A vegetation classification must both be consistent, and reflect as much about the nature of the vegetation as is reliably known.

Deciduousness as a criterion is limited by two problems. Increasing fire frequency eventually eliminates any original evergreen component. Should a forest be classified according to its present, or supposed original condition? Classification according to present condition merely anchors the type nomenclature at the stage of succession observed, which will surely alter over time. But classification based on the supposed original status in the absence of surviving evidence, notably evidence of any nearby dynamic migration front of evergreen elements into a currently deciduous stand, can slip into circular reasoning: through dependence on assumptions that other criteria, and especially physical factors such as rainfall seasonality, are consistently correlated.

Use of deciduousness is also constrained by the greater evergreenness of the woody flora on siliceous soils. The shorter leaflessness of sal compared to teak is well known. Evergreen elements are also better represented on siliceous soils in Deciduous Dipterocarp forest, whereas they may be absent in “moist” mixed deciduous forests on shallow loams.

Stature declines with increasing water stress, be it climatic or edaphic. It also eventually decreases with increasing fire frequency, and browsing intensity, in effect holding succession to an earlier sere. Use of stature as the criterion therefore results in a classification too generalised, and too unstable over time, to inform either the history of a forest, or its physical environment, or therefore its ecological and productive potential.

The field layer may remain more rich in shrubs and tree regeneration by seed on edaphically moist than on edaphically dry habitats, but is replaced by grass as either fires, or particularly browsing and grazing intensity by domestic cattle, increases. It therefore suffers the same disadvantages as stature as a criterion.

Floristic composition of the canopy tree flora, and specifically the presence of species characteristic of a forest type, seem to remain as the sole consistent and informative indicators of both forest formation and type, along with the germination characteristics. The woody flora both loses taxa along the continuum from “moist” to “dry” forest types, and gains a few. It is noteworthy that the majority of gains in Dry Deciduous forest flora in South Asia are unknown in Indo-Burma (Table 3). The Dry Deciduous woodlands of the upper Irrawaddy plain include a rich endemic flora, but significantly this is unknown elsewhere in Indo-Burma, though it has been claimed that *Tectona hamiltoniana* is synonymous with *Tectona philippinensis* of dry Luzon karst! In Indo-Burma, Deciduous Dipterocarp forests, like sal forests, present a noteworthy case because their canopy dipterocarps, all lacking more than brief seed dormancy, extend into Dry Deciduous forest and its associated climate, whereas the rest of the flora is restricted to species with dormant seed.

### A NEW NOMENCLATURE FOR ASIAN DECIDUOUS FORESTS

It may be argued that any forest classification, to be useful, must nowadays be interpretable by remote sensing. This implies that closed canopy types as those here considered must differ in canopy structure, or their canopy include diagnostic species recognized by a distinct crown architecture or physiognomy. In the case of tropical Asian deciduous forests, use of canopy structure, and stand stature, would currently result in a classification of types differing through anthropogenic influences, therefore seral types differing in age and degree of degradation. These types are essentially dynamic and temporary: They provide neither a reliable prediction of future change, nor of the potential of their sites for ultimate biomass or productivity. Such a classification would therefore result in forest types not or inconsistently correlated with soils, therefore substrate and topography, but rather with history.

The only attribute of forests which consistently reflect those characteristics of soils water economy and nutrient concentrations is their species composition. It has to be recognized that species may suffer extinction under severe degradation, but recognition of an association of several species, any of which alone can be accepted as diagnostic, minimises that risk. Besides, a forest so degraded that all its diagnostic species have been lost has limited scope for recovery. In many cases, even in species rich tropical forests, a diagnostic species can be found whose crown characteristics can be recognized in the high definition satellite images now available, provided taken at the phenologically appropriate season.

I have previously accepted Champion's classification, but suggested that “short” and “tall” be exchanged for “dry” and “moist”, in order to exclude any presumed causal relationship between forest type and climate or soil (ASHTON, 2014). But this is an unsatisfactory conclusion if it is accepted that short-statured stands with the floristics of adjacent tall statured stands share the same forest formation. Workers at the Pondicherry Institute have proposed a floristically based classification of Indian deciduous and semi-evergreen forests, correlated with the length of the dry season, mean annual temperature and rainfall. Finer grained than Champion's, their categories, which have been mapped in intricate detail in a series for all Peninsular India, nevertheless broadly fit within Champion's formations (LEGRIS, 1963; GAUSSEN, 1978).

If a new nomenclature is to be proposed, its highest categories must be common to both South Asia and Indo-Burma, which is not the case with the diagnostic species which the Pondicherry Institute has proposed. A candidate species for both “moist” deciduous and semi-

evergreen forest might be *Terminalia bellirica*, although that species extends into seasonal evergreen and, in Peninsular Malaysia, even mixed dipterocarp forest. None of the species used for dry deciduous forest in the Pondicherry nomenclature occur in Indo-Burma whereas, of the fourteen that appear frequently in Champion's lists for his dry deciduous forests, only five occur in Indo-Burma of which four (*Bridelia retusa*, *Buchanania lanzan*, *Butea monosperma*, *Dendrocalamus strictus*) occur there more widely than in Dry Deciduous forest, on siliceous soils or degraded land, leaving solely *Cochlospermum religiosum* as the diagnostic species common to all continental Asia's Dry Deciduous forests (Table 3).

Table 3. Species indicative of South Asian dry deciduous forests. Asterisked species are unknown in Indo-Burma (from ASHTON, 2014).

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<i>Anogeissus pendula</i> *
<i>Bridelia retusa</i>
<i>Buchanania lanzan</i>
<i>Butea monosperma</i>
<i>Chloroxylon swietenia</i> *
<i>Cleistanthus collinus</i> *
<i>Cochlospermum religiosum</i>
<i>Dalbergia lanceolaria</i> *
<i>Dendrocalamus strictus</i>
<i>Diospyros melanoxylon</i> *
<i>D. tomentosa</i> *
<i>Pterocarpus santalinus</i> *
<i>Sterculia urens</i>
<i>Ziziphus nummularia</i> *

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## CONCLUSION

I conclude, first, that the composition of the woody flora should be the definitive criterion for classification of the deciduous forests of tropical Asia, and specifically the presence of characteristic species. Second, I conclude that Dry Deciduous forest is currently confined in Indo-Burma to the upper Irrawaddy plain, although the presence in Indo-Burma of a more widespread characteristic species, *Cochlospermum religiosum*, implies that Dry Deciduous forests once also existed on the northern plains and adjacent foothills from the Chao Phraya to Mekong valleys.

There then remains the problem of forest type nomenclature: What are the species characteristic of Dry Deciduous forest throughout the continent? *Cochlospermum religiosum*? The answer must lie with those who better know the forests of the region as a whole, especially Indo-Burma. And should the various associations of Deciduous Dipterocarp forest be designated as separate edaphic subtypes of the dominant forest formation that surrounds them, or as a single edaphic formation which transects them all? We support this latter, which is accepted current practice.

## ACKNOWLEDGEMENTS

I have greatly benefitted, over the years, in discussions and field excursions with colleagues and friends, especially S. N. Rai, I. F. S. of the Karnataka forest service, D. Swain, I. F. S. of the Odisha, and H. S. Dattaraja and H. S. Suresh of the Indian Institute of Science; the late Tem Smitinand, Sarayudh Bunyavejchewin and Thawatchai Santisuk of the Royal Thai Forest Service; and the late Jules Vidal at Muséum National d'Histoire Naturelle, Paris. Indo-Burmese colleagues will doubtless take issue with some of my interpretations, and I trust that my presentation will stimulate alternative proposals based on further understanding.

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